Helicopter-based Emergency Medical Service: dispatches, decisions and patient outcome

HEMS in Western Norway

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Preface

Prehospital emergency medical care may be overwhelming. To encounter patients with severe injuries or illnesses, especially children, is a challenge for a caring person (often a parent themselves). Reducing morbidity and avoiding mortality are the main goals. In some cases, though, comfort and support for the next of kin are the only intervention we can offer.

Hippocrates (460–370 BCE) knew that we cannot save all patients, saying:

Cure sometimes
Treat often
Comfort always

Different treatment options are always possible in prehospital emergency medicine, and the rapid decisions to be made are often significant for the outcome.

How do we measure if the helicopter emergency medical service aids in achieving the Norwegian government's goal in the Coordination Reform: Proper treatment – at the right place and right time?

Contents

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Thanks to my own department and RAKOS for financial support. And thanks to Hanne Klausen for the inspiration to finalise this thesis.

To my dear family, Oline, Eirik, Håkon, and Ingunn: thank you for your love and support, despite my extensive absence as a family member the last few years. I also thank my mum and dad for their guidance and the encouragement in the choice of career.

Scientific environment

The studies presented in this thesis were performed during my work as a consultant in Bergen HEMS, Department of Anaesthesia and Intensive Care, Haukeland University Hospital, Bergen, Norway. Of the nine clinicians manning HEMS, three have a PhD degree and three are PhD students. The department's physicians contributed to 18 publications during the last three years.

I was accepted into the PhD-program at the Department of Clinical Medicine, Faculty of Medicine, University of Bergen.

The study period was funded by the Regional Centre for Emergency Medical Research and Development (RAKOS, Stavanger, Norway) and the Department of Anaesthesia and Intensive Care, Haukeland University Hospital, Bergen, Norway.

Abbreviations

AMB group	Ground ambulance missions; missions cancelled by HEMS due to concurrent commitments
Cancellations	A declined dispatch (before helicopter take-off or car moving) or a mission aborted after take-off but before the patient encounter
Concurrencies	Multiple concurrent dispatches to HEMS and the less life-threatening mission is referred to ground ambulance or other HEMS
ED	Emergency department
EMCC	Emergency medical communication centre
GCS	Glasgow Coma Scale
GP	General practitioner
HCM	HEMS crew member, assigned for the purpose of attending to any person in need of medical assistance carried in the helicopter and assisting the pilot during the mission
HDU	High dependency unit
HEMS	Helicopter emergency medical service. In Norway, this includes the possibility of using a rapid response car for transport to the patient when appropriate
HEMS group	Missions completed by HEMS
ICU	Intensive care unit
IQR	Interquartile range
NACA	National Advisory Committee for Aeronautics (severity score)
OST	On-Scene time, time from patient encounter to the start of patient transport from the scene (i.e., when the patient's stretcher started moving)
Primary mission	A response to a patient outside the hospital
Response time	The time from dispatch to patient encounter
Secondary mission	A transport of a patient between hospitals
Worthing PSS	Worthing physiology scoring system, an early warning score
SAR	Search and rescue

Abstract

Introduction
Although Norway has one of the most developed air ambulance services in the world, its helicopter emergency medical service (HEMS) capacity is limited. Few studies have assessed the medical decisions involved with Norway's HEMS, and little is known about the selection of missions and medical priorities on-scene. The aim of this work was to increase knowledge about HEMS use, HEMS physicians' medical priorities among patients, and factors influencing on-scene time.

Method
Extensive mission data from 42,500 dispatches of HEMS in Førde, Bergen, and Stavanger during 2004–2013 were analysed to assess mission profiles, identify variations in on-scene time and compare patient survival after transport by either ground ambulances or HEMS.

Results
The annual number of dispatches to primary missions was stable during the 10-year period. Summer, weekends, and daytime were the busiest times. More than one third of all dispatches were cancelled, with lower proportions cancelled in summer and during daytime. In 95% of the completed emergency missions, patients were reached within 45 minutes, and response and on-scene times in helicopter missions were short (24 and 11 min, respectively). There was a 2-minute decrease in on-scene time during the last five years of the study period. However, if HEMS performed endotracheal intubation of the patient, this increased on-scene time by almost 10 minutes. Basic treatment prior to HEMS arrival reduced on-scene time in patients suffering from acute myocardial infarction by almost 2 minutes. Trauma was the most common condition among the patients encountered in primary missions, followed by cardiac arrest and chest pain. One third of the HEMS patients were severely ill or injured and more than two thirds of this group received advanced interventions. When concurrent HEMS missions occurred, more of the patients prioritized by HEMS seemed to be critically ill compared with patients transported by ground ambulance, although survival was similar.

Conclusion

HEMS cancellation rates were rather low, and response and on-scene times in primary missions were short. One third of the patients were seriously ill or injured, and more than two thirds of this group received advanced interventions. When concurrent missions occurred, HEMS seemed to select the missions that may have the most impact. Prehospital data should be automatically registered to improve future research quality in the provision of both HEMS and ground ambulance services.

List of publications

Paper I

Østerås Ø, Brattebø G, Heltne J-K. Helicopter-based emergency medical services for a sparsely populated region: a study of 42,500 dispatches. Acta Anaesthesiologica Scandinavica 2016; 60: 659-67

Paper II

Østerås Ø, Heltne J-K, Vikenes B-C, Assmus J, Brattebø G. Factors influencing on-scene time in a rural Norwegian helicopter emergency medical service: a retrospective observational study. Scandinavian Journal of Trauma Resuscitation and Emergency Medicine 2017; 25: 97.

Paper III

Østerås Ø, Heltne J-K, Tønsager K, Brattebø G. Outcomes after cancelled helicopter emergency medical service missions due to concurrencies: a retrospective cohort study. Acta Anaesthesiologica Scandinavica 2018; 62: 116-24

Introduction

In emergency medical situations, time to treatment is critical. Sometimes, life-saving treatment may be provided on-scene, e.g., giving epinephrine to a person with an acute anaphylactic reaction. Many other conditions, such as major trauma, require care from multi-professional teams available only in a hospital. Initially, this need led to the development of prehospital systems that mainly focussed on transport. Later, the importance of providing emergency medical care and monitoring vital functions resulted in comprehensive and competent emergency medical services with well-trained personnel and suitable equipment. The need to provide high-quality emergency care for patients not only in urban areas but also in remote places, in combination with innovation and development in aviation, resulted in extensive use of air transport for acutely ill and injured patients, especially in rural or geographically challenging areas.[1] Fixed-wing planes are used for long-distance transport because they can cover long distances in a short time, while rotor-wing helicopters may operate in almost any area, given visibility and suitable weather conditions. The geography and vast rural nature of Norway, combined with a political will for equality in health care services, have been key drivers in the extensive development of patient air transport in Norway.

The first use of helicopters for air medical evacuations occurred during the Korean War in the early 1950s, and the practice was further developed and successfully used during the war in Vietnam in the 1960s.[2] This concept of evacuating combat casualties on stretchers on the helicopter skids is well known from the popular award-winning comedy movie and TV series called M.A.S.H. (Mobile Army Surgical Hospital), which was set in a fictitious military surgical hospital operating during the Korean War.

Figure 1 Bell-H-13-Sioux with stretchers on the helicopter's skids (picture from www.militaryfactory.com)

HEMS in Norway

The first known air ambulance transports in Norway involved seaplanes from the 1920s. Helicopter Emergency Medical Services (HEMS) in Norway started in 1978 with the Norwegian Air Ambulance Foundation, established by Dr Jens Moe, under the name "Bård Østgårds Stiftelse". Its founding was triggered by the death of a young child in a drowning accident. The model with physician-staffed small helicopters in medical emergency services was initiated with inspiration from Switzerland and West Germany.[1] In Norway, the Norwegian Air Ambulance Foundation has been a significant driving force for establishing the air ambulance service and in increasing the number of HEMS in the country. They initially provided rapid response cars on all helicopter bases, which are an alternative transport option for the crew. After being dispatched, the crew chooses whether the helicopter or the car is the most suitable, according to distance to the scene, weather conditions, and accessibility to the patient.

The National Air Ambulance Service was established in 1988 and all services are fully government-funded (not per mission). Currently, 9 fixed-wing and 13 rotor-wing aircrafts are on governmental contracts. All HEMS are quite similar in regard to helicopter types, crew composition, mission profiles, and patient treatment possibilities. In addition, the Norwegian Government finances six bases with large Westland Sea King helicopters, primarily for the purpose of sea and land rescue, which also are staffed with an anaesthesiologist. These respond to medical emergencies and trauma when they are the closest physician-staffed emergency service, as an alternative secondary response when HEMS needs support or is unavailable, or when there is a need for a larger cabin. Fixed-wing aircraft are mostly used for inter-hospital transports, but also for primary missions in the northern parts of Norway.[3]

Norway is a long and sparsely populated country with 5.2 million inhabitants on 324 000 km^2 (15.6 inhabitants per km^2 of the mainland). Eighty percent of the population live in villages and cities.[4] Air ambulances are advantageous in rural Norway because of the long distances, fjords, mountains, and low-quality roads. HEMS covers most of the populated mainland within a 30-minute flight time and is a key component in meeting the official declared political goal of equal access to advanced medical care for every inhabitant, regardless of location.[1] This goal may partly explain why Norway has on average one HEMS per 400,000 people.

Often, the HEMS crew cooperates with the GP and the ground ambulance service on-scene.[5] The municipalities are responsible for the primary healthcare service, including the primary care GPs, being on call 24-7. In addition, the municipalities are responsible for providing out-of-hours services, local emergency medical communication centers, and local casualty clinics. The patient does not present at a hospital emergency department without first being seen by a physician, except in some emergencies in which ground or air ambulances transport severely ill and injured patients directly to the hospital.

During 2014, Norwegian ground and boat ambulances performed 1315 missions per 10,000 inhabitants. The 22 air ambulance units transported 3% of the patients, but were responsible for 17.3% of all costs for the 570 ground, boat, and air ambulances.[3,4] According to official

data, a total of 19,440 patients (38 per 10,000 inhabitants) were encountered by the air ambulance services, including both fixed-wing and rotor-wing services.[6] Annual costs in 2014 for the Norwegian air ambulance services were more than 90 million EUR (> 900 million NOK).[6]

The three HEMS bases in Western Norway represent almost one quarter of Norwegian HEMS and use the same, intuitive database for mission reporting. Hence, the HEMS in Western Norway represents a suitable study choice for the national HEMS.

Studies describing and assessing the advantage of the service as a whole are sparse, despite 25 years of HEMS experience. Some groups have posed specific research questions and evaluated patient groups or specific parts of the service.[7-15] Some of the most important questions is whether HEMS makes the appropriate medical priority decisions during dispatch and in patient treatment, and if these decisions improve patient outcome. We hope that this thesis may add knowledge regarding these questions.

HEMS dispatch

Norway has a nationwide emergency communication system, and people facing an acute medical problem (injury or medical illness) are advised to call the national emergency number 113 to reach the nearest of the 16 emergency medical communication centres (EMCCs). The EMCCs are staffed with nurses and ambulance personnel with emergency medicine expertise, who will provide counselling and alert emergency health services if necessary.[16] The EMCCs dispatch ambulances (including HEMS) and alert the local GP on-call. The health care personnel working within the EMCC use a decision tool called the Norwegian Index for Medical Emergencies (the "Index") to classify the medical problems into different levels of responses.[17] A restricted and nationwide digital network (Nødnett) is used for communication among the GPs on-call, ambulance personnel, HEMS, and EMCCs.

Appropriate use of the service requires close cooperation between the emergency medical communication centre (EMCC) and HEMS. The HEMS crew has the final decision about whether to respond or not. Unfortunately, dispatches to primary missions often contain

sparse information, especially in trauma missions. When ground ambulances arrive on-scene, additional information regarding the patient's condition may lead to cancelling the HEMS mission. In secondary missions, more information about the patient's condition is most often available.

The most common reasons for declining or aborting a mission are; that there is no longer a medical indication, use of other resources is more appropriate, concurrent missions are ongoing, or a helicopter flight is not available (bad weather or technical issues). Determining if weather conditions are appropriate for a helicopter flight is the pilot's decision. The crew may also be restricted from responding because of exceeding duty hours; if a HEMS crew has worked 14 of the last 24 hours, they will be out of service for the next 8 hours according to Norwegian HEMS regulations. These regulations help to maintain flight safety in HEMS operations. Because extensive planning is not suitable and most of the landing sites are unknown prior to a mission, the accident risk in HEMS missions is increased compared to commercial flights.

In the Norwegian national HEMS, activation time and response time are kept short by using small helicopters and having the crew residing at the base. A location away from the nearest airport also reduces "air traffic jams" and potential conflicts with commercial flight operations. Inter-operator variability is likely in terms of missions to which HEMS is dispatched and which ones the crew accepts.[18] Several aspects must be considered – e.g., weather conditions, patient condition, accessibility from a road, distance to hospital, and proximity of other resources.

The Norwegian HEMS use rate has been suggested to be as low as 11 primary missions with patient encounter per 10,000 inhabitants per year (obtained by extrapolating the incidence of patient encounters in a prospective registration during 4 weeks). It has been estimated to be even lower (7.5) using data from the Norwegian Air Ambulance Service.[7,8] Verification of these numbers is important for governmental planning for the future of HEMS in Norway.

Treatment and on-scene time

Patients suffering from a severe illness or injury require immediate prehospital assessment, appropriate treatment, and in many cases, rapid transport to the hospital accompanied by competent personnel. A European project accentuated the so-called "First Hour Quintet" as critical conditions of great importance in prehospital emergency care (cardiac arrest, respiratory failure, trauma, acute coronary syndrome, and stroke).[19]

Many studies have assessed on-scene time (OST), often without a conclusion regarding an association with increased survival. Factors affecting OST in time-dependent patient conditions are important to assess in HEMS missions. An on-scene HEMS physician does not necessarily increase the OST, though more advanced interventions may be performed.[20-22] However, only essential interventions should be performed before initiating transport, i.e., those that increase the likelihood of survival and reduce morbidity.[23,24] The OST is the segment of prehospital time interval that can be reduced, as flight times are mostly determined by the distance to the hospital. Prolonged OST seems to increase mortality for trauma patients, although not in all settings and conditions.[25] The main factors affecting OST have been described for trauma patients, but not specifically for the other medical emergencies in the First Hour Quintet.[23,26-29] However, reducing the interval between diagnosis and definitive treatment for stroke and myocardial infarction is clearly beneficial.[30,31]

Identifying and assessing factors affecting prehospital time may improve decision-making and treatment protocols and provide a basis for targeted training to reduce OST in specific classes of patients.

HEMS reliability

When planning prehospital care systems, HEMS is ideally regarded as reliable. This reliability may be characterised as being predictable, responding in a similar way to comparable emergencies, and having a low cancellation rate due to weather, technical issues, exceeded duty-time, or concurrent requests.

HEMS is an important and established "sharp end" of the emergency medical service, but unfortunately, capacity is limited, and several dispatches may occur at the same time. A high rate of such concurrent missions can be a sign of too low HEMS capacity, an over-triage, or both. In Norway, between 4% and 5% of HEMS missions are cancelled because of concurrent missions, an incidence that has been found acceptable until now.[6,32] An unknown proportion of these are completed by other HEMS bases nearby. A Canadian study reported a similar level of aborted requests because of concurrent missions (3.5%).[33] Patient outcomes in HEMS missions cancelled for concurrencies have to our knowledge not been described before.

For patients suffering severe trauma or medical emergencies and for their next of kin, the most important factor is probably being able to rely on a fast response, qualified medical assessment and treatment, and rapid transport. This need is especially the case when the hospital is far away. HEMS decisions must often be made within short time limits with potentially serious consequences for patient outcome. Research on the reliability of HEMS is limited. Such insight is relevant for discussing planning of emergency preparedness, e.g., centralisation of ambulances and GP out-of-hour services, in addition to the number and geographical location of HEMS bases.

The main objectives of this work were to assess HEMS missions in three bases in a sparsely populated region and to describe the HEMS' physicians medical priorities among patients, in addition to time used and medical priorities on-scene.

Aims

Aim, paper I:

The objective of this study was to assess patterns of medical conditions and treatments in the HEMS serving a geographically large but sparsely populated region.

Aim, paper II:

The objectives were to assess OSTs in the HEMS and investigate whether selected factors affect it in four severe conditions in which a short OST was anticipated. Cardiac arrest patients were also assessed for comparison, with an increased OST anticipated for this group.

Aim, paper III:

This study compared the outcomes of patients transported by ground ambulances in missions cancelled by HEMS because of concurrent requests to outcomes for patients in the missions prioritised and completed by HEMS.
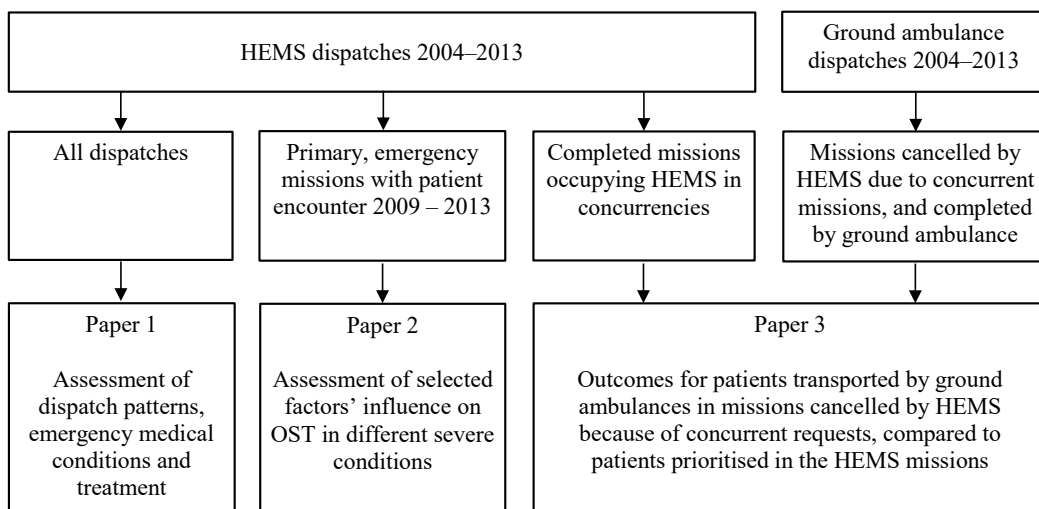
Methods

Study setting

The studies were based on patient records from dispatches during the period 2004–2013 for the three HEMS bases in Førde, Bergen, and Stavanger. The population in Western Norway was close to 1.1 million people in an area of 45,000 km^2.[4] One third lived in Stavanger and Bergen, but outside these cities, the population density was only 15 persons per km^2. The rural area of Western Norway involves large distances with long response and transport times by ground ambulances. Four EMCCs served as dispatch centres for 94 ground ambulances and three HEMS in the region. GPs were on call and responded together with ambulances to many of the emergencies in rural areas. Five local hospitals, two regional hospitals, and two university hospitals are located in the area. Two search and rescue (SAR) helicopters were operating in Western Norway and one of these was in some cases dispatched if HEMS declined or aborted a mission. The HEMS were continuously open for operations and responded to both trauma and medical emergencies.

The helicopter bases had a rapid response car as an alternative transport to the patient, when the scene was close to the base or when a helicopter flight was not possible. The helicopters (Eurocopter EC135) had a standard capacity for one supine and one sitting patient and were staffed with a pilot, a HEMS crew member (HCM), and an anaesthesiologist. All HEMS bases had so-called night vision goggles and the capacity for instrumental flight. In the latter case, a landing at an airport or a known landing site had to be planned. This helicopter equipment enables HEMS to perform flights in low-light conditions or in reduced visibility because of weather conditions. The HEMS helicopters were not equipped with de-icing, so were restricted flying in fog or cloud during cold weather. The HEMS physician was responsible for triaging dispatches based on information from the EMCC, but dispatch criteria at the three bases were not entirely identical. As noted, if HEMS crew had worked 14 of the last 24 hours, they would be out of service for 8 hours according to Norwegian HEMS regulations.

Figure 2 Flow-chart displaying data sources, inclusion criteria, and the aims of the papers

HEMS dispatches 2004–2013			Ground ambulance dispatches 2004–2013
All dispatches	Primary, emergency missions with patient encounter 2009 – 2013	Completed missions occupying HEMS in concurrencies	Missions cancelled by HEMS due to concurrent missions, and completed by ground ambulance
Paper 1 Assessment of dispatch patterns, emergency medical conditions and treatment	**Paper 2** Assessment of selected factors' influence on OST in different severe conditions	**Paper 3** Outcomes for patients transported by ground ambulances in missions cancelled by HEMS because of concurrent requests, compared to patients prioritised in the HEMS missions	

Definition of dispatches and missions

The terms "dispatch" and "mission" are often used in a similar way. EMCC dispatches ground and air ambulances. Although the ground ambulance service in Norway responds to each dispatch, the physician-staffed HEMS in Western Norway chooses to accept the dispatch or not. A HEMS mission was defined as a dispatch from the EMCC leading to a response with the helicopter or the rapid response car. Cancellations were defined as either a declined dispatch (before helicopter take-off or car moving) or a mission aborted after take-off but before the patient encounter. A primary mission was defined as a response to a patient outside the hospital, while secondary (inter-hospital) missions were defined as transports for patients between hospitals, most often to receive more specialized care. The HEMS crew also responded to SAR operations. SAR missions may be lifesaving, e.g., hypothermia will increase mortality in injured patients.[34]

Data source and management

All activity was already registered in a database called "Airdoc" (Filemaker 8, Filemaker Inc., CA, USA). The data included administrative, time, and patient data; vital signs; treatment performed; and a free-text option. For the ground ambulance missions assessed, the data were found in the hospital patient records. Time intervals were based on time events registered by the HEMS physician and defined as shown in Table 1. Unusual, extreme, or missing values were assessed by reading the free-text field and cross-checking other sources (e.g., EMCC records and pilots' flight logs). Missing or obviously incorrect values were corrected if reliable data were identified, but otherwise these values were excluded.

Table 1 Time events recorded by the HEMS physician and important time intervals

	Alarm call to dispatch centre	HEMS dispatch	Take-off or car moving	HEMS arrival on-scene	Arrival to the patient	Start of patient transport	HEMS leaving scene	Landing at hospital or other site	End of patient care	Ended mission
Recorded by HEMS		+	+		+	+			+	+
Dispatch time	▬▬▬▬									
Reaction time		▬▬▬▬								
Response time		▬▬▬▬▬▬▬▬								
On-scene time					▬▬▬▬					
Total mission time		▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬								

Interventions

Interventions performed by HEMS were considered basic or advanced, as defined in Table 2. Basic interventions were referenced to the treatment options available in the ground ambulance service in the region. Advanced interventions were the additional interventions available in HEMS missions.

Table 2 The two groups of interventions used in the study

Basic interventions	Advanced interventions
Basic airway procedures (manual airway opening/ oropharyngeal airway)	intubation/tracheostomy
suction	mechanical ventilation
oxygen therapy	thoracostomy/chest drain
assisted ventilation or CPAP	thoracic needle decompression
defibrillation/electro-conversion	chest compression device
CPR	external cardiac pacing
ECG	anaesthesia
immobilisation (stiff neck collar, backboard, pelvic-sling, splint)	central venous, arterial, or intraosseous cannulation
	blood products
	use of neonatal incubator; nerve blocks, ultrasound
use of drugs according to medical treatment protocols and available in the ground ambulance service; epinephrine, cyclizine, metoclopramide, glucose, sublingual glycerol nitrate, acetylsalicylic acid, crystalloids, inhalational ipratropium bromide and salbutamol, naloxone, flumazenil, paracetamol	use of other drugs not available in the ground ambulance

Ethics

The Regional Committee for medical and health research ethics West (REK Vest 2010/2930, 15.12.2010), had no objections to the study and waived the need for their approval. The Ministry of Health and Care Services (2011-02407), the Norwegian Data Protection Authority (12/00291-3), and Data Protection Officials for Research all approved the project. The Ministry of Health and Care Services waived the need for consent from the patients or next-of-kin.

Methods – Paper I

All HEMS missions in Western Norway during 2004–2013 were assessed. An extensive data cleaning was necessary because the database allowed entering non-standard values (i.e., time registered as 1453, 14.53 or 14:53). The National Advisory Committee for Aeronautics (NACA) score was modified to be used for prehospital medical emergencies and trauma in 1980 (Table 3).[35] This severity score from level 0 (no injury or disease) to level 7 (death) was used in Norwegian HEMS. Conditions with a NACA score of 5–7 were considered to represent patients with severe illness or injury.

Table 3 The NACA scale; as used by the Norwegian Air Ambulance Service*

NACA	Description	
0	No injury or disease.	
1	Injuries/diseases without any need for acute physician care.	*E.g., transient hypotension and abrasions.*
2	Injuries/diseases requiring examination and therapy by a physician, but hospital admission is not indicated.	*E.g., moderate soft tissue injury and ruptured tendons.*
3	Injuries/diseases without acute threat to life, but requiring hospital admission.	*E.g., cerebral concussion (unconscious < 15 min, no pathological neurology), large lacerations, open wounds with vascular or neurological injury, and fractures.*
4	Injuries/diseases that can possibly lead to deterioration of vital signs.	*E.g., cerebral concussion (unconscious > 15 min), fracture of tubular bone, several rib-fractures, and thoracic injury with unilateral haemo- or pneumothorax.*
5	Injuries/diseases with acute threat to life.	*E.g., large and complex fractures, several tubular bone fractures or single femur fracture, rib-fracture with respiratory distress, and cerebral concussion with anticipated increased intracerebral pressure.*
6	Injuries/diseases transported after successful resuscitation of vital signs.	*E.g., central nerve system injury affecting respiration or circulation, thoracic injury with respiratory distress or multiple fractures, and respiratory or cardiac arrest.*
7	Lethal injuries or diseases (with or without resuscitation attempts).	

* This NACA scale is the version modified by Tryba et al. in 1980 for severity assessment in prehospital services.[35] The original scale was developed by the NACA and used for trauma severity scoring 24 hours after admittance to the hospital.[36]

Descriptive statistical methods were used. Linear regression models were applied to evaluate the association between continuous data, and R^2 for goodness of fit. Yearly incidence of missions was calculated by the ratio of total missions over the entire population in the area, divided by the number of study years. Population data were based on census data. Data were analysed with IBM SPSS Statistics for Windows, Version 22 (IBM Corp., Armonk, NY, USA), and linear regression was performed in Excel 2010 (Microsoft Corp., WA, USA). A P value of <0.05 was considered statistically significant.

Methods – Paper II

All primary emergency HEMS missions, using a helicopter or rapid response car, with patient encounters from 2009 through 2013 were included in the analysis in this retrospective cohort study. SAR missions and inter-hospital transfers were excluded. Patients who were entrapped when the HEMS arrived were also excluded from the analysis if transport was delayed because of the entrapment. A free-text field in the mission report was assessed in all such cases. A ground ambulance was most often present on-scene when the HEMS arrived and offered an alternative mode of transportation to the hospital.[9]

Our primary outcome was analysing OST and associated factors in five patient groups. We analysed variables available in our database or through additional questions to the HEMS physicians. OST was defined as the time from patient encounter to the start of patient transport from the scene (i.e., when the patient's stretcher started moving). All HEMS physicians involved in missions during the study period reported the year they became a specialist in anaesthesiology. Darkness was defined for each mission according to civil twilight for the dispatch time, date, and latitude/longitude for the scene (centre of the municipality). When Glasgow Coma Scale (GCS) data were missing, a normal value (GCS=15) was used in the analysis.

Five patient subgroups were selected for further analysis: acute myocardial infarction, stroke, head injuries, penetrating torso injuries, and cardiac arrest. To ensure that the selected patients were in fact severely ill or injured, cases with NACA 0–3 (none or no serious conditions) and NACA 7 (dead on-scene or during transport) were excluded. We

hypothesised that the observed OST would be longer for cardiac arrest and shorter for the other groups, compared to overall median OST.

We used descriptive methods to characterise the sample and OST for the subgroups and graphics (histograms) to illustrate distributions. The effects of factors were assessed for each of the subgroups by graphical methods and linear regression models using the OST as the outcome variable. The models were built in three steps, separately for each group. First, we estimated the unadjusted model for each factor. Next, we estimated the fully adjusted model containing all factors. In the third step, we estimated the final model containing all factors with a *P* value <0.1 in one of the previous steps or that were considered clinically important. For all subgroups except penetrating torso injuries, we used a linear mixed effects model adjusted for HEMS base and with a random intercept for the individual doctor. The size of the penetrating torso injuries subgroup was too small (n = 57) to perform a similar analysis, so we estimated a simple linear model. The significance level was set to 0.05. Descriptive statistics were calculated using IBM SPSS Statistics for Windows, Version 22 (IBM Corp., Armonk, NY, USA), and the linear model using R 3.3 package nlme. [37,38] The graphics were created using MATLAB 7.10 (The MathWorks Inc., Natick, MA, USA).

Methods – Paper III

This study presented patient outcome in missions cancelled by HEMS because of concurrent missions for the three HEMS bases in Western Norway. Data on both completed and cancelled HEMS missions were registered. At first, all missions cancelled because of another concurrent mission during 2004–2013 were identified ("AMB" group). Then, for each of the cancelled missions, we manually identified the completed mission that occupied the actual HEMS ("HEMS" group). If data from a cancelled mission were unavailable, the corresponding HEMS mission was not assessed. Patient records for both cancelled and completed missions were assessed in the nine receiving hospitals. The primary outcome was survival to hospital discharge. Secondary outcomes were physiology score in the emergency department (ED), immediate emergency interventions in the receiving hospital, type of

department for patient admittance, and length of hospital stay. Worthing Physiological Scoring System (The Worthing PSS, Table 4) scores were used for scoring physiology status at admittance.[39] An early warning score was chosen for its robustness in handling missing values, and the Worthing PSS (ranging from 0 to 14) was chosen because of a previous validation against survival during the complete hospital stay. Patients under age 16 years were excluded when reporting Worthing PSS because it is validated only for adults.

Table 4 The Worthing Physiology Scoring System (Worthing PSS)*

		Score			
		0	**1**	**2**	**3**
Breathing	Respiratory rate (/minute)	≤ 19	20–21	≥ 22	
	Oxygen saturation in air (%)	96–100	94 or 95	92 or 93	≤ 91
Circulation	Pulse (/minute)	≤ 101	≥ 102		
	Systolic blood pressure (mmHg)	≥ 100		≤ 99	
	Temperature (°C)	≥ 35.3			≤ 35.2
Disability	AVPU**	Alert			Other

* Table is modified from Duckitt et al.[39]
** AVPU; Alert, response to Verbal stimuli, response to Pain or Unresponsive.

Emergency interventions were defined as life-saving emergency procedures performed within 24 hours after admittance. Admittance to an intensive care unit (ICU), high-dependency unit (HDU), or regular hospital ward was registered. NACA score was registered in all HEMS missions, using the most severe patient condition observed by HEMS during the mission. For the cancelled HEMS mission, for which patients were transported by ground ambulances, the NACA was retrospectively scored for the prehospital phase based on patient records from the ambulance and the ED, but without assessing further examinations or discharge notes. Three consultant anaesthesiologists and two research fellows performed the data extraction from the patient records and the NACA scoring.

Descriptive methods were used to characterise the sample. Categorical data were analysed with Pearson's chi-square test, Mann Whitney U test was used for continuous data, and normally distributed data were compared using t-tests for independent samples. Survival was analysed using Kaplan-Meier plots and Breslow test to determine differences between survival distributions.[40] A P value <0.05 was considered statistically significant. Data were analysed using IBM SPSS Statistics for Windows Version 23 (IBM Corp., Armonk, NY, USA). One of the figures was created using MATLAB 7.10 (The MathWorks Inc., Natick, MA, USA).

Results

One third of patients in primary missions were severely ill or injured (33%), and two thirds (66%) of this group received advanced interventions. Almost all patients in primary emergency missions were reached within an hour (98%). Most dispatches were to primary missions, and more than one third of all dispatches were declined or aborted. Despite a 13% population increase, the annual number of dispatches did not change during the study period (Figure 3).

Figure 3 Population and the number of annual HEMS dispatches to primary and secondary missions in Western Norway in the study period.
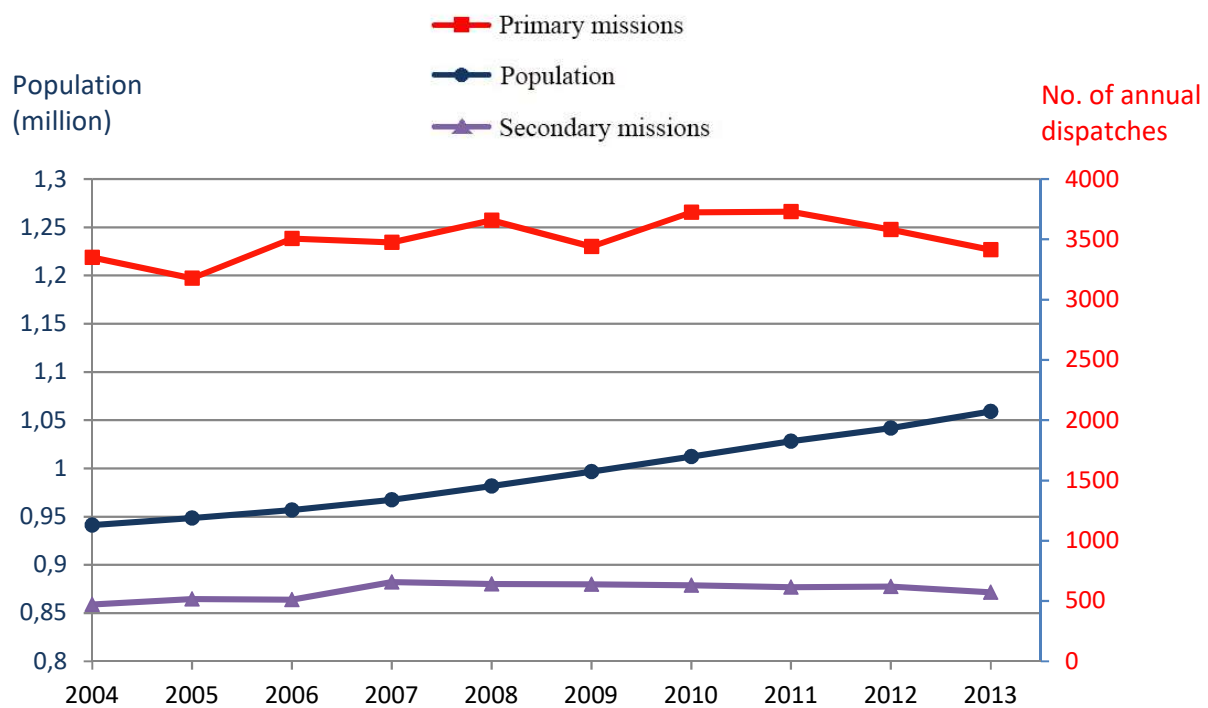
Results – Paper I

All 42,456 HEMS dispatches registered during the 10 years were included. Summer, weekends, and daytime were the busiest times. Most dispatches were to primary missions (83%), and the annual number of dispatches and patients encountered did not change. In all emergency primary missions, 95% of the patients were reached within 45 minutes and 98% within the first hour. When using the helicopter for such missions, median times were as follows: activation time, 5 minutes; response time, 24 minutes; OST, 11 minutes; and transport time, 25 minutes.

More than one third of all dispatches were cancelled, with lower proportions of cancellations in summer and during daytime. The HEMS anaesthesiologist reported cancellation because of no longer medical indication in 28% of dispatches to primary missions, bad weather in 5%, and concurrent missions in 4%. During night-time, almost every second dispatch to primary missions was cancelled, with two thirds classified as no longer medical indication. Weather conditions precluding helicopter flights were reported more frequently at night and during winter.

**Table 5** Conditions in 21,135 patient encounters in primary missions

Condition	
Trauma	32.8 %
Cardiac arrest	15.2 %
Chest pain	12.2 %
Acute neurology	10.1 %
Stroke	4.7 %
Breathing difficulties	4.7 %
Psychiatry including intoxication	3.6 %
Infection	3.5 %
Obstetrics and childbirth	2.3 %
Other medical diagnoses	9.4 %
Missing diagnose	1.6 %

Trauma and cardiovascular diseases (cardiac arrest, chest pain, and stroke) were the most frequent conditions in patients encountered by HEMS, each representing almost one third of the conditions in primary missions (Table 5).

Advanced interventions were performed in 41% of all primary missions and basic treatment in 34%. A severe illness or injury was encountered in one third of the primary missions, and two thirds of the patients in these missions received advanced interventions. The proportion of patients who received advanced and basic treatment showed a large variation among the different NACA groups (Figure 4).

Figure 4 Distribution of NACA in primary missions with patient encounter and level of treatment performed in the different NACA groups.
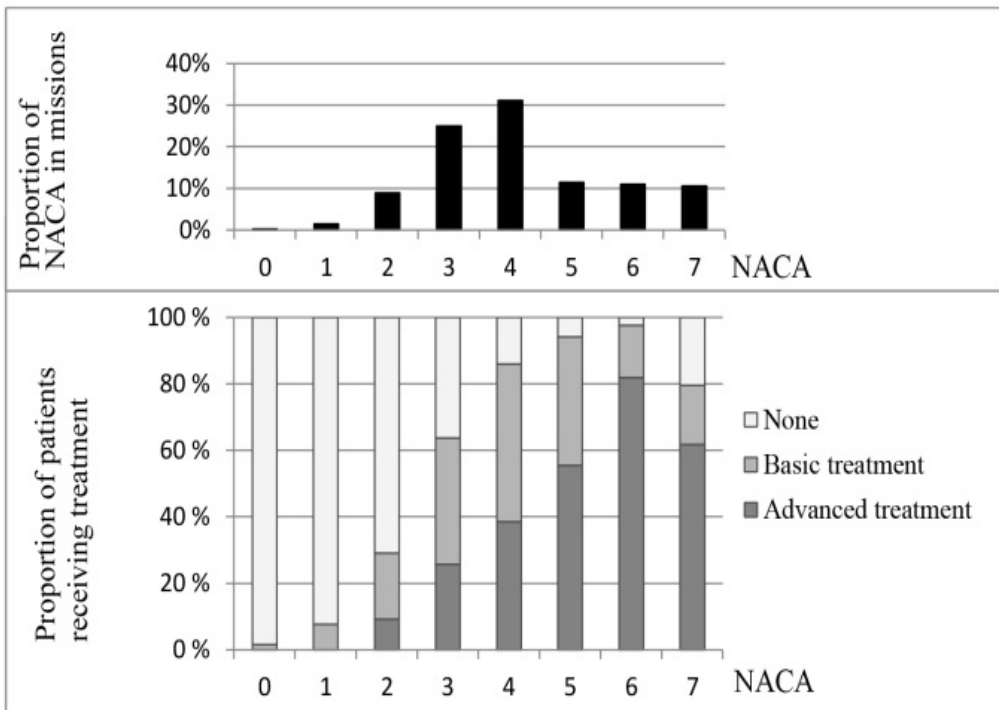
Results – Paper II

All emergency primary missions with patient encounter (n = 9757) during the 5-year study period were assessed. The overall median OST was 10 minutes. The largest difference in median OST was found between the subgroups "penetrating torso injuries" and "cardiac arrest", with 5 and 20 minutes, respectively.

Table 6 Factors affecting on-scene time (linear mixed-effect model)

Predictor	Final model		
	N = 1599		
	B	**95% CI**	**P value**
Year in study period	-0.42	(-0.67, -0.16)	**0.001**
Daylight (yes)	-	-	-
Age	0.03	(0.01, 0.05)	**0.005**
Male (yes)	-0.26	(-1.02, 0.50)	0.504
Trauma (yes)	1.60	(0.58, 2.62)	**0.002**
NACA score	1.44	(0.78, 2.11)	**<0.001**
Glasgow Coma Scale	0.02	(-0.14, 0.17)	0.846
Treatment prior to HEMS (yes)	-1.68	(-2.46, -0.90)	**<0.001**
Experience (years as specialist)	-	-	-
Analgesics (yes)	3.07	(2.25, 3.88)	**<0.001**
Intubation (yes)	9.71	(8.05, 11.37)	**<0.001**
Helicopter transport (yes)	3.54	(2.44, 4.65)	**<0.001**

Patients with a NACA score of 4–6 and acute myocardial infarction, stroke, head injury, or penetrating torso injury (N = 1605) were included. Estimates were adjusted for HEMS base, and the individual physician was used as a random effect. B = unstandardized coefficient in the regression model (minutes per unit of predictor). Positive values are associated with increased on-scene time. A full table including all three steps of the model is presented in paper 2.

Multivariate linear regression analysis identified age, NACA score, helicopter transport, the use of intravenous analgesics, treatment prior to HEMS arrival, intubation, year in study period, and trauma missions as factors associated with significantly altered OST in missions for patients who suffered one of the four severe conditions with anticipated short OST (acute myocardial infarction, stroke, head injuries, or penetrating torso injuries). Endotracheal intubation increased the OST by almost 10 minutes. Treatment prior to HEMS arrival reduced OST in patients suffering from acute myocardial infarction by almost 2 minutes (Table 6). A 2-minute decrease in OST was identified from the first to last years of the study period.

Results – Paper III

All missions involved in concurrencies were assessed (n = 1237), of which 858 were
included. All missions in the AMB group were primary missions, compared to four out of
five in the HEMS group. HEMS encountered more patients with a prehospital acute threat
to life compared to AMB and had a shorter OST. A larger proportion of patients in the
AMB group died on-scene, were discharged on-scene, or were entrusted to care by a GP. In
addition, HEMS had a larger proportion of patients with deranged physiology in the ED, the
need for immediate emergency interventions (e.g., intubation, surgery, or procedure), and
admission to ICU or HDU. A larger proportion of the in-hospital deaths occurred in the first
24 hours in the AMB group. Survival to discharge was similar in both groups.

In a subgroup analysis of patients in primary missions with a prehospital acute threat to life
(NACA 5–6), patients in HEMS missions were younger, but had increased survival (Table
7).

Table 7 Primary and secondary outcomes for 142 patients in primary missions with a
prehospital acute threat to life and who were admitted to the hospital

	Prehospital acute threat to life; NACA 5–6 (*n* = 142)		
	AMB group	**HEMS group**	
	Cancelled by HEMS (*n* = 56)	Completed HEMS missions (*n* = 86)	*P*
Discharged alive, *n* (%)	33 (58.9)	59 (68.6)	**0.023** [a]
Time of in-hospital death [b]			**0.004** [c]
First 24 hours, *n* (%)	19 (33.9)	11 (12.8)	
After 24 hours, *n* (%)	4 (7.9)	16 (18.6)	
Physiology in ED, age >15 years			
Worthing PSS >1, *n* (%)	42 (77.8)	60 (81.1)	0.960 [c]
Median Worthing PSS, median (IQR)	4 (2–5)	3 (2–5)	0.566 [d]
Emergency interventions <24 h, *n* (%)	25 (46.3)	32 (38.6)	0.369 [c]
Admitted to HDU or ICU, *n* (%)	28 (53.8)	61 (73.5)	**0.019** [c]
Length of hospital stay, median (IQR)	4 (1–11)	8 (2–18)	0.094 [d]
Length of hospital stay >10 days, *n* (%)	8 (25.0)	24 (40.7)	0.135 [c]

[a] Breslow Test of different survival distributions from Kaplan–Meier plot. [b] Time of in-hospital death was reported as
number (*n*) and proportion of all patients admitted to the hospital within the AMB or HEMS group (%) and tested
using 2×2 chi-square test for the time of in-hospital deaths in the two groups. [c] Pearson's chi-square test. [d] Mann–
Whitney U test for independent samples. ED = Emergency department; HDU = High dependency unit; ICU =
Intensive care unit

Discussion

The results from these studies indicate that HEMS is a reliable emergency medical service that makes appropriate medical decisions. First, although the weather-related cancellation rate was higher through winter and night-time, only 5% of all dispatches to primary missions were cancelled for this reason. The cancellation rate for concurrent missions, technical issues, and exceeded duty time was also low. Patients were encountered or HEMS were no longer needed in nine out of ten primary missions. The proportion of cancellations compares well with similar services.[33,41] Second, response times were in keeping with the official political goals. OSTs were low in primary missions to patients suffering conditions for which a short OST was anticipated. Third, with concurrent missions, HEMS selected those involving the most severe illness or injury but still had similar outcomes compared to those for patients transported by ground ambulances.

Norway has some of the most comprehensive air ambulance coverage in the world, with sophisticated medical equipment, physician staffing, and advanced helicopters.[42] The medical staffing and service population of helicopters differ among countries. In the US, HEMS are staffed with paramedics or nurses.[21] UK had 2.5 million inhabitants per helicopter in 2009, while Norway had 400,000 inhabitants per helicopter.[6,43] Norway's high coverage of air ambulances is related to its geography and official political goals of equal access to advanced medical care, regardless of location.[1] An advantage of Norwegian HEMS, in addition to the possibility of rapid transport and providing advanced interventions, is the assessment and triage of critically ill patients by a specially trained and experienced anaesthesiologist. Being able to offer individualised treatment to the patient and rapid transport directly to the appropriate hospital is important in most emergencies.[24]

We found a larger incidence of patient encounter (21.3 per 10,000 inhabitants) compared to previous reports. The Norwegian HEMS use was estimated to 11 primary missions with patient encounter per 10,000 inhabitants by extrapolating the incidence of patients encountered in 4 weeks, compared to 7.5 per 10,000 using data from the Norwegian Air Ambulance Service in 2011.[7,8] The discrepancy between these findings is most likely the

result of differences in study design, data definitions, and services included. A study involving SAR missions (which differ largely from HEMS) or a study design using limited periods is not optimal when estimating the rate of patient encounter by HEMS in Western Norway.

Dispatch and cancellations

The need for rapid transport, assessment or treatment by an anaesthesiologist, and/or a patient's being less accessible by road (e.g., mountain rescue) are the main criteria in the national guidelines for dispatch of the Norwegian HEMS.[3] In rural settings, the local GP often accompanied the ambulance and may in some cases have reduced the need for HEMS. Ambulances and GPs are most often present on-scene.[44] An appropriate dispatch depends on relevant information from the scene, and the HEMS crew's decision is made in collaboration with the EMCC operators. In the initial phase of a mission, reliable data on the patient's condition is often limited, and prioritising between concurrent emergency missions is challenging. Continuously updated information regarding the patient's condition, geographical location, and other emergency resources is available at each HEMS base, in the rapid response car, or in the helicopter.

Dispatch criteria and priority decisions between missions are important to ensure availability when really needed and avoid either exceeded duty time or a concurrent mission. The approach to concurrent missions and dispatch criteria differ among HEMS and EMCCs in each country.[45] HEMS is a limited resource that must be properly administered, and the decision about which dispatches to accept is critical. HEMS should respond only to medically indicated missions, where rapid transport and advanced medical care may benefit the patient, and turn down dispatches to non-emergency missions that can be handled appropriately using other available prehospital resources. However, HEMS is in retrospect being dispatched to more patients than actually needed.[46,47] A certain level of over-triage has to be accepted to encounter most of the patients in need of HEMS. In addition, a lower threshold for dispatch may be appropriate when in doubt, to avoid cancellation of missions to patients in true need for HEMS. A layperson calling the EMCC can obviously be misled

about the severity of a given acute illness or injury. A Danish study found that 18% of the calls to the EMCC represented unclear medical problems and emphasised the complexity of the dispatch decision.[48] Physician-staffed mobile medical teams showed a larger over-triage when being dispatched with a deliberately low threshold in the Netherlands, resulting in 43.5% of the missions being aborted.[41] An Australian study found that a physician-staffed HEMS crew more effectively identified cases of severe paediatric trauma when screening and triaging emergency calls as an alternative dispatch procedure to the centralised dispatch system operated by paramedics.[49]

More than one third of all dispatches in the present material were declined or aborted, mostly because of no continued medical indication, weather conditions, or concurrent requests. Most dispatches occurred during daytime, especially in the afternoon. A German study reported a similar pattern, although their peak rate (missions per hour) was before noon.[50] The summer was a busy period, probably because of more outdoor-related activity, and the frequency of cancellations caused by concurrent missions increased in these periods. However, a lower number of cancellations because of bad weather were reported in the summer and daytime. During late autumn and winter, a larger number of missions were cancelled, as Western Norway has only 8 hours of daylight per day and frequent storms and snow with low visibility. Helicopter flights at night and in low-visibility conditions are associated with a higher risk, and helicopter pilots follow stricter flight rules in these circumstances.[51]

If the EMCC requested HEMS to engage in exactly the same type of missions during daytime and night-time, the increased proportion of declined night-time dispatches because of "no longer a medical indication" is difficult to explain. Several factors influenced the decision to decline, including EMCC operator experience, HEMS crew experience, pilot concerns about weather conditions, and fatigue.[45] All of these factors may have justified the use of other available emergency resources. In Canada, Lawless et al. reported that almost 10% of the missions were declined or aborted because the air transport was no longer required.[33] The divergence may indicate a lower threshold for dispatch in our service, differences in populations, or different levels of HEMS crew experience. Our proportion of

cancelled helicopter flights caused by bad weather was only slightly more than half that reported in their study, probably because of different helicopters, pilot experience, and local weather conditions.[33]

Response time

Regarding response time in emergency missions, the results from our study are better than the political goal of reaching 90% of Norway's inhabitants with air ambulance within 45 minutes.[1] Median activation time for emergency helicopter flights (5 minutes) was lower than that reported by Krüger et al. They found 7 minutes of median activation time and 90% of patients reached within the first hour, but rural HEMS and large SAR helicopters were included in their study.[7,9] The location of the HEMS base away from a commercial airport to avoid "air traffic jams", our use of small helicopters with a short start-up time, and having the crew residing at the HEMS base each reduce activation time and thus response time.

On-scene time

One third of the conditions in emergency primary missions were cardiovascular diseases (cardiac arrest, myocardial infarction, and stroke), and yet another third involved trauma, altogether representing four of the five conditions in the First Hour Quintet.[19] Applying NACA score, we showed that one third of the patients in our primary missions were severely ill or injured. The score has been reported as useful for predicting mortality and the need for early respiratory therapy with a low inter-rater variability, despite being a crude scale.[11,52] In our primary trauma missions, the median NACA score was lower than expected, with a questionable indication for HEMS, and a lower median score compared to medical emergencies. This finding may be explained by a lower threshold for responding to trauma missions or by the fact that the initial phase after an accident is often characterised by uncertainty.[53] Increasing severity (i.e., higher NACA score) prolonged the OST as anticipated, agreeing with a study on paramedic-staffed ambulances responding only to trauma.[54]

In paper II, we found a short OST in preselected conditions compared to other studies.[31,55-57] Reducing the prehospital time is important in many severe medical emergencies and trauma, but the ideal OST cannot be applied for all conditions.[58,59] A short OST will not reduce morbidity or mortality for any given patient. Even in our four subgroups of severe conditions with definitive care available only in the hospital, reducing the OST may not increase survival for most patients. Newgard et al. found no association between OST and mortality in trauma patients with abnormal physiology.[60] Five years later, the same group reported that OST did not affect outcome in two cohorts including haemorrhagic shock and traumatic brain injuries. Their subgroup analysis of patients suffering haemorrhagic shock showed an association between longer out-of-hospital time and mortality in patients requiring early critical resources or suffering blunt trauma.[58] Gonzales et al. reported a correlation between prolonged prehospital time and increased patient mortality in rural vehicular trauma.[22] A 2015 review presented inconsistent results for correlations between prehospital time intervals and different outcomes for trauma patients, including some studies reporting OST as correlated with outcome in specific settings and conditions.[25] It is difficult to identify which of the severely ill or injured patients will benefit from a short OST. Hence, the appropriate approach may be to strive for a short OST in all critically ill patients where definitive care is available only in the hospital.

OST was four times greater in missions to patients suffering cardiac arrest compared to penetrating torso injuries, representing the two extremes. Hence, if missions to cardiac arrest patients are included in reports on the OST, important factors affecting OST in other conditions may have been neglected. Reported factors affecting the overall OST in all missions for a service are of little interest because of the large variation among different patient groups. HEMS in the US, Canada, Australia, and Europe differ greatly in crew composition, service hours, mission types, patient conditions, and on-scene strategy; therefore, different OSTs are reported (8 to 40 minutes).[26,54,55,61-63]

Advanced interventions that cannot be expected from ambulance personnel or regular GPs were provided in more than two thirds of the missions with a severely ill or injured patient. Other researchers have described that advanced interventions was performed in 23.1% of their HEMS missions, including several rural services and using a different study design.[7] We anticipated changes to OST when advanced interventions were performed on-scene. Studies assessing whether HEMS interventions alter OST are heterogeneous and report contradictory results.[13,23,25-29,56,58,64,65] Half of the patients with a NACA score of 4–6 received advanced interventions on-scene or during transport. Intubation had a large impact on OST, as reported by similar services.[66] However, our median OST was rather short even when the patient was intubated. A German study reported a mean OST of nearly 40 minutes, and close to two thirds of their patients were intubated on-scene.[63] The large difference from our study probably reflects different on-scene priorities rather than differences in patient conditions. The valuable OST should be spent only for necessary assessments and interventions to avoid immediate threats to life. Interventions required prior to helicopter flights because of limited resources and space available in the helicopter increase the OST.[29,66] Our data also showed increased OST when using the helicopter for evacuation. This effect may partly be explained by the knowledge that rapid initiation of transport without assessing airway, breathing, and circulation may worsen outcome. However, if the intervention can be performed by the ground ambulance crew or GPs, the OST may be reduced. This possibility was confirmed by the reduced OST in acute myocardial infarction if treatment before HEMS arrival was recorded. In addition, the increased focus on reducing OST for patients with acute myocardial infarction and stroke is the most likely cause of the decreased OST over the last five study years (2 minutes).

The OST increased by 2 seconds for each year of increase in patient age, assuming that the variable was linear. No information was available on patient morbidity prior to incidents, but we think a patient's current condition is more important and that this small increase in OST may reflect an increased rate of comorbidity rather than increased age itself.

The effect of the qualified assessment of critically ill patients and triage to the appropriate level of care is difficult to measure.[67] Our chosen method did not reveal an influence of physician experience on the OST. A German study reported increased prehospital times with junior physicians compared to senior physicians.[50] The advantage of a physician attending on-scene is debatable but does not necessarily increase OST.[20,21,66,68-72] Physician-staffed HEMS services can speed up the decision to depart from the scene, but may also increase OST if more advanced interventions are being performed.

The HEMS physician's role

A specially trained prehospital anaesthesiologist performing triage and prehospital care is an advantage when encountering critically ill patients. A large proportion of severe conditions and a high rate of advanced interventions may indicate the need for an anaesthesiologist. The benefit of physician-staffed EMS has been debated for decades and to what extent HEMS contributes to increased survival and improved patient outcome has not been settled.[10,21,68,73-76] A Cochrane review on the use of HEMS in adult trauma patients concluded that certainty is elusive regarding which elements provided by HEMS are most beneficial for the patients.[77-79] Some of these elements may be highly specialised care or reduced pain and secondary tissue injury, as well as reduced transport times to the appropriate level of care. A recent study from Norway indicated that HEMS physicians could restore deranged physiology in the prehospital phase, and other studies have found survival benefit in selected conditions for HEMS compared to ground ambulance services. This benefit is best documented for trauma patients.[10,13,21,63,69,70,75,80-82] Several other studies have found no benefit of a prehospital emergency physician or HEMS. The advantage of an experienced anaesthesiologist capable of early and sound clinical judgement may often be of more value than performing advanced interventions, because the avoidance of extensive interventions and a short OST might be best practice in many cases. The physicians in our HEMS have several years of experience.[83] Our results indicate that they can select the most severely ill or injured patient when experiencing concurrencies.

Outcome in cancelled missions and priority between dispatches

The fate of patients who cannot be reached by HEMS deserved further exploration. We chose to compare patient characteristics and outcome in missions with concurrent requests. Despite careful decisions about whether to respond, concurrencies will occur. These missions are important because they involve patients whom HEMS would like to encounter if not busy with another mission. However, the low incidence of concurrent missions indicates that our HEMS capacity has not reached its upper limit. To our knowledge, patient outcome has not previously been reported for missions cancelled by HEMS for another concurrent mission, perhaps because of the challenge in such assessments.

The survival rate was lower in our data than in a study of a ground ambulance service in Denmark reporting a 30-day mortality of less than 5%, but outcome definitions were dissimilar.[84] The survival rates may differ because missions in our study were initially dispatched to HEMS, indicating that the patients were more critically ill than the average ground ambulance patients. For all included missions, the survival rate was similar in the HEMS and AMB groups. The patients in the HEMS group showed a higher degree of deranged physiology, more often received emergency interventions, had higher admission frequencies to ICU or HDU, and had an increased length of hospital stay compared to the AMB group. One third of the primary HEMS missions were to patients with a prehospital acute threat to life. Of note, a larger proportion of these patients were admitted to ICU or HDU compared to the AMB group, even though Worthing PSS were similar on arrival in the ED. This similarity may be because of a lower threshold for admitting a patient to an ICU or HDU when being transported to hospital by HEMS or because physicians in our service have worked or are currently also working in the receiving ICUs. Yet another explanation may be that the HEMS physician could restore normal physiology, e.g., a hypotensive patient receiving boluses of intravenous fluid may have returned to normal measures for blood pressure and pulse rate in the ED. These patients could have experienced improved vital signs at the time of admission but still have been severely ill. Supporting this idea is the difference in the proportion of early in-hospital deaths. In the AMB group, the proportion of deaths within the first 24 hours was greater.

The fact that the HEMS patients were younger may also explain the increased proportion of ICU admissions. In the validation of Worthing PSS, higher mortality was revealed for groups with increasing age.[39] The different proportion in admissions to ICU or HDU may also have skewed the survival between the two groups because increased survival is expected with treatment in ICU/HDU, if the patient groups otherwise are similar. The increased survival for the group of patients with acute threat to life in the HEMS compared to the AMB group may indicate that HEMS treatment and/or rapid transport improve(s) patient outcome.

The anaesthesiologists in Norwegian HEMS work in the operating room and/or the ICU in addition to their prehospital work.[83] Most interventions used in the prehospital setting are a part of the daily in-hospital work. Other interventions are a part of regular training in controlled situations. These experiences enhance the ability to make quick and critical decisions as a response to rapid shifts in patient condition, which can be the difference between life and death for the patient. We encourage establishing a running system for follow-up, which can aid in improving dispatch criteria and dispatch decisions while avoiding some concurrencies, thus improving patient outcome.

HEMS changes

It is interesting that the annual number of dispatches to primary HEMS missions did not change, despite an increase in regionalisation, population, annual emergency calls, and annual emergency ambulance missions. This stability could trace to an unchanged number of patient conditions requiring HEMS, more ambulance dispatches defined as emergency missions, or stricter HEMS dispatch criteria. Similar seasonal variation was found in all study years. The recent advances in treatment options have also led to an increased number of HEMS missions to patient suffering from myocardial infarction and stroke.

No major changes were introduced in HEMS during the study period. EMCCs have increased their focus on a short response time for answering emergency calls and performing dispatch. The GPs became responsible for larger regions in the out-of-hours

service, and some small hospitals were shut down during the 10-year study period. Patients were more often transported to the larger hospitals, especially when experiencing trauma. Prompt transport of patients to a larger, specialised trauma centre are emphasised and recommended in both national and international guidelines.[24,85]

In recent years, the service has increased the range of advanced interventions available, i.e., HEMS in Western Norway currently may bring whole blood, freeze-dried plasma, portable ultrasound, videolaryngoscope, and a chest compression device.

Helicopter safety and economy

The use of a helicopter to bring "the hospital to the patient" is obviously not without substantial costs. Willingness to pay for HEMS has been studied in the UK.[86] Basic costs for the service are the dominating factor, and the extra costs for each mission are minor. However, the number of HEMS crew lives lost in accidents is far more important than the economic expenses. To justify the use of a helicopter in patient transport, the improved outcome for patients must be substantial compared to the increased risk for the crew. Economy, cost-benefit, and risk-benefit assessments were not within the scope of this thesis.

HEMS safety is important in our service. In primary missions, unknown landing sites are a safety hazard. Darkness and bad weather further increase the risk in these missions. Air obstacles and power lines are the most feared safety concern and have been the reason for several fatal HEMS accidents. Flight following is performed by the EMCCs and involves following the helicopter on the map and keeping in close radio contact with the helicopter. Recently, flight following has become coordinated in some dedicated EMCCs to gain a better overview of all HEMS in a larger area. This overview is also important for national coordination of air ambulances in large incidents. In the last 25 years, there has been an improvement in helicopter safety. From previously using the analogue BO 105, Norwegian HEMS is currently employing the latest Eurocopter H135/H145 technology with a digital "glass cockpit", improved navigation including moving maps, increased automation,

powerful engines, GPS, night-vision goggles, and regular simulator training for both pilots and HCM.

HEMS has experienced several accidents.[51,87-89] The last fatal accident in Norway occurred in January 2014. We lost two colleagues, and a third was severely injured. Yet again, a power line was the contributing factor in the accident, proving that our top-equipped helicopters do not provide a completely safe environment for our crew.

Strengths and limitations

The multicentre design involved three HEMS bases from the same time period and with a similar national HEMS profile. Although retrospective studies have weaknesses, a large number of missions were available for assessment and made it possible to evaluate OST in severe conditions with anticipated low OST. No data were recorded automatically in our HEMS. Time data were often registered after the mission was ended. The lack of automatic recording of mission times makes these data less reliable. As an example, dispatch time was set when the EMCC operator registered the dispatch in the data program, but this operation was not directly linked to the alarm in the crew's radio transmitters. Another is that the time for take-off or car moving is recorded based on the on-board computer and a possibly different computer clock setting. Yet another challenge is that data from patient monitors and diagnostic measurements are not automatically recorded but are based on manual registration on paper forms, which often is challenging during the mission.

The paper-based standardised report forms were in some cases filled in after the mission and therefore are subject to recall bias. Some information was not recorded in the report forms or the database, as reported by others.[90] However, we have no reason to believe that these gaps led to a systematic bias.

In most other studies, OST is defined as the time from the landing of the helicopter to take-off. Our definition of OST does not include the time used for shut-down, loading, and start-up of the helicopter and is more representative for the time used for medical assessment, triage, and treatment. However, intubations performed in the helicopter after leaving the

scene, either before take-off or during transport, were not recorded as part of the OST because our database does not differentiate between interventions on-scene or during transport. This distinction may have reduced OST compared to other studies. Many of the excluded variables may have had an impact on OST but were unavailable for analysis; i.e., in a road traffic accident with several patients, the actual number of patients assessed on-scene probably affects the OST.

It is probable that not all interventions performed are registered; hence, the rate of advanced interventions might be underreported. Some dispatches may not be registered if an EMCC has avoided scrambling a crew already busy with another mission or that is out of service. The patient records in the hospitals were of variable quality, and in some of the cases, the patient was not identified.

Regarding concurrent missions, a selection bias may have been present because HEMS may in some cases have been too far away from the scene to make a strict medical selection between missions. The patient in the "new mission" would in these cases be transported to the nearest hospital by a ground ambulance before HEMS could detach from the current mission. However, if the crew were already in-flight, the reaction time to another new mission may also have been reduced.

Differences in dispatch and acceptance policies among the Norwegian EMCCs and HEMS bases are interesting and may have influenced the results but are beyond the scope of this thesis. The three HEMS in Western Norway did not have the exact same dispatch criteria or handle the dispatch in a similar way. The presumed equal equipment, treatment options, personnel competence, and patient handling make this difference hard to understand. More research on the consequences of this difference is needed.

Geographical challenges (e.g., long distances, fjords, mountains, low-quality roads, and sparsity of suitable landing sites) and regional organisation (e.g., operational pattern, patient referral system, and resource availability) may differ from other HEMS, so generalisations from this thesis must be made with caution.

Future perspectives

A continuous registration of mission data and a prospective design are recommended to improve dispatch criteria and medical priority decisions by HEMS physicians. Laws and research ethics in emergency medicine must account for the challenge that patient or next-of-kin informed consent is most often not achievable in the initial phase.

Decisions in prehospital emergency medicine are often based on sparse information about the patient, a rapid examination, and without laboratory tests or radiological imaging. Research on the accuracy of the dispatch criteria in the EMCCs and the consequences of the anaesthesiologists' decisions is important. Data on patient outcomes after HEMS treatment are needed, and tools should be developed to offer individualised patient treatment and better identify which patients will benefit the most from this service. Future research in prehospital emergency medicine should aim to compare and improve dispatch criteria and guide physician decision-making.

Quality indicators are widely used in Norwegian and international health care. In Norwegian HEMS, however, few data that are suitable as quality indicators for patient care are reported regularly. Thus, OST or an increased survival in patients transported by HEMS may have changed without the change being noted. An expert group has developed a promising list of 26 response- and system-specific quality indicators for physician-staffed prehospital services.[91] Another challenge in emergency medicine research is the limited consensus on variable definitions, but an expert group also has defined a feasible template for reporting data in prehospital physician-staffed services.[92] The HEMS in Finland (FinnHEMS) are recording data from their missions in accordance with this template, and further research in HEMS should incorporate the template. Collecting reliable information in emergency situations is difficult, and the focus is and should remain on assessing and treating the patient. Future technology should enable automatically recording of data from patient monitors and diagnostic measurements to ensure that prehospital data are accurately registered in hospital records and to improve the quality of prehospital research. Quality indicators for HEMS activity and patient treatment should be systematically reported, made

available for research, and used for individual benchmarking for the HEMS physicians and for comparison between the different HEMS services.[92]

Improved technology and medical treatment options are constantly becoming available. For example, prehospital treatment of stroke may be changed with an ability to distinguish intracerebral infarction from intracerebral haemorrhage. HEMS in Western Norway is involved in the research on Strokefinder[TM] (Medfield Diagnostics, Göteborg, Sweden), which may prove to be an efficient and lightweight diagnostic tool using microwave radiation for patients with symptoms of stroke. New laboratory tests may be developed, such as biomarkers for brain tissue damage and a lactate quick-test for use in trauma. Future standard treatments may involve extracorporeal membrane oxygenation or nitric oxide treatment during inter-hospital transfers, which are already standard options in other HEMS in Norway.

The results from our studies indicate the advantage of an anaesthesiologist in HEMS, but further research is needed for validation of this. More research is also needed to address which of the elements provided by HEMS that are most beneficial for patient outcome.

Conclusions

In conclusion, the evidence indicates that HEMS is a reliable service for several reasons. First, cancellation rates because of weather, concurrent missions, technical issues, and exceeded duty time are low. Second, response times are shorter than the official political goal, and OST is low in primary missions in which a short OST is to be expected. Third, when concurrent missions arise, HEMS selects missions with more severe illnesses or injuries, while maintaining outcomes similar to those for patients in the cancelled missions. In addition, patients with prehospital acute threat to life have an increased survival rate after being transported by HEMS compared to transport by ground ambulances.

The annual number of primary missions has been stable, with a higher incidence of patient encounter than in previous reports. One third of the patients in these studies were severely ill or injured, and more than two thirds of this group received advanced interventions. Important factors associated with an increased OST were identified. Ambulances and GPs treatment before HEMS arrival reduced OST in important time-dependent medical conditions such as myocardial infarction and stroke.

References

1. Øgar P. NOU 1998:8 Air ambulance service in Norway (Document in Norwegian). In: SHD, ed., 1998.
2. Neel S. Army aeromedical evacuation procedures in Vietnam: implications for rural America. JAMA 1968; 204: 309-13.
3. Norwegian Air Ambulance Service. http://www.luftambulanse.no/about-national-air-ambulance-services-norway [accessed 20.03.2019].
4. Statistics Norway. http://www.ssb.no/en/ [accessed 20.03.2019].
5. Hjortdahl M, Zakariassen E, Halvorsen PA. Self reported involvement in emergency medicine among GPs in Norway. Scand J Prim Health Care 2018; 36: 161-69.
6. Norwegian Air Ambulance Service Annual Reports 2009–15. [Web site in Norwegian]. http://www.luftambulanse.no/arsrapporter [accessed 20.03.2019].
7. Krüger AJ, Lossius HM, Mikkelsen S, Kurola J, Castrén M, Skogvoll E. Pre-hospital critical care by anaesthesiologist-staffed pre-hospital services in Scandinavia: a prospective population-based study. Acta Anaesthesiol Scand 2013; 57: 1175-85.
8. Zakariassen E, Uleberg O, Roislien J. Helicopter emergency medical services response times in norway: do they matter? Air Med J 2015; 34: 98-103.
9. Krüger AJ, Skogvoll E, Castrén M, Kurola J, Lossius HM, ScanDoc Phase 1a Study G. Scandinavian pre-hospital physician-manned Emergency Medical Services--same concept across borders? Resuscitation 2010; 81: 427-33.
10. Lossius HM, Søreide E, Hotvedt R, Hapnes SA, Eielsen OV, Førde OH, Steen PA. Prehospital advanced life support provided by specially trained physicians: is there a benefit in terms of life years gained? Acta Anaesthesiol Scand 2002; 46: 771–8.
11. Raatiniemi L, Mikkelsen K, Fredriksen K, Wisborg T. Do pre-hospital anaesthesiologists reliably predict mortality using the NACA severity score? A retrospective cohort study. Acta Anaesthesiol Scand 2013; 57: 1253–9.
12. Nakstad AR, Strand T, Sandberg M. Landing sites and intubation may influence helicopter emergency medical services on-scene time. J Emerg Med 2011; 40: 651-7.
13. Reid BO, Rehn M, Uleberg O, Krüger AJ. Physician-provided prehospital critical care, effect on patient physiology dynamics and on-scene time. Eur J Emerg Med 2016 Nov 22; Epub ahead of print. doi: 10.1097/MEJ.0000000000000432.
14. Sollid SJ, Lossius HM, Soreide E. Pre-hospital intubation by anaesthesiologists in patients with severe trauma: an audit of a Norwegian helicopter emergency medical service. Scand J Trauma Resusc Emerg Med 2010; 18: 30.
15. Sunde GA, Heradstveit BE, Vikenes BH, Heltne JK. Emergency intraosseous access in a helicopter emergency medical service: a retrospective study. Scand J Trauma Resusc Emerg Med 2010; 18: 52.
16. Ellensen EN, Wisborg T, Hunskaar S, Zakariassen E. Dispatch guideline adherence and response interval-a study of emergency medical calls in Norway. BMC Emerg Med 2016; 16: 40.
17. Norwegian_Medical_Association. Norsk indeks for medisinsk nødhjelp (Norwegian Index for Medical Emergency Assistance) 3. Laerdal Medical AS, 2009.
18. McQueen C, Smyth M, Fisher J, Perkins G. Does the use of dedicated dispatch criteria by Emergency Medical Services optimise appropriate allocation of advanced care resources in cases of high severity trauma? A systematic review. Injury 2015; 46: 1197–206.
19. Krafft T, Garcia Castrillo-Riesgo L, Edwards S, Fischer M, Overton J, Robertson-Steel I, König A. European Emergency Data Project (EED Project): EMS data-based health surveillance system. Eur J Public Health 2003; 13: 85-90.

20.   Dissmann PD, Le Clerc S. The experience of Teesside helicopter emergency services: doctors do not prolong prehospital on-scene times. Emerg Med J 2007; 24: 59-62.

21.   Garner A, Rashford S, Lee A, Bartolacci R. Addition of physicians to paramedic helicopter services decreases blunt trauma mortality. Aust N Z J Surg 1999; 69: 697-701.

22.   Gonzalez RP, Cummings G, Mulekar M, Rodning CB. Increased mortality in rural vehicular trauma: identifying contributing factors through data linkage. J Trauma 2006; 61: 404-9.

23.   Meizoso JP, Valle EJ, Allen CJ, Ray JJ, Jouria JM, Teisch LF, Shatz DV, Namias N, Schulman CI, Proctor KG. Decreased mortality after prehospital interventions in severely injured trauma patients. J Trauma Acute Care Surg 2015; 79: 227-31.

24.   National Institute for Health and Care Excellence (NICE) guideline; Major Trauma: service delivery. https://www.nice.org.uk/guidance/ng40/chapter/recommendations#prehospital-triage [accessed 20.03.2019].

25.   Harmsen AM, Giannakopoulos GF, Moerbeek PR, Jansma EP, Bonjer HJ, Bloemers FW. The influence of prehospital time on trauma patients outcome: a systematic review. Injury 2015; 46: 602-9.

26.   Spaite DW, Tse DJ, Valenzuela TD, Criss EA, Meislin HW, Mahoney M, Ross J. The impact of injury severity and prehospital procedures on scene time in victims of major trauma. Ann Emerg Med 1991; 20: 1299-305.

27.   Carr BG, Brachet T, David G, Duseja R, Branas CC. The time cost of prehospital intubation and intravenous access in trauma patients. Prehosp Emerg Care 2008; 12: 327-32.

28.   van der Velden MWA, Ringburg AN, Bergs EA, Steyerberg EW, Patka P, Schipper IB. Prehospital interventions: time wasted or time saved? An observational cohort study of management in initial trauma care. Emerg Med J 2008; 25: 444-9.

29.   Wyen H, Lefering R, Maegele M, Brockamp T, Wafaisade A, Wutzler S, Walcher F, Marzi I, TraumaRegister DGU. The golden hour of shock - how time is running out: prehospital time intervals in Germany--a multivariate analysis of 15, 103 patients from the TraumaRegister DGU(R). Emerg Med J 2013; 30: 1048-55.

30.   Herlitz J, WireklintSundström B, Bang A, Berglund A, Svensson L, Blomstrand C. Early identification and delay to treatment in myocardial infarction and stroke: differences and similarities. Scand J Trauma Resusc Emerg Med 2010; 18: 48.

31.   Simonsen SA, Andresen M, Michelsen L, Viereck S, Lippert FK, Iversen HK. Evaluation of pre-hospital transport time of stroke patients to thrombolytic treatment. Scand J Trauma Resusc Emerg Med 2014; 22: 65.

32.   Østerås Ø, Brattebø G, Heltne JK. Helicopter-based emergency medical services for a sparsely populated region: A study of 42,500 dispatches. Acta Anaesthesiol Scand 2016; 60: 659–67.

33.   Lawless J, Tallon JM, Petrie D. Aborted air medical missions: a 4-year quality review of a Canadian province-wide air medical program. Air Med J 2005; 24: 79–82.

34.   Weuster M, Bruck A, Lippross S, Menzdorf L, Fitschen-Oestern S, Behrendt P, Iden T, Hocker J, Lefering R, Seekamp A, Kluter T, TraumaRegister DGU. Epidemiology of accidental hypothermia in polytrauma patients: An analysis of 15,230 patients of the TraumaRegister DGU. J Trauma Acute Care Surg 2016; 81: 905-12.

35.   Tryba M, Brüggemann H, Echtermeyer V. [Klassifizierung von Erkrankungen und Verletzungen in Notarztrettungssystemen]. Notfallmed 1980; 6: 725–7.

36.   The National Committee on Aeronautics. https://history.nasa.gov/naca/ [accessed 20.03.2019].

37.   Pinheiro J BD, DebRoy S, Sarkar D and R Core Team,. _nlme: Linear and Nonlinear Mixed Effects Models_. R package version 3.1-127. 2016.

38.   R Core Team. R: A language and environment for statistical computing.: R Foundation for Statistical Computing, Vienna, Austria., 2016.

39. Duckitt RW, Buxton-Thomas R, Walker J, Cheek E, Bewick V, Venn R, Forni LG. Worthing physiological scoring system: derivation and validation of a physiological early-warning system for medical admissions. An observational, population-based single-centre study. Br J Anaesth 2007; 98: 769–74.

40. Kleinbaum DG, Klein M. Kaplan-Meier Survival Curves and the Log-Rank Test. Survival Analysis: A Self-Learning Text, Third Edition. New York, NY: Springer New York, 2012: 55–96.

41. Giannakopoulos GF, Lubbers WD, Christiaans HMT, van Exter P, Bet P, Hugen PJC, Innemee G, Schubert E, de Lange-Klerk ESM, Goslings JC, Jukema GN. Cancellations of (helicopter-transported) mobile medical team dispatches in the Netherlands. Langenbecks Arch Surg 2010; 395: 737–45.

42. Roislien J, van den Berg PL, Lindner T, Zakariassen E, Uleberg O, Aardal K, van Essen JT. Comparing population and incident data for optimal air ambulance base locations in Norway. Scand J Trauma Resusc Emerg Med 2018; 26: 42.

43. Littlewood N, Parker A, Hearns S, Corfield A. The UK helicopter ambulance tasking study. Injury 2009; 41: 27-9.

44. Reid BO, Rehn M, Uleberg O, Pleym LEN, Kruger AJ. Inter-disciplinary cooperation in a physician-staffed emergency medical system. Acta Anaesthesiol Scand 2018; 62: 1007-13.

45. Ellensen EN, Hunskaar S, Wisborg T, Zakariassen E. Variations in contact patterns and dispatch guideline adherence between Norwegian emergency medical communication centres--a cross-sectional study. Scand J Trauma Resusc Emerg Med 2014; 22: 2.

46. Palumbo L, Kubincanek J, Emerman C, Jouriles N, Cydulka R, Shade B. Performance of a system to determine EMS dispatch priorities. Am J Emerg Med 1996; 14: 388–90.

47. Giannakopoulos GF, Bloemers FW, Lubbers WD, Christiaans HMT, van Exter P, de Lange-de Klerk ESM, Zuidema WP, Goslings JC, Bakker FC. Criteria for cancelling helicopter emergency medical services (HEMS) dispatches. Emerg Med J 2012; 29: 582–6.

48. Møller TP, Kjærulff TM, Viereck S, Østergaard D, Folke F, Ersbøll AK, Lippert FK. The difficult medical emergency call: A register-based study of predictors and outcomes. Scand J Trauma Resusc Emerg Med 2017; 25: 22.

49. Garner AA, Lee A, Weatherall A. Physician staffed helicopter emergency medical service dispatch via centralised control or directly by crew - case identification rates and effect on the Sydney paediatric trauma system. Scand J Trauma Resusc Emerg Med 2012; 20: 82.

50. Schuster M, Pints M, Fiege M. Duration of mission time in prehospital emergency medicine: effects of emergency severity and physicians level of education. Emerg Med J 2010; 27: 398-403.

51. Chesters A, Grieve PH, Hodgetts TJ. A 26-year comparative review of United Kingdom helicopter emergency medical services crashes and serious incidents. J Trauma Acute Care Surg 2014; 76: 1055-60.

52. Raatiniemi L, Liisanantti J, Tommila M, Moilanen S, Ohtonen P, Martikainen M, Voipio V, Reitala J, Iirola T. Evaluating helicopter emergency medical missions: a reliability study of the HEMS benefit and NACA scores. Acta Anaesthesiol Scand 2017; 61: 557-65.

53. Ringburg AN, de Ronde G, Thomas SH, van Lieshout EM, Patka P, Schipper IB. Validity of helicopter emergency medical services dispatch criteria for traumatic injuries: a systematic review. Prehosp Emerg Care 2009; 13: 28-36.

54. Goodacre SW, Gray A, McGowan A. On-scene times for trauma patients in West Yorkshire. J Accid Emerg Med 1997; 14: 283-5.

55. McCoy CE, Menchine M, Sampson S, Anderson C, Kahn C. Emergency medical services out-of-hospital scene and transport times and their association with mortality in trauma patients presenting to an urban Level I trauma center. Ann Emerg Med 2013; 61: 167-74.

56.   Funder KS, Petersen JA, Steinmetz J. On-scene time and outcome after penetrating trauma: an observational study. Emerg Med J 2011; 28: 797-801.

57.   Aydin S, Overwater E, Saltzherr TP, Jin PH, van Exter P, Ponsen KJ, Luitse JSK, Goslings JC. The association of mobile medical team involvement on on-scene times and mortality in trauma patients. J Trauma 2010; 69: 589-94; discussion 94.

58.   Newgard CD, Meier EN, Bulger EM, Buick J, Sheehan K, Lin S, Minei JP, Barnes-Mackey RA, Brasel K, Investigators ROC. Revisiting the "Golden Hour": An Evaluation of Out-of-Hospital Time in Shock and Traumatic Brain Injury. Ann Emerg Med 2015; 66: 30-41, 41 e1-3.

59.   Hoejenbos MJ, McManus J, Hodgetts T. Is there one optimal medical treatment and evacuation chain for all situations: "scoop-and-run" or "stay-and-play". Prehosp Disaster Med 2008; 23: s74-8.

60.   Newgard CD, Schmicker RH, Hedges JR, Trickett JP, Davis DP, Bulger EM, Aufderheide TP, Minei JP, Hata JS, Gubler KD, Brown TB, Yelle JD, Bardarson B, Nichol G, Resuscitation Outcomes Consortium I. Emergency medical services intervals and survival in trauma: assessment of the "golden hour" in a North American prospective cohort. Ann Emerg Med 2010; 55: 235-46 e4.

61.   Carr BG, Caplan JM, Pryor JP, Branas CC. A meta-analysis of prehospital care times for trauma. Prehosp Emerg Care 2006; 10: 198-206.

62.   Taylor CB, Liu B, Bruce E, Burns B, Jan S, Myburgh J. Primary scene responses by Helicopter Emergency Medical Services in New South Wales Australia 2008-2009. BMC Health Serv Res 2012; 12: 402.

63.   Andruszkow H, Lefering R, Frink M, Mommsen P, Zeckey C, Rahe K, Krettek C, Hildebrand F. Survival benefit of helicopter emergency medical services compared to ground emergency medical services in traumatized patients. Crit Care 2013; 17: R124.

64.   Bonatti J, Göschl O, Larcher P, Wödlinger R, Flora G. Predictors of short-term survival after helicopter rescue. Resuscitation 1995; 30: 133-40.

65.   Høyer CC, Christensen EF, Andersen NT. On-scene time in advanced trauma life support by anaesthesiologists. Eur J Emerg Med 2006; 13: 156-9.

66.   Hoyer CC, Christensen EF, Andersen NT. On-scene time in advanced trauma life support by anaesthesiologists. Eur J Emerg Med 2006; 13: 156-9.

67.   Reid BO, Rehn M, Uleberg O, Kruger AJ. Physician-provided prehospital critical care, effect on patient physiology dynamics and on-scene time. Eur J Emerg Med 2018; 25: 114-19.

68.   Roberts K, Blethyn K, Foreman M, Bleetman A. Influence of air ambulance doctors on on-scene times, clinical interventions, decision-making and independent paramedic practice. Emerg Med J 2009; 26: 128-34.

69.   Bøtker MT, Bakke SA, Christensen EF. A systematic review of controlled studies: do physicians increase survival with prehospital treatment? Scand J Trauma Resusc Emerg Med 2009; 17: 12.

70.   Pakkanen T, Virkkunen I, Kämäräinen A, Huhtala H, Silfvast T, Virta J, Randell T, Yli-Hankala A. Pre-hospital severe traumatic brain injury - comparison of outcome in paramedic versus physician staffed emergency medical services. Scand J Trauma Resusc Emerg Med 2016; 24: 62.

71.   Nielsen EW, Ulvik A, Carlsen AW, Rannestad B. When is an anesthesiologist needed in a helicopter emergency medical service in northern Norway? Acta Anaesthesiol Scand 2002; 46: 785-8.

72.   Dickinson ET, Schneider RM, Verdile VP. The impact of prehospital physicians on out-of-hospital nonasystolic cardiac arrest. Prehosp Emerg Care 1997; 1: 132-5.

73. Wisborg T, Guttormsen AB, Sorensen MB, Flaatten HK. The potential of an anaesthesiologist-manned ambulance service in a rural/urban district. Acta Anaesthesiol Scand 1994; 38: 657-61.

74. Moecke H, von Knobelsdorff G. The anesthesiologist in prehospital and hospital emergency medicine. Curr Opin Anaesthesiol 2008; 21: 228-32.

75. Hesselfeldt R, Steinmetz J, Jans H, Jacobsson MLB, Andersen DL, Buggeskov K, Kowalski M, Præst M, Øllgaard L, Höiby P, Rasmussen LS. Impact of a physician-staffed helicopter on a regional trauma system: a prospective, controlled, observational study. Acta Anaesthesiol Scand 2013; 57: 660–8.

76. Gunnarsson SI, Mitchell J, Busch MS, Larson B, Gharacholou SM, Li Z, Raval AN. Outcomes of Physician-Staffed Versus Non-Physician-Staffed Helicopter Transport for ST-Elevation Myocardial Infarction. Journal of the American Heart Association 2017; 6.

77. Bieler D, Franke A, Lefering R, Hentsch S, Willms A, Kulla M, Kollig E, TraumaRegister DGU. Does the presence of an emergency physician influence pre-hospital time, pre-hospital interventions and the mortality of severely injured patients? A matched-pair analysis based on the trauma registry of the German Trauma Society (TraumaRegister DGU(R)). Injury 2017; 48: 32–40.

78. Butler DP, Anwar I, Willett K. Is it the H or the EMS in HEMS that has an impact on trauma patient mortality? A systematic review of the evidence. Emerg Med J 2010; 27: 692–701.

79. Galvagno Jr SM, Thomas S, Stephens C, Haut ER, Hirshon JM, Floccare D, Pronovost P. Helicopter emergency medical services for adults with major trauma. Cochrane Database Syst Rev 2013; 3: CD009228.

80. McVey J, Petrie DA, Tallon JM. Air versus ground transport of the major trauma patient: a natural experiment. Prehosp Emerg Care 2010; 14: 45–50.

81. Giannakopoulos GF, Kolodzinskyi MN, Christiaans HMT, Boer C, de Lange-de Klerk ESM, Zuidema WP, Bloemers FW, Bakker FC. Helicopter Emergency Medical Services save lives: outcome in a cohort of 1073 polytraumatized patients. Eur J Emerg Med 2013; 20: 79–85.

82. Tsuchiya A, Tsutsumi Y, Yasunaga H. Outcomes after helicopter versus ground emergency medical services for major trauma--propensity score and instrumental variable analyses: a retrospective nationwide cohort study. Scand J Trauma Resusc Emerg Med 2016; 24: 140.

83. Bjornsen LP, Solheim AM, Uleberg O, Skogvoll E. Compliance With a National Standard by Norwegian Helicopter Emergency Physicians. Air Med J 2018; 37: 46-50.

84. Christensen EF, Bendtsen MD, Larsen TM, Jensen FB, Lindskou TA, Holdgaard HO, Hansen PA, Johnsen SP, Christiansen CF. Trends in diagnostic patterns and mortality in emergency ambulance service patients in 2007-2014: a population-based cohort study from the North Denmark Region. BMJ open 2017; 7: e014508.

85. NKT-Traume. (2016) National plan for trauma care. [Web site in Norwegian]. http://traumeplan.no [accessed 20.03.2019].

86. Ringburg AN, Buljac M, Stolk EA, van Lieshout EM, van Beeck EF, Patka P, Schipper IB. Willingness to pay for lives saved by Helicopter Emergency Medical Services. Prehosp Emerg Care 2009; 13: 37-43.

87. Bledsoe BE, Smith MG. Medical helicopter accidents in the United States: a 10-year review. J Trauma 2004; 56: 1325-8; discussion 28-9.

88. Hinkelbein J, Dambier M, Viergutz T, Genzwurker H. A 6-year analysis of German emergency medical services helicopter crashes. J Trauma 2008; 64: 204-10.

89. Hinkelbein J, Schwalbe M, Wetsch WA, Spelten O, Neuhaus C. Helicopter type and accident severity in Helicopter Emergency Medical Services missions. Aviat Space Environ Med 2011; 82: 1148-52.

90. Staff T, Sovik S. A retrospective quality assessment of pre-hospital emergency medical documentation in motor vehicle accidents in south-eastern Norway. Scand J Trauma Resusc Emerg Med 2011; 19: 20.

91. Haugland H, Rehn M, Klepstad P, Kruger A, group EQ-c. Developing quality indicators for physician-staffed emergency medical services: a consensus process. Scand J Trauma Resusc Emerg Med 2017; 25: 14.

92. Kruger AJ, Lockey D, Kurola J, Di Bartolomeo S, Castren M, Mikkelsen S, Lossius HM. A consensus-based template for documenting and reporting in physician-staffed pre-hospital services. Scand J Trauma Resusc Emerg Med 2011; 19: 71.

Erratum

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I

Helicopter-based emergency medical services for a sparsely populated region: A study of 42,500 dispatches

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Conflicts of interest
The authors declare no conflicts of interest.

Background: The Helicopter Emergency Medical Service (HEMS) in Norway is operated day and night, despite challenging geography and weather. In Western Norway, three ambulance helicopters, with a rapid response car as an alternative, cover close to 1 million inhabitants in an area of 45,000 km^2. Our objective was to assess patterns of emergency medical problems and treatments in HEMS in a geographically large, but sparsely populated region.

Methods: Data from all HEMS dispatches during 2004–2013 were assessed retrospectively. Information was analyzed with respect to patient treatment and characteristics, in addition to variations in services use during the day, week, and seasons.

Results: A total of 42,456 dispatches were analyzed. One third of the patients encountered were severely ill or injured, and two thirds of these received advanced treatment. Median activation time and on-scene time in primary helicopter missions were 5 and 11 min, respectively. Most patients (95%) were reached within 45 min by helicopter or rapid response car. Patterns of use did not change. More than one third of all dispatches were declined or aborted, mostly due to no longer medical indication, bad weather conditions, or competing missions.

Conclusion: One third of the patients encountered were severely ill or injured, and more than two thirds of these received advanced treatment. HEMS use did not change over the 10-year period, however HEMS use peaked during daytime, weekends, and the summer. More than one third of all dispatches were declined or aborted.

Editorial comment: what this article tells us
This report describes the pattern of utilization of a regional helicopter-based air ambulance system serving a sparsely populated large geographical area. With critical care personnel and resources on board, advanced care can be initiated early for severely ill or injured patients.

Vast rural areas, a long coastline, fjords, high mountains, and great distances make the Helicopter Emergency Medical Service (HEMS) an important supplement to ground services in Western Norway. In particular, HEMS is a key component of meeting the declared political goal of equal access to advanced medical care, regardless of location. The unofficial national

standard for emergency missions is that 90% of the population should be reached by a physician-staffed ambulance within 45 min.[1] The Norwegian health care system has become more centralized with increased specialization, and several smaller hospitals consequently have closed. General practitioners (GPs) on call in municipalities may be responsible for a large geographic area, as municipalities often share services.[2] The result is an increase in both ambulance missions and transport distance.

Norwegian HEMS operate day and night, despite challenging factors related to weather, geography, and light conditions (night and winter darkness). A rapid response car is available on every base. Missions include primary and secondary (inter-hospital) missions for both medical emergencies and trauma, but also search and rescue (SAR), patients with minor injuries in the mountains, and inter-hospital incubator transports of newborns.[3] This role is in contrast to many international HEMS that are limited only to operating during daytime, responding to trauma, or performing inter-hospital transfers.[4–6] Several HEMS have published their experiences,[4,5,7–11] but comparing such services is challenging.[12] Some publications have described the Norwegian and Scandinavian emergency medical services,[3,13–16] and the Norwegian National Air Ambulance Service publishes a short annual report based on data from each HEMS base.[17]

Anesthesiologists in pre-hospital emergency services are common in Scandinavia, and Norway has a long tradition of staffing HEMS with an anesthesiologist as the emergency physician. Triaging and careful use of HEMS are important to avoid both under- and overuse of the service. Competing missions, bad weather, logistic challenges, and other factors can lead to declined dispatches or aborted missions (cancelations). Knowledge about the temporal variations and occurrence of cancelations is lacking, despite its importance for planning services. Hence, more information is needed to evaluate medical priorities, patient outcome, and patterns of use. We hypothesized that our HEMS responded to severely ill or injured patients and a large part of these patients needed advanced medical treatment.

The objective of the present study was to assess patterns of emergency medical problems and treatments in the pre-hospital system, in a geographically large but sparsely populated region, where helicopter emergency medical services were involved.

Methods

This retrospective study presents analysis of patient records from all dispatches during the period 2004–2013 for the three HEMS bases in Førde, Bergen, and Stavanger.

Population and geography

Western Norway has a population of 1,087,000 and is 45,000 km^2 in area.[18] One third of the population lives in Stavanger and Bergen; outside these cities, population density is only 15 persons per km^2. The rural area consists of islands, long fjords, high mountains, rough terrain, and low quality roads, resulting in prolonged response and transport times by ground ambulances.

Emergency medical services in Western Norway

Four emergency medical call centers (EMCCs) serve as dispatch centers for 94 ground ambulances and three HEMS in the region. GPs are on call and may respond together with ambulances in rural areas. Five local hospitals, two regional hospitals, and two university hospitals serve the area (Supplemental files, Fig. S1). The region also has two SAR helicopters, which in some cases are dispatched if HEMS declines or aborts a mission. Data on these missions were included as canceled missions in our study. All services are fully government funded (not per mission).

All of our bases are continuously open for operations and have a rapid response car as an alternative for local missions or when the helicopter is not available. The helicopters (EC135) have a standard capacity for one supine and one sitting patient and are staffed with a pilot, a rescue paramedic, and an anesthesiologist. The HEMS physician is responsible for triaging patients/missions based on information from the

EMCC, but dispatch criteria at the three bases are not entirely identical. If a HEMS crew has worked 14 of the last 24 h, they will be out of service for 9 h according to Norwegian HEMS regulations.

Data source, data cleaning, and variables

The HEMS in Western Norway register all activity in a database called "Airdoc" (File-maker 8, Filemaker Inc., CA, USA). The data include administrative, time, and patient data; vital signs; treatment performed; and a free-text option. Unusual, extreme, or missing values were assessed by reading the free-text field and cross-checking other sources (e.g., EMCC records and pilot flight logs). Missing or obviously incorrect values were corrected when reliable data were identified, but otherwise, these values were excluded. A HEMS mission was defined as a dispatch from the EMCC, leading to a response with the rapid response car or helicopter. Cancelations were defined as either a declined dispatch (before helicopter take-off or car moving) or an aborted mission. Seasons were defined in 3-month units (e.g., December, January, and February as winter; March, April, and May as spring). Activation time were defined as time from dispatch to helicopter take-off or car moving, response time from dispatch to encountering the patient, on-scene time from encountering the patient to start of patient transport from the scene, and transport time from start of patient transport from scene to end of patient care. The National Advisory Committee for Aeronautics score (NACA, Supplemental files, Table S1) was modified to be used for pre-hospital medical emergencies and trauma in 1980.[19,20] This severity score from level 0 (no injury or disease) to level 7 (death) is used in Norwegian HEMS. Conditions with a NACA score of 5–7 were considered to represent patients with severe illness or injury.

Statistical methods

All HEMS dispatches during 2004–2013 were included. Normally distributed data are presented as mean with standard deviation (SD); otherwise, median and inter-quartile range (IQR) are presented. The Chi-square test was used to examine proportions of advanced treatment between different groups of NACA scores, and between observed missions with patient encounter, declined dispatches, aborted missions, reasons for declining or aborting, and the total of the others. Linear regression models were applied to evaluate the association between continuous data, and R^2 for goodness of fit. Yearly incidence of missions was calculated by the ratio of total missions over the entire population in the area, divided by the number of study years. Population data were based on census data. Data were analyzed with IBM SPSS Statistics for Windows, Version 22 (IBM Corp., Armonk, NY, USA), and linear regression was performed in Excel 2010 (Micro-soft Corp., WA, USA). A P-value of < 0.05 was considered statistically significant.

The Regional Committee for medical and health research ethics West (REK Vest 2010/2930, 15.12.2010, committee head Jon Lekven), waived the requirement for formal review, but had no objections to publication of the data. The Ministry of Health and Care Services (2011-02407), the Norwegian Data Protection Authority (12/00291-3), and Data Protection Officials for Research all approved the project.

Results

All 42,456 dispatches registered during the 10 years were included (Fig. 1). Most dispatches were to primary missions, 82.6% ($n = 35,051$), and the number of dispatches to primary missions did not change during the study period ($R^2 = 0.28$; Table 1). Consistently across the 10-year period, the busiest times were during summer, weekends, and daytime.

Primary missions with patient encounter

Despite a 12.5% population increase,[18] the number of missions was constant ($R^2 = 0.12$). Table 2 gives the characteristics of the missions. The proportion of patients suffering from stroke increased from 4% to 7.5% ($R^2 = 0.76$), but other conditions showed only minor variation. About 10% of the patients were < 10 years old. Mean NACA score was 4.3 (SD = 0.8). Trauma and cardiovascular diseases (cardiac arrest, chest
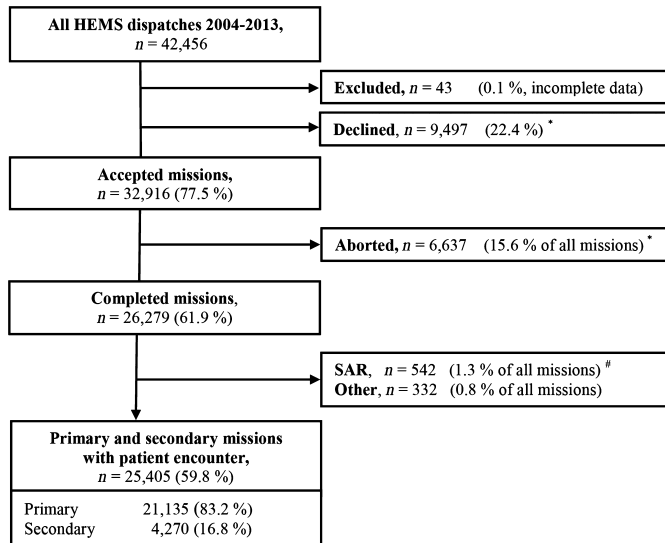
Fig. 1. Flowchart showing all HEMS missions, with excluded and declined dispatches, aborted and completed missions, and the proportion of completed primary and secondary missions with patient encounter. Primary missions were defined as responses to patients outside hospitals. Secondary missions were defined as inter-hospital transfers, transporting patients to a higher level of care. Search and Rescue (SAR) missions include searching for the patient or a missing person, or when rescue techniques were used (e.g., rope rescue operation). Examples of other missions are inter-hospital transportation of a patient to a lower level of care, and transporting blood products, surgeons, or fire crew. *470 declined, and 117 aborted missions (total 1.4% of all HEMS missions) were transferred to other HEMS in the area; hence, these incidents are counted as two dispatches. Some dispatches were declined or aborted with helicopter but completed (with patient encounter) using a rapid response car. #1/3 of the completed SAR missions included patient encounter (n = 175).

Table 1 Population, emergency calls to EMCC, ambulance missions, and emergency HEMS dispatches in 2004 and 2013.

	2004		2013		Increase	
	n	Per 10,000	n	Per 10,000	%	R^2*
Population[18]	941,129		1,058,994		12.5	0.99
Ambulance missions †	79,681	846.7	119,493	1,128.4	50.0	0.95
Emergency ambulance missions	16,141	171.5	31,438	296.9	94.8	0.99
All emergency HEMS dispatches	3456	36.7	3513	33.2	1.6	0.36

*Linear regression, R^2 for goodness of fit. †All ambulance missions from EMCC data, including ambulance transports home from hospital. All types of emergency HEMS missions are included.

pain, and stroke) were the two major groups of conditions, each representing almost one third of the missions.

Medical treatment in primary missions

Advanced treatment was performed in 41.2% (n = 8421) of all primary missions and basic treatment in 34.2% (n = 6991). A severe illness or injury (NACA = 5–7) was encountered in 33.3% (n = 6745) of primary missions. These patients received advanced medical treatment in 66.3% (n = 4474) of the missions while basic treatment was provided in 24.3% (n = 1642) (Fig. 2). A larger proportion of patients with NACA 5–7 received advanced treatment compared to patients with NACA 0–4 (z > 10, P < 0.001).

Table 2 Primary and secondary missions, with a total of 25,405 patient encounters.

	All		Primary missions			Secondary missions	
	N (%)	NACA, median (inter-quartile range)	N (%)	Incidence per 10,000 inhabitants per year*	NACA, median (inter-quartile range)	N (%)	NACA, median (inter-quartile range)
Missions with patient encounter	25,405 (100.0)	4 (2)	21,135 (100.0)	21.3	4 (2)	4270 (100.0)	4 (1)
Patients < 2 years	1292 (5.1)	4 (1)	991 (4.7)	1.0	4 (1)	301 (7.0)	4 (2)
Patients < 10 years	2600 (10.2)	4 (1)	2179 (10.3)	2.2	3 (1)	421 (9.9)	4 (1)
Patients > 75 years	3,596 (14.2)	4 (2)	2833 (13.4)	2.9	5 (2)	763 (17.9)	4 (1)
Missing	974 (3.8)	4 (2)	891 (4.2)		4 (2)	83 (1.9)	4 (1)
Condition†							
Trauma	7519 (29.6)	3 (1)	6932 (32.8)	7.0	3 (1)	587 (13.7)	4 (2)
Cardiac arrest	3264 (12.8)	7 (1)	3211 (15.2)	3.2	7 (1)	53 (1.2)	6 (0)
Chest pain	4044 (15.9)	4 (0)	2582 (12.2)	2.6	4 (0)	1462 (34.2)	4 (0)
Acute neurology (excl. stroke)	2312 (9.1)	4 (1)	2138 (10.1)	2.2	4 (1)	174 (4.1)	4 (1)
Stroke	1369 (5.4)	4 (1)	986 (4.7)	1.0	4 (1)	383 (9.0)	5 (1)
Breathing difficulties	1201 (4.7)	4 (1)	983 (4.7)	1.0	4 (2)	218 (5.1)	4 (1)
Psychiatry including intoxication	789 (3.1)	4 (2)	758 (3.6)	0.8	4 (2)	31 (0.7)	4 (2)
Infection	1044 (4.1)	4 (1)	733 (3.5)	0.7	4 (1)	311 (7.3)	4 (1)
Obstetrics and childbirth	756 (3.0)	3 (1)	491 (2.3)	0.5	3 (1)	265 (6.2)	4 (1)
Other medical diagnoses	2724 (10.7)	4 (1)	1985 (9.4)	2.0	4 (1)	739 (17.3)	4 (1)
Missing	383 (1.5)		336 (1.6)			47 (1.1)	

	Primary missions, n (%)
Transport to scene	
Helicopter	14,720 (69.6)
Rapid response car	6400 (30.3)
No vehicle	15 (0.1)
Transport from scene	
Helicopter	10,747 (50.8)
Ambulance	7375 (34.9), HEMS physician attending in 4,503 (61.1)
Not transported	1927 (9.1)
Other	118 (0.6)
Not reported	968 (4.6)

*Yearly incidence of missions was calculated by the ratio of total missions over the total population in the area, divided by the number of study years. †The pre-hospital medical diagnoses made by the physician on call were categorized into 10 medical conditions (main reason for response), according to the reporting recommendation.[12] All external impacts causing injury were classified as trauma, including drowning, foreign body airway obstruction, and cardiac arrest caused by trauma. Patients were already categorized according to the NACA severity score.[19,20] Missing NACA scores in table, 827 (3.3%).

Mission times in emergency primary missions

Regarding response time in emergency missions, 94.9% (n = 14,715) of the patients were reached within 45 min and 98.3% (n = 15,236) within the first hour, including both helicopter and rapid response car missions. Median times for helicopter mission stages were as follows: 5 min (IQR = 5 min) activation time, 24 min (IQR = 16 min) response time, 11 min (IQR = 11 min) on-scene time, and 25 min (IQR = 19 min) transport time.

Reasons for cancelations

More than one third (38.0%; n = 16,135) of all dispatches were canceled, with lower proportions in the summer and during daytime. "No
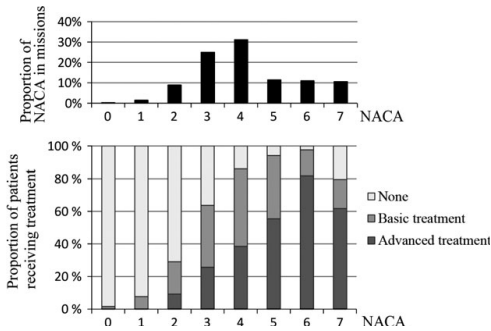
Fig. 2. Distribution of NACA in primary missions with patient encounter and level of treatment performed in the different NACA groups. Basic treatment: Basic airway procedures (manual airway opening/ oropharyngeal airway), suction, oxygen therapy, assisted ventilation, CPAP, defibrillation/electro-conversion, CPR, naso-gastric tube, ECG, immobilization (stiff neck collar, backboard, pelvic-sling, splint), or use of drugs available in the ground ambulance service; epinephrine (only during CPR), cyclizine, metoclopramide, glucose, sublingual glycerol nitrate, acetylsalicylic acid, crystalloids, inhalational ipratropium bromide and salbutamol, naloxone, flumazenil, and paracetamol. Advanced treatment: Intubation/tracheostomy, mechanical ventilation, thoracostomy, chest compression device, thoracic needle decompression, external cardiac pacing, anesthesia, central venous/arterial/intraosseus cannulation, use of neonatal incubator, nerve blocks, ultrasound, use of blood products, and use of drugs not mentioned in the basic treatment. NACA 4 are patients with a condition that can possibly lead to deterioration of vital signs, while NACA 5 and 6 are patients with deranged vital signs and a confirmed life-threatening injury or disease.[19] NACA scoring was missing (not reported) in 706 missions.

indication", as evaluated by the HEMS anesthesiologist, was reported in 28.0% ($n = 9808$) of dispatches to primary missions, bad weather in 5.1% ($n = 1774$), competing missions in 3.5% ($n = 1230$), and other reasons in 3.1% ($n = 1104$). The proportion and nature of reasons for canceled primary missions did not change.

During nighttime, almost every second dispatch to primary missions was canceled (48.3%; $n = 2116$), with two thirds classified as "no indication" (Fig. 3). Weather conditions precluding helicopter flights were reported more frequently at night (10.4%; $n = 457$) and during winter (8.4%; $n = 687$). To further explore the effect of nighttime on these two reasons for cancelations of primary missions, the declined dispatches and aborted missions were separated; revealing an increased nighttime rate of both
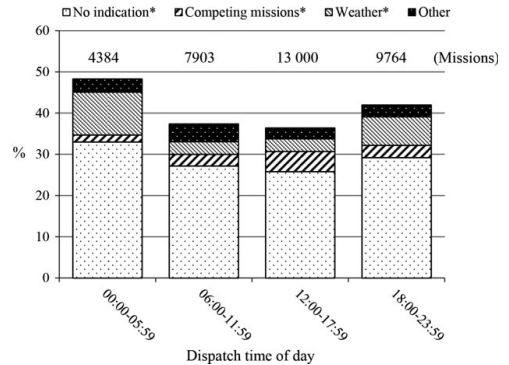

Fig. 3. Temporal distribution of reasons for declining or aborting primary HEMS dispatches with respect to time of day. *P-value < 0.05 for difference between observed "no indication," competing missions, and bad weather, for declining and aborting dispatches (for time of day) and the total of the others compared by Chi-square test. "No indication" describes when HEMS was dispatched by the EMCC, but the HEMS physician on call decided no indication for advanced medical treatment or helicopter transport, and also includes "coordination" (e.g., other suitable ambulance/resource available). Competing mission specifies a dispatch occurring simultaneously with another mission. "Other reasons" for declining or aborting a dispatch includes patient deceased before arrival, technical problems, crew out of service due to flight regulations, or patient not suitable for transport.

declined and aborted helicopter missions as a result of bad weather conditions ($z > 10$, $P < 0.001$). The proportion of aborted missions due to "no indication" showed no variation, while the proportion of declined dispatches for the same reason increased during nighttime ($z > 10$, $P < 0.001$).

Additional data describing temporal distributions and reasons for canceling are available from the corresponding author.

Discussion

Our study is a large evaluation of HEMS missions, with data from close to 42,500 dispatches over 10 years, using the NACA score to assess the severity of patient's condition. The NACA score is a crude scale but is reported to be useful for predicting mortality and the need for early respiratory therapy.[20] Applying NACA, we showed that one third of the patients in our primary missions were severely ill or injured (NACA 5–7). Advanced treatment was provided

in more than two thirds of these missions, which cannot be expected from ambulance personnel or regular GPs. Indeed, many patients with serious conditions and a high rate of providing advanced medical treatment may indicate the need for an anesthesiologist or at least a physician well-trained in emergency medicine; however, the benefit of physician-staffed HEMS has been debated for decades.[9,13,15,21,22] In addition, the advantage of an experienced anesthesiologist capable of early and sound clinical judgment may be of more value than performing advanced interventions, as the avoidance of an intervention is best practice in some cases. Other researchers have found that advanced treatment was performed in only 23.1% of HEMS missions, but they included several rural services and used a different study design.[14] The use of HEMS has changed slightly in recent years, with a focus on rapid transport to a hospital with appropriate medical, high-tech interventions in patients suffering myocardial infarction or stroke. However, we report an increase only in the proportion of missions with patients suffering stroke. We observed an increase in myocardial infarctions, but this increase was absorbed into the large group reported as chest pain.

In our primary trauma missions, the median NACA score was low, with a questionable indication for HEMS and a lower median score than is associated with medical emergencies. This result may indicate a lower threshold for responding to trauma than to medical emergencies. The initial phase after an accident is often characterized by uncertainty, which may contribute to over-triage in HEMS, as others have reported.[23] A number of rescued hikers and skiers who sustain relatively minor trauma also reduced the median NACA for trauma patients in the current study.

Our service had a short median activation time and a median response time of 24 min. In primary emergency helicopter missions, 97.7% of patients were reached within the first hour after dispatch. This result compares well with Krüger et al., who reported 7 min of median activation time and 90% of patients reached within the first hour, but rural HEMS and large SAR helicopters were included in their studies.[3,14] A small helicopter with the crew

residing at the HEMS base reduces activation time and thus response time. A location away from the nearest airport also avoids "air traffic jams". Reducing time on-scene has received great focus in our services, and we found a short median on-scene time (11 min) in helicopter missions. A German study reported close to 40 min on-scene time; however, many of their patients (65.7%) were intubated on-scene.[24]

The Norwegian HEMS use rate has been suggested to be as low as 11 primary missions with patient encounter per 10,000 inhabitants (obtained by extrapolating the incidence of patient encounters in a prospective registration during 4 weeks), and even lower, at 7.5, using data from the Norwegian Air Ambulance Service.[14,16] The discrepancy from our results (21.3) is most likely due to differences in study design, data definitions, and services included. Because HEMS is a limited resource, the decision about which dispatches to accept is critical. Our HEMS crews must try to anticipate when rapid transport and advanced medical care may benefit the current patient most. In rural settings, the local GP often accompanies the ambulance and may reduce the need for HEMS, particularly if well-trained in emergency medicine.

HEMS may be called a reliable resource, as 88.3% of the dispatches to primary missions either led to patient encounter or a deliberate cancelation ("no indication"). Our proportion of cancelations compares well with similar services.[10,11] Among several reasons for cancelations, the most common was "no indication," especially at night. If the EMCC dispatches HEMS to exactly the same type of missions at all times of day, the increased proportion of nighttime dispatches declined due to "no indication" is hard to explain. However, several factors influenced the decision to decline, including EMCC operator experience, HEMS crew experience, pilot concerns about weather conditions, and tiredness, which may have justified the use of other available emergency resources. As expected, we also found a higher prevalence of cancelations due to bad weather during nighttime, autumn, and winter. During late autumn and winter, our region has only 8 h of daylight and frequent storms and snow with low visibility. Helicopter flights at night and in low

visibility are associated with a higher level of risk, and helicopter pilots follow stricter flight rules.[7] Our proportion of canceled helicopter flights caused by bad weather are only slightly more than half of what Lawless et al. reported, probably because of different helicopters, pilot experience, and local weather conditions.[11] However, our cancelations due to "no indication" were almost four times higher, which may indicate broader dispatch criteria in our service, differences in populations, and different levels of HEMS crew experience.

The annual number of dispatches to primary HEMS missions did not change, despite the increase in regionalization, population, number of emergency calls, and emergency ambulance missions. It is interesting that while the number of emergency ambulance missions doubled during the period, we found no increase in primary HEMS missions. This stability could be a result of an unchanged number of patient conditions requiring HEMS, more ambulance dispatches defined as emergency missions, or stricter HEMS dispatch criteria. Most dispatches occurred during daytime, especially in the afternoon. A German study reported a similar pattern, although their peak proportion of missions per hour was before noon.[25] The summer is a busy period, probably because of more outdoor-related activity, and the frequency of competing missions increased in these periods. Our low incidence of competing missions indicates that our HEMS capacity has not reached its upper limit. Seasonal variation was unchanged during the study years. This unchanged HEMS dispatch profile provides important information for future governmental planning.

The fate of patients who cannot be reached by HEMS, the selection when prioritizing among competing requests, and in-hospital morbidity and mortality, deserve further exploration. Differences in acceptance policies among the Norwegian HEMS bases are interesting. In comparison to others, our study results are transferable to similar physician-staffed HEMS operating during day and night.

The paper-based standardized report forms were in some cases filled in after the mission and therefore prone to recall bias. However, we have no reason to believe that this process led to a systematic bias. The quality of data (definition and compliance) is important for implementing results from retrospective studies. All procedures performed are probably not registered; hence, the rate of advanced treatment performed might be underreported. Finally, some dispatches may not be registered if an EMCC has avoided scrambling a crew already busy with another mission or being out of service.

In conclusion, one third of the patients were severely ill or injured, and more than two thirds of these patients received advanced treatment. HEMS use did not change over the 10-year period, however HEMS use peaked during daytime, weekends, and the summer. More than one third of all dispatches were declined or aborted, primarily because of no longer medical indication or due to weather conditions.

Acknowledgements

Author contributors

ØØ and GB conceived and ØØ designed the study. ØØ prepared the figures, conducted the data analysis, and drafted the initial manuscript. All authors interpreted the data and critically revised the manuscript. All authors read and approved the final manuscript.

Guarantor

Guttorm Brattebø.

References

1. Øgar P. NOU 1998:8 Air ambulance service in Norway (Document in Norwegian). SHD 1998: 161.
2. Zakariassen E, Hansen EH, Hunskaar S. Incidence of emergency contacts (red responses) to Norwegian emergency primary healthcare services in 2007–a prospective observational study. Scand J Trauma Resusc Emerg Med 2009; 17: 30.
3. Kruger AJ, Skogvoll E, Castren M, Kurola J, Lossius HM. Scandinavian pre-hospital physician-

manned Emergency Medical Services – same concept across borders? Resuscitation 2010; 81: 427–33.

4. Kaufmann M, Moser B, Lederer W. Changes in injury patterns and severity in a helicopter air-rescue system over a 6-year period. Wilderness Environ Med 2006; 17: 8–14.

5. Leaman AM, Nutbeam T. Trauma systems and medical helicopters in the UK. Injury 2011; 42: 12–4.

6. Tiamfook-Morgan TO, Kociszewski C, Browne C, Barclay D, Wedel SK, Thomas SH. Helicopter scene response: regional variation in compliance with air medical triage guidelines. Prehosp Emerg Care 2008; 12: 443–50.

7. Chesters A, Grieve PH, Hodgetts TJ. A 26-year comparative review of United Kingdom helicopter emergency medical services crashes and serious incidents. J Trauma Acute Care Surg 2014; 76: 1055–60.

8. Littlewood N, Parker A, Hearns S, Corfield A. The UK helicopter ambulance tasking study. Injury 2009; 41: 27–9.

9. Roberts K, Blethyn K, Foreman M, Bleetman A. Influence of air ambulance doctors on on-scene times, clinical interventions, decision-making and independent paramedic practice. Emerg Med J 2009; 26: 128–34.

10. Giannakopoulos GF, Lubbers WD, Christiaans HM, van Exter P, Bet P, Hugen PJ, Innemee G, Schubert E, de Lange-Klerk ES, Goslings JC, Jukema GN. Cancellations of (helicopter-transported) mobile medical team dispatches in the Netherlands. Langenbecks Arch Surg 2010; 395: 737–45.

11. Lawless J, Tallon JM, Petrie D. Aborted air medical missions: a 4-year quality review of a Canadian province-wide air medical program. Air Med J 2005; 24: 79–82.

12. Kruger AJ, Lockey D, Kurola J, Di Bartolomeo S, Castren M, Mikkelsen S, Lossius HM. A consensus-based template for documenting and reporting in physician-staffed pre-hospital services. Scand J Trauma Resusc Emerg Med 2011; 19: 71.

13. Wisborg T, Guttormsen AB, Sorensen MB, Flaatten HK. The potential of an anaesthesiologist-manned ambulance service in a rural/urban district. Acta Anaesthesiol Scand 1994; 38: 657–61.

14. Kruger AJ, Lossius HM, Mikkelsen S, Kurola J, Castren M, Skogvoll E. Pre-hospital critical care by anaesthesiologist-staffed pre-hospital services in

Scandinavia: a prospective population-based study. Acta Anaesthesiol Scand 2013; 57: 1175–85.

15. Lossius HM, Soreide E, Hotvedt R, Hapnes SA, Eielsen OV, Forde OH, Steen PA. Prehospital advanced life support provided by specially trained physicians: is there a benefit in terms of life years gained? Acta Anaesthesiol Scand 2002; 46: 771–8.

16. Zakariassen E, Uleberg O, Roislien J. Helicopter emergency medical services response times in Norway: do they matter? Air Med J 2015; 34: 98–103.

17. Norwegian Air Ambulance Service annual reports 2004–2013 (Document in Norwegian). [www document] Available at: http://www.luftambulanse.no/aarsrapporter.aspx (accessed 20 April 2015).

18. Statistics Norway. [www document] Available at: http://www.ssb.no/en/ (accessed 20 April 2015).

19. Tryba M, Brüggemann H, Echtermeyer V. Klassifizierung von Erkrankungen und Verletzungen in Notartztrettungssystemen. Notfallsmedizin 1980; 6: 725–7.

20. Raatiniemi L, Mikkelsen K, Fredriksen K, Wisborg T. Do pre-hospital anaesthesiologists reliably predict mortality using the NACA severity score? A retrospective cohort study. Acta Anaesthesiol Scand 2013; 57: 1253–9.

21. Moecke H, von Knobelsdorff G. The anesthesiologist in prehospital and hospital emergency medicine. Curr Opin Anaesthesiol 2008; 21: 228–32.

22. Hesselfeldt R, Steinmetz J, Jans H, Jacobsson ML, Andersen DL, Buggeskov K, Kowalski M, Praest M, Ollgaard L, Hoiby P, Rasmussen LS. Impact of a physician-staffed helicopter on a regional trauma system: a prospective, controlled, observational study. Acta Anaesthesiol Scand 2013; 57: 660–8.

23. Ringburg AN, de Ronde G, Thomas SH, van Lieshout EM, Patka P, Schipper IB. Validity of helicopter emergency medical services dispatch criteria for traumatic injuries: a systematic review. Prehosp Emerg Care 2009; 13: 28–36.

24. Andruszkow H, Lefering R, Frink M, Mommsen P, Zeckey C, Rahe K, Krettek C, Hildebrand F. Survival benefit of helicopter emergency medical services compared to ground emergency medical services in traumatized patients. Crit Care 2013; 17: R124.

25. Schuster M, Pints M, Fiege M. Duration of mission time in prehospital emergency medicine: effects of emergency severity and physicians level of education. Emerg Med J 2010; 27: 398–403.

Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Figure S1. Map of Europe and Western Norway showing the hospitals and the HEMS bases. Size of hospital symbols indicates university hospitals (large), regional hospitals (medium), and local hospitals (small). Helicopter symbols indicate a HEMS base close to hospital.

Table S1. The NACA scale; a severity scoring used by the Norwegian Air Ambulance Service.[19,20]

II

ORIGINAL RESEARCH　　　　　　　　　　　　　　　　　　　　**Open Access**

Factors influencing on-scene time in a rural Norwegian helicopter emergency medical service: a retrospective observational study

Øyvind Østerås[1,2*] , Jon-Kenneth Heltne[1,2], Bjørn-Christian Vikenes[1], Jörg Assmus[3] and Guttorm Brattebø[1,2,4]

Abstract

Background: Critically ill patients need to be immediately identified, properly managed, and rapidly transported to definitive care. Extensive prehospital times may increase mortality in selected patient groups. The on-scene time is a part of the prehospital interval that can be decreased, as transport times are determined mostly by the distance to the hospital. Identifying factors that affect on-scene time can improve training, protocols, and decision making. Our objectives were to assess on-scene time in the Helicopter Emergency Medical Service (HEMS) in our region and selected factors that may affect it in specific and severe conditions.

Methods: This retrospective cohort study evaluated on-scene time and factors that may affect it for 9757 emergency primary missions by the three HEMSs in western Norway between 2009 and 2013, using graphics and descriptive statistics.

Results: The overall median on-scene time was 10 minutes (IQR 5–16). The median on-scene time in patients with penetrating torso injuries was 5 minutes (IQR 3–10), whereas in cardiac arrest patients it was 20 minutes (IQR 13–28). Based on multivariate linear regression analysis, the severity of the patient's condition, advanced interventions performed, mode of transport, and trauma missions increased the on-scene time. Endotracheal intubation increased the OST by almost 10 minutes. Treatment prior to HEMS arrival reduced the on-scene time in patients suffering from acute myocardial infarction.

Discussion: We found a short OST in preselected conditions compared to other studies. For the various patient subgroups, the strength of association between factors and OST varied. The time spent on-scene and its influencing factors were dependent on the patient's condition. Our results provide a basis for efforts to improve decision making and reduce OST for selected patient groups.

Conclusions: The most important factors associated with increased on-scene time were the severity of the patient's condition, the need for intubation or intravenous analgesic, helicopter transport, and trauma missions.

Keywords: On-scene time, Scene time, Helicopter, Hems, Air ambulances, Emergency medical services, First hour quintet, Norway

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Background

Patients suffering from a severe illness or injury require immediate prehospital assessment, appropriate treatment, and, in many cases, rapid transport to the hospital accompanied by competent personnel. A European project accentuated the so-called "First Hour Quintet" (cardiac arrest, respiratory failure, trauma, acute coronary syndrome, and stroke) as critical conditions of great importance in prehospital emergency care [1]. Many studies have assessed on-scene time (OST), but not all have found an association with mortality. Prolonged OST seems to increase mortality for trauma patients, however not in all settings and conditions [2]. The value of shortening the prehospital time has not received similar attention in medical emergencies, but reducing the interval between diagnosis and treatment for stroke and myocardial infarction seems beneficial [3, 4].

The backbone of Norwegian prehospital emergency medical care is ground ambulances and on-call general practitioners in the municipalities. An important supplement is the physician-staffed emergency medical services, including the helicopter emergency medical service (HEMS) [5]. An on-scene HEMS physician does not necessarily increase the OST, though more advanced interventions may be initiated [6–8]. The OST is the prehospital time interval that can be reduced, as transport times are mostly determined by the distance to the hospital. The main factors affecting OST have been described for trauma patients, but not specifically for all five conditions in the First Hour Quintet [9–13]. Clarifying these factors may improve decision making and treatment protocols, and provide a basis for targeted training, aiming to reduce OST in specific missions.

Our objectives were to assess OST in the HEMS and to investigate whether selected factors affect it in four specific and severe conditions in which a short OST was anticipated. Cardiac arrest patients were also assessed for comparison, with an increased OST anticipated for this group.

Methods

Study design and setting

This is a retrospective cohort study designed to investigate OST in the three HEMS bases in Førde, Bergen, and Stavanger, which cover the western region of Norway. The catchment area of these services is rural and includes islands, fjords, mountains, rough terrain, and narrow roads, as well as two major cities, Stavanger and Bergen. The total population is approximately 1.1 million on 45,000 km^2 (17,400 mi^2) of land, an area equivalent to mainland Denmark [14, 15]. Outside the cities, the population density is 15 persons/km^2.

The Norwegian HEMS operates day and night year-round and may choose to respond with a rapid response car rather than a helicopter when the scene is nearby or the weather conditions prohibit the use of a helicopter. A ground ambulance is most often present on-scene when the HEMS arrives and offers an alternative mode of transportation to the hospital [16]. The helicopters (Eurocopter, EC 135 P2) are staffed with a pilot, a rescue paramedic, and a specially trained anesthesiologist and have capacity for one supine and one sitting patient. The HEMS in western Norway has been described previously in more detail [16, 17].

Data source and management

On missions, the individual physician documented data in a paper-based form, which was subsequently registered in a database called "Airdoc" (Filemaker 8, Filemaker Inc., CA, USA). Landing and take-off times were also available immediately after each mission from data recorded by the pilot. All primary emergency HEMS missions, using a helicopter or rapid response car, with patient encounters from 2009 through 2013 were included in the analysis. Search and Rescue (SAR) missions and inter-hospital transfers were excluded. Patients who were entrapped when the HEMS arrived were also excluded from the analysis if transport was delayed due to the entrapment (Additional file 1). A free-text field in the mission report was assessed in all such cases.

Methods and measurements

Our primary outcome was the OST and associated factors in five patient subgroups. We analyzed variables available in our database or through additional questions to the HEMS physicians. An overview of the variables included and the reason for exclusion is available from the corresponding author. OST was defined as the time from the patient encounter to the start of patient transport from the scene (i.e., when the patient's stretcher started moving). Information about the mission, prehospital times, and patient data (vital signs, treatments performed, patient condition, and a free-text field) were available in the database. Advanced interventions were defined as interventions that could not be performed by the ground ambulance crew (e.g., intubation/tracheostomy; mechanical ventilation; thoracostomy/chest drain; chest compression device; thoracic needle decompression; external cardiac pacing; anesthesia; central venous, arterial, or intraosseous cannulation; use of neonatal incubator; nerve blocks; ultrasound; blood products; and the use of drugs not administered by the ground ambulance crew alone). All HEMS physicians involved in missions during the study period reported the year they became a specialist in anesthesiology. Darkness was defined for each mission according to civil twilight for the dispatch time, date, and latitude/longitude for the scene

Østerås et al. Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine (2017) 25:97

Page 3 of 11

(center of the municipality). Unexpected, extreme, or missing values were assessed by reading the free-text fields and by cross-checking other data sources, such as the Emergency Medical Call Centre (EMCC) records and pilots' flight logs. Values that were clearly incorrect were replaced if reliable data could be determined; otherwise, the values were excluded. When Glasgow Coma Scale (GCS) data were missing, a normal value (GCS = 15) was used in the analysis.

Five patient subgroups were selected for further analysis: acute myocardial infarction, stroke, head injuries, penetrating torso injuries, and cardiac arrest. In 1980, the National Advisory Committee for Aeronautics (NACA) score (Additional file 2) was modified for use in severity scoring of prehospital medical emergencies and trauma, and it is currently used by Norwegian HEMS [18]. To ensure that the selected patients were in fact severely ill or injured, cases with NACA 0–3 (none or no serious conditions) and NACA 7 (dead on-scene or during transport) were excluded. We hypothesized that the observed OST would be longer for cardiac arrest and shorter for the other groups, compared to overall OST.

Analysis

We used descriptive methods to characterize the sample and OST for the subgroups and graphics (histograms) to illustrate distributions. The effects of factors were assessed for each of the subgroups by graphical methods and linear regression models using the OST as the outcome variable. The models were built in three steps, separately for each group. First, we estimated the unadjusted model for each factor. Next, we estimated the fully adjusted model containing all factors. In the

third step, we estimated the final model containing all factors with a p-value <0.1 in one of the previous steps, in addition to age and gender. For all subgroups except penetrating torso injuries, we used a linear mixed effects model adjusted for HEMS base and with a random intercept for the individual doctor. The size of the penetrating torso injuries subgroup was too small to do the same, so we estimated a simple linear model. The significance level was set to 0.05. Descriptive statistics were calculated using IBM SPSS Statistics for Windows, Version 22 (IBM Corp., Armonk, NY), and the linear model using R 3.3 package nlme [19, 20]. The graphics were created using Matlab 7.10 (The MathWorks Inc., Natick MA, USA).

Results

A total of 9757 emergency primary missions with patient encounters occurred during the study period (Fig. 1). The overall median OST was 10 min (IQR 5–16). Table 1 shows the patient characteristics. Higher NACA scores and lower GCS values were associated with an increase in OST (Fig. 2).

OST varied between the five selected patient subgroups and was significantly different in both head injuries and cardiac arrest subgroups compared to all other groups (Table 1). The largest difference in OST was found between the penetrating torso injuries and cardiac arrest subgroups. The different distributions of OST are shown in Fig. 3.

Figure 4 displays factors affecting OST in the five subgroups using dichotomous variables. Advanced treatment and a more severe condition based on the GCS and NACA score were associated with increased OST. For patients suffering from cardiac arrest, no advanced
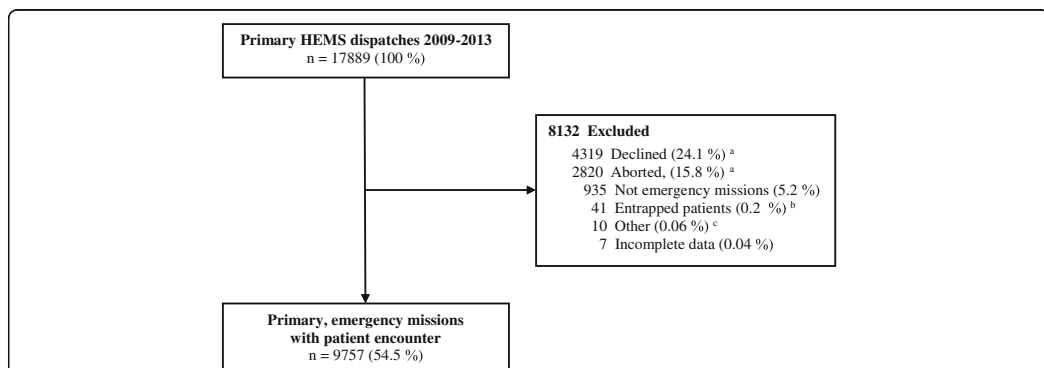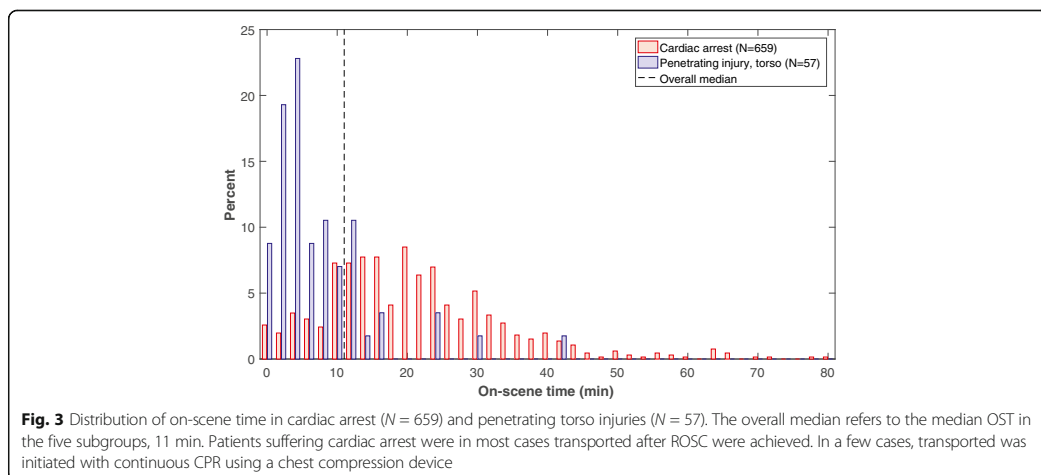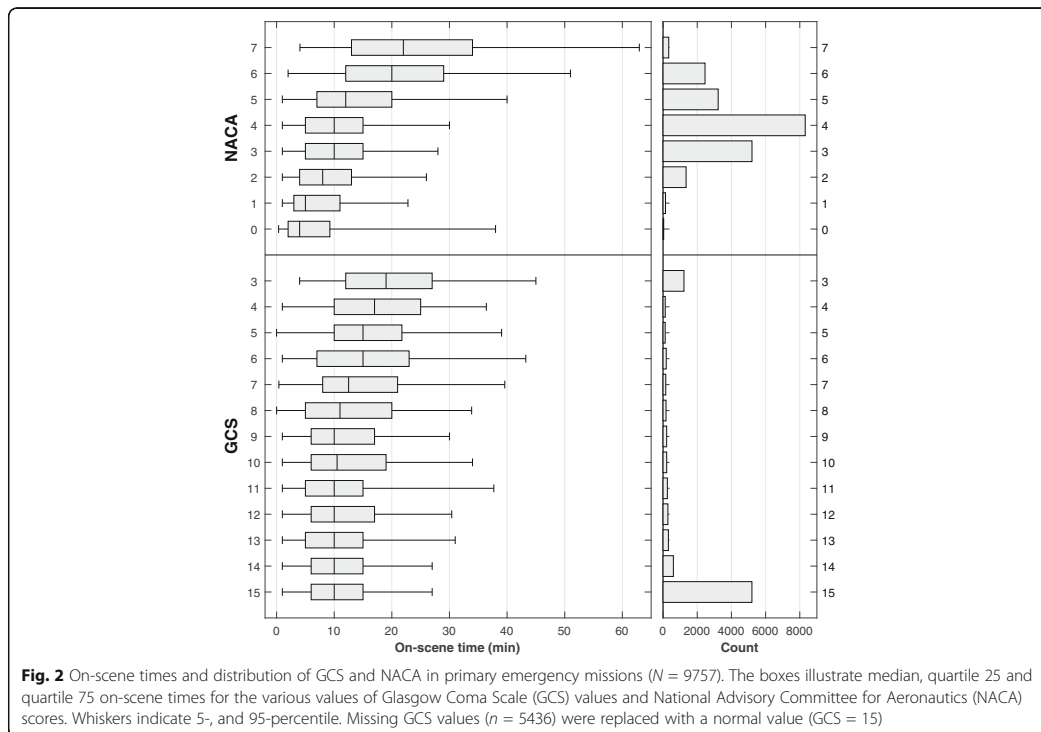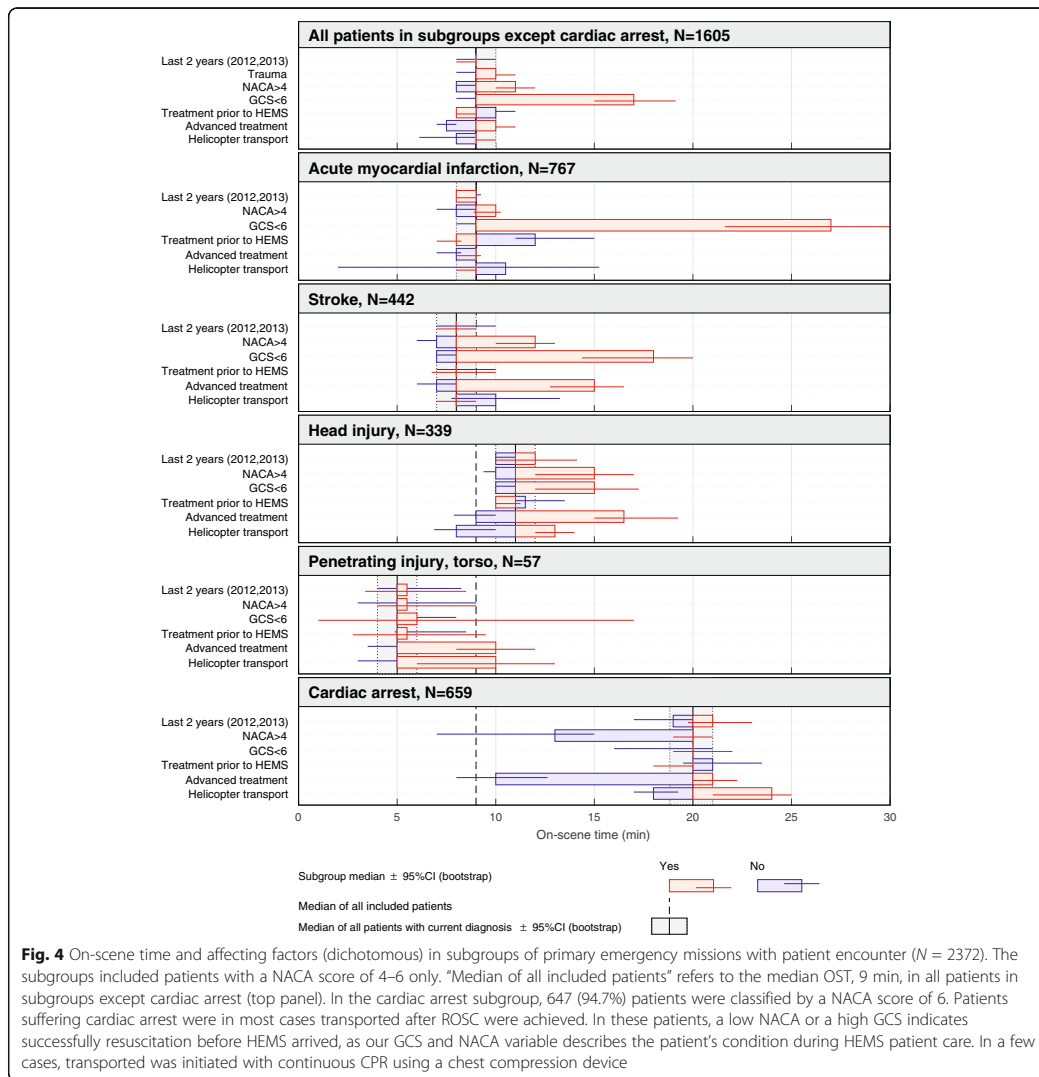

Fig. 1 Flow chart showing all primary HEMS dispatches, with excluded and completed missions. Primary missions were defined as responses to patients outside hospitals. [a]Declined dispatches or aborted missions were due to medical indication no longer being present, weather, concurrent missions, unable to perform a flight, or other reasons; 109 of the declined and 33 of the aborted missions (total 0.8% of the dispatches) were transferred to another HEMS in the area. Therefore, these incidents are reported as two separate dispatches. [b]The characteristics of the 41 entrapped patients are presented in Additional File 1. [c]HEMS base very close to the incident, completed without using a vehicle

Østerås et al. Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine (2017) 25:97

Page 4 of 11

Table 1 Patient characteristics and on-scene time in primary emergency missions with patient encounter (N = 9757)

	All	NACA score = 0–3	NACA score = 4–6	NACA score = 7	Subgroups with NACA score of 4–6				
					Acute myocardial infarction	Stroke	Head injury[a]	Penetrating torso injuries	Cardiac arrest[a]
N (proportion of all)	9757 (100%)	3022 (31.0%)	5448 (55.8%)	1115 (11.4%)	777 (8.0%)	458 (4.7%)	348 (3.6%)	59 (0.6%)	683 (7.0%)
Median OST, minutes (IQR)	10 (5–16)	10 (5–16)	10 (5–14)	20 (13–31)[b]	9 (5–13)	8 (5–14)	11 (6–17)	5 (3–10)	20 (13–28)
Median age, years (IQR)	51.0 (27.0–67.0)	35 (16–57)	55 (32–69)	64 (48–75)	64 (54–73)	69.5 (57–79)	36 (20–58)	31 (24–39)	64 (52–73)
<18 years, N (%)	1495 (15.7%)	771 (26.7%)	665 (12.4%)	143 (3.3%)	1 (0.1%)	0	68 (19.8%)	5 (8.9%)	15 (2.2%)
Male gender, N (%)	6412 (66.2%)	1738 (58.8%)	3726 (68.4%)	810 (72.6%)	617 (79.4%)	267 (58.3%)	257 (73.9%)	46 (78.0%)	494 (72.3%)
Trauma, N (%)	2950 (30.1%)	1364 (45.1%)	1343 (24.7%)	159 (14.3%)	0	0	348 (100%)	59 (100%)	0
Advanced interventions, N (%)	4058 (41.6%)	595 (19.7%)	2725 (50.0%)	682 (61.2%)	557 (71.7%)	98 (21.4%)	134 (38.5%)	21 (35.6%)	603 (88.3%)
Intubated by HEMS, N (%)	1353 (13.9%)	8 (0.3%)	850 (15.6%)	479 (43.0%)	10 (1.3%)	54 (11.8%)	89 (25.3%)	5 (8.5%)	409 (59.9%)
Median GCS (IQR)	14 (6–15)	15 (15–15)	14 (6–15)	3 (3–3)	15 (15–15)	13 (9–15)	11 (6–14)	15 (14–15)	3 (3–3)

Missing data are presented in Additional file 8. [a]On-scene time (OST) was significantly different from each of the other subgroups (p < 0.001; Kruskal-Wallis and Dunn's Multiple Comparison Test). [b]For 982 patients with a NACA score of 7, OST was missing, as the start of patient transport from the scene was not relevant for patients who were pronounced dead on scene. Patients suffering cardiac arrest were in most cases transported after ROSC were achieved. In a few cases, transported was initiated with continuous CPR using a chest compression device

Østerås *et al. Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine* (2017) 25:97

Page 5 of 11

Fig. 2 On-scene times and distribution of GCS and NACA in primary emergency missions (*N* = 9757). The boxes illustrate median, quartile 25 and quartile 75 on-scene times for the various values of Glasgow Coma Scale (GCS) values and National Advisory Committee for Aeronautics (NACA) scores. Whiskers indicate 5-, and 95-percentile. Missing GCS values (*n* = 5436) were replaced with a normal value (GCS = 15)

Fig. 3 Distribution of on-scene time in cardiac arrest (*N* = 659) and penetrating torso injuries (*N* = 57). The overall median refers to the median OST in the five subgroups, 11 min. Patients suffering cardiac arrest were in most cases transported after ROSC were achieved. In a few cases, transported was initiated with continuous CPR using a chest compression device

Østerås *et al. Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine* (2017) 25:97

Page 6 of 11

Fig. 4 On-scene time and affecting factors (dichotomous) in subgroups of primary emergency missions with patient encounter (N = 2372). The subgroups included patients with a NACA score of 4–6 only. "Median of all included patients" refers to the median OST, 9 min, in all patients in subgroups except cardiac arrest (top panel). In the cardiac arrest subgroup, 647 (94.7%) patients were classified by a NACA score of 6. Patients suffering cardiac arrest were in most cases transported after ROSC were achieved. In these patients, a low NACA or a high GCS indicates successfully resuscitation before HEMS arrived, as our GCS and NACA variable describes the patient's condition during HEMS patient care. In a few cases, transported was initiated with continuous CPR using a chest compression device

treatment and a low NACA score were associated with reduced OST. The factor helicopter transport was associated with increased OST in the head injuries, penetrating torso injuries, and cardiac arrest subgroups, whereas treatment prior to HEMS arrival was associated with reduced OST in the subgroup with acute myocardial infarction.

Multivariate linear regression analysis identified age, NACA score, helicopter transport, the use of intravenous analgesics, treatment prior to HEMS arrival, intubation, year in study period, and trauma missions as factors associated with significantly altered OST when including four patient groups (i.e., excluding cardiac arrest; Table 2). Gender, GCS, physician's experience, and daylight were not identified as factors affecting OST. Median transport time in these cases was 25 min (IQR 16–35). The multivariate linear regression analyses for each subgroup are presented in Additional files 3, 4, 5, 6 and 7.

No significant differences in OST were found for season of the year, month, day of the week, time of day, Revised Trauma Score, or between the three HEMS bases. Missing values are presented in Additional file 8.

Østerås et al. Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine (2017) 25:97

Page 7 of 11

Table 2 Factors affecting on-scene time (linear mixed effect model)

Predictor	Unadjusted model N = 1605			Fully adjusted model N = 1597			Final model[b] N = 1599		
	B	95% CI	p-value	B	95% CI	p-value	B	95% CI	p-value
Year in study period[a]	−0.31	(−0.60, −0.01)	0.040	−0.43	(−0.72, −0.14)	0.004	−0.42	(−0.67, −0.16)	0.001
Daylight (yes)	0.00	(−0.84, 0.83)	0.992	0.34	(−0.39, 1.06)	0.367	–	–	–
Age	−0.01	(−0.03, 0.01)	0.310	0.03	(0.01, 0.05)	0.008	0.03	(0.01, 0.05)	0.005
Male gender (yes)	−0.16	(−1.04, 0.71)	0.713	−0.26	(−1.02, 0.50)	0.505	−0.26	(−1.02, 0.50)	0.504
Trauma (yes)	1.96	(1.04, 2.87)	<0.001	1.61	(0.59, 2.63)	0.002	1.60	(0.58, 2.62)	0.002
NACA score	3.88	(3.25, 4.51)	<0.001	1.44	(0.77, 2.11)	<0.001	1.44	(0.78, 2.11)	<0.001
Glasgow Coma Scale	−0.70	(−0.82, −0.58)	<0.001	0.02	(−0.14, 0.17)	0.838	0.02	(−0.14, 0.17)	0.846
Treatment prior to HEMS (yes)	−1.12	(−2.00, −0.23)	0.014	−1.68	(−2.46, −0.90)	<0.001	−1.68	(−2.46, −0.90)	<0.001
Experience (years as specialist)	−0.06	(−0.19, 0.08)	0.409	0.01	(−0.14, 0.15)	0.921	–	–	–
Analgesics (yes)	5.68	(4.86, 6.49)	<0.001	3.06	(2.24, 3.87)	<0.001	3.07	(2.25, 3.88)	<0.001
Intubation (yes)	12.41	(11.22, 13.60)	<0.001	9.75	(8.09, 11.41)	<0.001	9.71	(8.05, 11.37)	<0.001
Helicopter transport (yes)	1.68	(0.51, 2.86)	0.005	3.51	(2.40, 4.61)	<0.001	3.54	(2.44, 4.65)	<0.001

Patients with a NACA score of 4–6 and acute myocardial infarction, stroke, head injury, or penetrating torso injury (N = 1605) were included. [a]Year in study period refers to year 1–5 of the period from 2009 to 2013. [b]Variables chosen for final model included multivariate regression analyses of variables that differed significantly, in addition to age and gender. The fully adjusted model is an intermediate calculation step to select factors for the final model. Estimates were adjusted for HEMS base, and the individual physician was used as a random effect. B = unstandardized coefficient in the regression model (minutes per unit of predictor). Positive values are associated with increased on-scene time. Fully adjusted model is an intermediate calculation step to select factors for final model. Missing values: 6 for age and 2 for daylight. OST was missing in 37 (2.3%) of the 1642 identified missions in the four included subgroups

Discussion

We found a short OST in preselected conditions compared to other studies [4, 21–23]. For the various patient subgroups, the strength of association between factors and OST varied. However, none of the directions of effects changed between the subgroups with an anticipated short OST. Reducing the prehospital time is important in many severe medical emergencies and trauma, but the ideal OST cannot be stated for all conditions, such as when patient access is a challenge due to entrapment or in water or mountain rescue [24, 25].

A short OST will not reduce morbidity or mortality for any given patient. Even in our four subgroups of severe conditions with definitive care only available in hospital, reducing the OST may not affect survival for most patients. A recent Norwegian study reported that HEMS was able to restore deranged physiology, even when prolonging on-scene time, in 240 emergency medical and trauma patients [26]. Newgard et al. found no association between OST and mortality in trauma patients with abnormal physiology [27]. Five years later, the same group reported that OST did not affect outcome in two cohorts including hemorrhagic shock and traumatic brain injuries. However, analysis of patients suffering hemorrhagic shock, showed an association between longer out-of-hospital time and mortality in subgroups of patients suffering blunt trauma or requiring in-hospital critical care [24]. Gonzales et al. reported correlation between prolonged prehospital time and increased patient mortality in rural vehicular trauma [8]. A review in 2015

presented inconsistent results of correlations between prehospital time intervals and different outcomes for trauma patients, including some studies reporting OST to be correlated with outcome in specific settings and conditions [2]. It is difficult to identify which of the severely ill or injured patients that will benefit from a short OST. Hence, the appropriate approach may be to strive for a short OST in all critically ill patients where definitive care is only available in the hospital. The valuable scene time should only be spent for necessary assessments and interventions to avoid immediate threats to life and prepare for safe transport.

Increasing severity (i.e., higher NACA score) prolonged the OST as anticipated, consistent with a study on paramedic-staffed ambulances responding to trauma only [28]. The same association was not found for reduced GCS values in the final analysis in the linear mixed effect model. However, in the univariate analysis, a lower GCS value had a strong effect. Thus, some of the other factors better explained the variation in OST.

If a patient was transported by helicopter, the OST also increased. Interventions and preparations are often required before flight because of limited resources and space available in the helicopter, increasing OST [29, 30]. In ground ambulance transports with the HEMS physician attending, many interventions can be performed during transport instead of on-scene. However, this decrease in OST must be balanced against increased transport time.

We anticipated altered OST when advanced interventions were performed on-scene. Half of the patients with

Østerås *et al. Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine* (2017) 25:97

Page 8 of 11

a NACA score of 4–6 received advanced interventions on-scene or during transport. Intubation by the HEMS had a large impact on OST. Yet, the median OST was rather short even when the patient was intubated, highlighting our focus on a short OST in severe conditions with need for in-hospital interventions. The unexpected low proportion of intubations in head injuries most probably reduced the median OST in this subgroup. A German study reported a mean OST of nearly 40 min, and a large proportion of their patients (65.7%) were intubated on-scene [30]. The large difference from our study probably reflects different on-scene priorities rather than differences in the patients' conditions. Even though severe conditions or deranged physiology make the HEMS strive to immediately start transportation from the scene, rapid initiation of transport without assessing the airway, breathing, and circulation may decrease survival. The necessity of performing a given intervention during a particular mission cannot be determined in our retrospective design, but identifying the interventions that justify increased time on-scene could be an interesting aim for prospective studies. In some cases, the best choice may be to avoid interventions due to the short transport time to the hospital. We think that an experienced HEMS physician trained to make these crucial decisions is a major advantage.

Previous studies assessing whether HEMS interventions alter the OST are heterogeneous and report contradictory results [2, 9–13, 22, 24, 26, 31, 32]. Intravenous access is often established prior to HEMS arrival, but we found a significantly increased OST in missions with patients in need of intravenous analgesics. The time needed for the administration of drugs, as well as the evaluation of its effect, may explain the increased OST. In contrast, the decreased OST when using intravenous analgesics in cardiac arrest probably indicates that patients were successfully resuscitated in a shorter time and were responsive during the mission.

When advanced treatment is necessary prior to helicopter flights (i.e., intubation, thoracostomy, etc.), the time spent on-scene will unavoidably increase [13]. This is particularly important if paramedics on-scene cannot perform the intervention prior to HEMS arrival; thus, OST is also influenced by local treatment protocols. This may explain why we found no increased OST for patients with acute myocardial infarction when choosing helicopter flight. In most such cases, treatment protocols (e.g., drugs, ECG) were already followed by paramedics or general practitioners before HEMS arrival. This was confirmed by the OST in acute myocardial infarction being reduced if treatment before HEMS arrival was reported.

The OST increased by 2 s for each year increase in patient age, assuming that the variable was linear. No information was available on patients' morbidity prior to the incident, but we think the patient's current condition is more important and this small increase in OST reflects comorbidity rather than the age itself. The decrease in OST (2 min from the first to the last study year) can be explained by an increased focus on reducing OST in acute myocardial infarction and stroke. The factor "study year" differed significantly only in these two conditions, but these conditions represented three-fourths of the patients in the subgroups with an anticipated short OST.

The assessment and triage of critically ill patients by a qualified emergency physician, including transport to the appropriate level of care, is an advantage of the HEMS in our opinion. Our chosen method did not reveal an influence of physician experience on the OST. This effect is sparsely described in the literature. A German study reported increased prehospital times with junior physicians compared to senior physicians [33]. The advantage of a physician attending on-scene is debatable, but it does not seem to prolong the OST [6, 7, 34–38]. Physician-staffed HEMS services can speed-up the decision to depart from the scene, but may also increase the OST due to more advanced interventions being performed. The diagnostic competence and clinical decision-making are important assets of our HEMS. On-scene decisions made by the prehospital team also demand both technical and non-technical skills [39, 40]. If rapid transport is prioritized, a trained HEMS physician accompanying the patient to the hospital can provide more targeted interventions depending on the patient's condition and acute needs. The impact of physicians' skills and experience on the OST deserves further investigation.

Contrary to what we assumed, no difference was found in the OST of day versus night missions. We also did not find any difference in the OST in regards to the time of day. This may be due to the treatment protocols and operating procedures used by our services, the crews being accustomed to challenging weather and darkness, and that an ambulance was on-scene to assist the HEMS in most cases and able to provide artificial light. A German study reported darkness as a significant factor for increased OST.

Reported factors affecting the OST in all missions by a service are of little interest due to the large variation between different patient groups. The HEMSs in the US, Canada, Australia, and Europe differ greatly in crew composition, service hours, mission types, patient conditions, and on-scene strategy; therefore, different OSTs are reported (8 to 40 min) [9, 21, 28, 30, 41, 42]. Comparisons to such heterogeneous studies are challenging. In our data, the median OST was 4-times greater in cardiac arrest cases than patients with penetrating torso injuries. Therefore, if missions with cardiac arrest are

Østerås *et al. Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine* (2017) 25:97

Page 9 of 11

included in reports on the OST for a service, important factors affecting OST can be neglected.

A strength of our study is the definition of OST used, which does not include the time used for shut-down, loading, and start-up of the helicopter. This definition is different from most other studies, which define OST as the time from the helicopter landing to take-off. However, this may have reduced our OST compared to other studies. Another strength of this study was the multicenter design involving three different HEMS bases with a similar national HEMS profile. The retrospective design provided a large number of missions, which allowed us to analyze the OST in specific and severe conditions and assess whether factors affecting OST varied between different patient conditions. Finally, we excluded conditions with NACA scores of 0–3 or 7 from most analyses, as increased OST among these patients is not likely to be associated with worse patient outcomes.

Limitations

A retrospective design has weaknesses, such as misclassifications (e.g., failure to report patient entrapment in missions associated with increased OST). Missing data are another challenge. In our HEMS, no data were recorded automatically. In a large proportion of missions, GCS was not registered. It is not mandatory to register GCS on every patient in our HEMS, and it is often not registered when encountering awake and alert patients. We replaced missing GCS data with normal values to avoid losing half of the cases in the regression analysis. This may have increased the likelihood of a type 2 error, but not a type 1 error. Our database does not differentiate between interventions on-scene or during transport; thus, some of the interventions performed may not have influenced the OST. Many of the excluded variables may have had an impact on OST but were unavailable for analysis; for example, in a road traffic accident with several patients, the actual number of patients assessed on-scene probably affects the OST. For patients who died on-scene or during transport (NACA score = 7), OST was recorded in only 133 missions (12%) and probably reflects the missions in which transport was initiated but the patient died before arriving at the hospital. No major HEMS changes were introduced during the study period.

Conclusive data on patient outcomes after HEMS treatment are needed. Given the costs involved, tools should be developed to better identify patients who will benefit the most from this service. As geographical challenges and regional organization (e.g., operational pattern, patient referral system, and resource availability) may differ from other HEMSs, generalizations from our study must be made with caution.

Conclusions

We have demonstrated a rather short OST in our service compared to other published studies. The time spent on-scene and its influencing factors were dependent on the patient's condition and shortest in penetrating torso injuries. The most important factors associated with an increased OST were the severity of the patient's condition, the recorded use of endotracheal intubation or intravenous analgesics, helicopter transport, and trauma missions. Treatment prior to HEMS arrival reduced OST in patients suffering from acute myocardial infarction or stroke. Our results provide a basis for efforts to improve decision making and reduce OST for selected patient groups.

Additional files

Additional file 1: Patient characteristics and on-scene time (OST) in primary emergency missions with entrapped patient ($N = 41$). (XLS 27 kb)

Additional file 2: The NACA scale; a severity scoring used by the Norwegian Air Ambulance Service. (XLS 28 kb)

Additional file 3: Factors affecting on-scene time (linear mixed effect model) in acute myocardial infarction. (XLS 33 kb)

Additional file 4: Factors affecting on-scene time (linear mixed effect model) in stroke. (XLS 33 kb)

Additional file 5: Factors affecting on-scene time (linear mixed effect model) in head injuries. (XLS 33 kb)

Additional file 6: Factors affecting on-scene time (simple linear model) in penetrating torso injuries. (XLS 33 kb)

Additional file 7: Factors affecting on-scene time (linear mixed effect model) in cardiac arrest. (XLS 33 kb)

Additional file 8: Missing registrations of variables in the 9757 missions in Table 1. (XLS 31 kb)

Authors' contributions
ØØ, BCV, JKH, and GB conceived and designed the study. ØØ retrieved data. ØØ and BCV prepared the tables and figures and wrote the first draft of the manuscript. JA and ØØ analyzed the data. All authors interpreted the data and critically revised the manuscript. All authors read and approved the final manuscript. ØØ and GB are responsible for the paper as a whole.

Østerås *et al. Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine* (2017) 25:97

Page 10 of 11

Services (2011–02407), the Norwegian Data Protection Authority (12/00291–3), and the Data Protection Officials for Research approved the study.

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References
1. Krafft T, Garcia Castrillo-Riesgo L, Edwards S, Fischer M, Overton J, Robertson-Steel I, König A. European emergency data project (EED project): EMS data-based health surveillance system. Eur J Pub Health. 2003;13:85–90.
2. Harmsen AM, Giannakopoulos GF, Moerbeek PR, Jansma EP, Bonjer HJ, Bloemers FW. The influence of prehospital time on trauma patients outcome: a systematic review. Injury. 2015;46:602–9.
3. Herlitz J, WireklintSundström B, Bang A, Berglund A, Svensson L, Blomstrand C. Early identification and delay to treatment in myocardial infarction and stroke: differences and similarities. Scand J Trauma Resusc Emerg Med. 2010;18:48.
4. Simonsen SA, Andresen M, Michelsen L, Viereck S, Lippert FK, Iversen HK. Evaluation of pre-hospital transport time of stroke patients to thrombolytic treatment. Scand J Trauma Resusc Emerg Med. 2014;22:65.
5. Krüger AJ, Lossius HM, Mikkelsen S, Kurola J, Castrén M, Skogvoll E. Pre-hospital critical care by anaesthesiologist-staffed pre-hospital services in Scandinavia: a prospective population-based study. Acta Anaesthesiol Scand. 2013;57:1175–85.
6. Dissmann PD, Le Clerc S. The experience of Teesside helicopter emergency services: doctors do not prolong prehospital on-scene times. Emerg Med J. 2007;24:59–62.
7. Garner A, Rashford S, Lee A, Bartolacci R. Addition of physicians to paramedic helicopter services decreases blunt trauma mortality. Aust N Z J Surg. 1999;69:697–701.
8. Gonzalez RP, Cummings G, Mulekar M, Rodning CB. Increased mortality in rural vehicular trauma: identifying contributing factors through data linkage. J Trauma. 2006;61:404–9.
9. Spaite DW, Tse DJ, Valenzuela TD, Criss EA, Meislin HW, Mahoney M, Ross J. The impact of injury severity and prehospital procedures on scene time in victims of major trauma. Ann Emerg Med. 1991;20:1299–305.
10. Carr BG, Brachet T, David G, Duseja R, Branas CC. The time cost of prehospital intubation and intravenous access in trauma patients. Prehosp Emerg Care. 2008;12:327–32.
11. Meizoso JP, Valle EJ, Allen CJ, Ray JJ, Jouria JM, Teisch LF, Shatz DV, Namias N, Schulman CI, Proctor KG. Decreased mortality after prehospital interventions in severely injured trauma patients. J Trauma Acute Care Surg. 2015;79:227–31.
12. van der Velden MWA, Ringburg AN, Bergs EA, Steyerberg EW, Patka P, Schipper IB. Prehospital interventions: time wasted or time saved? An observational cohort study of management in initial trauma care. Emerg Med J. 2008;25:444–9.
13. Wyen H, Lefering R, Maegele M, Brockamp T, Wafaisade A, Wutzler S, Walcher F, Marzi I, TraumaRegister DGU. The golden hour of shock - how time is running out: prehospital time intervals in Germany–a multivariate

analysis of 15, 103 patients from the TraumaRegister DGU(R). Emerg Med J. 2013;30:1048–55.
14. Statistics Norway. http://www.ssb.no/en/. Accessed 11 Aug 2017.
15. Statistics Denmark. http://www.dst.dk/en/. Accessed 11 Aug 2017.
16. Kruger AJ, Skogvoll E, Castren M, Kurola J, Lossius HM. ScanDoc Phase 1a Study G. Scandinavian pre-hospital physician-manned Emergency Medical Services–same concept across borders? Resuscitation. 2010;81:427–33.
17. Østerås Ø, Brattebø G, Heltne JK. Helicopter-based emergency medical services for a sparsely populated region: a study of 42,500 dispatches. Acta Anaesthesiol Scand. 2016;60:659–67.
18. Tryba M, Brüggemann H, Echtermeyer V. Klassifizierung von Erkrankungen und Verletzungen in Notartztrettungssystemen. Notfallmed. 1980;6:725–7.
19. Pinheiro J BD, DebRoy S, Sarkar D and R Core Team,. _nlme: Linear and Nonlinear Mixed Effects Models_. R package version 3.1–1272016.
20. R Core Team. R: A language and environment for statistical computing.: R Foundation for Statistical Computing, Vienna, Austria.; 2016.
21. McCoy CE, Menchine M, Sampson S, Anderson C, Kahn C. Emergency medical services out-of-hospital scene and transport times and their association with mortality in trauma patients presenting to an urban level I trauma center. Ann Emerg Med. 2013;61:167–74.
22. Funder KS, Petersen JA, Steinmetz J. On-scene time and outcome after penetrating trauma: an observational study. Emerg Med J. 2011;28:797–801.
23. Aydin S, Overwater E, Saltzherr TP, Jin PH, van Exter P, Ponsen KJ, Luitse JS, Goslings JC. The association of mobile medical team involvement on on-scene times and mortality in trauma patients. J Trauma. 2010;69:589–94. discussion 594
24. Newgard CD, Meier EN, Bulger EM, Buick J, Sheehan K, Lin S, Minei JP, Barnes-Mackey RA, Brasel K, Investigators ROC. Revisiting the "Golden Hour": An Evaluation of Out-of-Hospital Time in Shock and Traumatic Brain Injury. Ann Emerg Med. 2015;66:30–41, 41 e31–33.
25. Hoejenbos MJ, McManus J, Hodgetts T. Is there one optimal medical treatment and evacuation chain for all situations: "scoop-and-run" or "stay-and-play". Prehosp Disaster Med. 2008;23:s74–8.
26. Reid BO, Rehn M, Uleberg O, Krüger AJ. Physician-provided prehospital critical care, effect on patient physiology dynamics and on-scene time. Eur J Emerg Med. 2016;
27. Newgard CD, Schmicker RH, Hedges JR, Trickett JP, Davis DP, Bulger EM, Aufderheide TP, Minei JP, Hata JS, Gubler KD, Brown TB, Yelle JD, Bardarson B, Nichol G, Resuscitation outcomes consortium I. Emergency medical services intervals and survival in trauma: assessment of the "golden hour" in a north American prospective cohort. Ann Emerg Med. 2010;55:235–46. e234
28. Goodacre SW, Gray A, McGowan A. On-scene times for trauma patients in West Yorkshire. J Accid Emerg Med. 1997;14:283–5.
29. Talving P, Teixeira PG, Barmparas G, DuBose J, Inaba K, Lam L, Demetriades D. Helicopter evacuation of trauma victims in Los Angeles: does it improve survival? World J Surg. 2009;33:2469–76.
30. Andruszkow H, Lefering R, Frink M, Mommsen P, Zeckey C, Rahe K, Krettek C, Hildebrand F. Survival benefit of helicopter emergency medical services compared to ground emergency medical services in traumatized patients. Crit Care. 2013;17:R124.
31. Bonatti J, Goschl O, Larcher P, Wodlinger R, Flora G. Predictors of short-term survival after helicopter rescue. Resuscitation. 1995;30:133–40.
32. Hoyer CC, Christensen EF, Andersen NT. On-scene time in advanced trauma life support by anaesthesiologists. Eur J Emerg Med. 2006;13:156–9.
33. Schuster M, Pints M, Fiege M. Duration of mission time in prehospital emergency medicine: effects of emergency severity and physicians level of education. Emerg Med J. 2010;27:398–403.
34. Roberts K, Blethyn K, Foreman M, Bleetman A. Influence of air ambulance doctors on on-scene times, clinical interventions, decision-making and independent paramedic practice. Emerg Med J. 2009;26:128–34.
35. Bøtker MT, Bakke SA, Christensen EF. A systematic review of controlled studies: do physicians increase survival with prehospital treatment? Scand J Trauma Resusc Emerg Med. 2009;17:12.
36. Pakkanen T, Virkkunen I, Kamarainen A, Huhtala H, Silfvast T, Virta J, Randell T, Yli-Hankala A. Pre-hospital severe traumatic brain injury - comparison of outcome in paramedic versus physician staffed emergency medical services. Scand J Trauma Resusc Emerg Med. 2016;24:62.
37. Nielsen EW, Ulvik A, Carlsen AW, Rannestad B. When is an anesthesiologist needed in a helicopter emergency medical service in northern Norway? Acta Anaesthesiol Scand. 2002;46:785–8.

Østerås *et al. Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine* (2017) 25:97

Page 11 of 11

38. Dickinson ET, Schneider RM, Verdile VP. The impact of prehospital physicians on out-of-hospital nonasystolic cardiac arrest. Prehosp Emerg Care. 1997;1:132–5.
39. Flin R, Maran N. Identifying and training non-technical skills for teams in acute medicine. Qual Saf Health Care. 2004;13(Suppl 1):i80–4.
40. Flin R, Patey R, Glavin R, Maran N. Anaesthetists' non-technical skills. Br J Anaesth. 2010;105:38–44.
41. Carr BG, Caplan JM, Pryor JP, Branas CC. A meta-analysis of prehospital care times for trauma. Prehosp Emerg Care. 2006;10:198–206.
42. Taylor CB, Liu B, Bruce E, Burns B, Jan S, Myburgh J. Primary scene responses by helicopter emergency medical Services in new South Wales Australia 2008-2009. BMC Health Serv Res. 2012;12:402.

III

Outcomes after cancelled helicopter emergency medical service missions due to concurrencies: a retrospective cohort study

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Conflict of interest

The authors declare no conflicts of interest.

Background: Appropriate dispatch criteria and helicopter emergency medical service (HEMS) crew decisions are crucial for avoiding over-triage and reducing the number of concurrencies. The aim of the present study was to compare patient outcomes after completed HEMS missions and missions cancelled by the HEMS due to concurrencies.

Methods: Missions cancelled due to concurrencies (AMB group) and completed HEMS missions (HEMS group) in Western Norway from 2004 to 2013 were assessed. Outcomes were survival to hospital discharge, physiology score in the emergency department, emergency interventions in the hospital, type of department for patient admittance, and length of hospital stay.

Results: Survival to discharge was similar in the two groups. One-third of the primary missions in the HEMS group and 13% in the AMB group were patients with pre-hospital conditions posing an acute threat to life. In a sub group analysis of these patients, HEMS patients were younger, more often admitted to an intensive care unit, and had an increased survival to discharge. In addition, the HEMS group had a greater proportion of patients with deranged physiology in the emergency department according to an early warning score.

Conclusion: Patients in the HEMS group seemed to be critically ill more often and received more emergency interventions, but the two groups had similar in-hospital mortality. Patients with pre-hospital signs of acute threat to life were younger and presented increased survival in the HEMS group.

Editorial comment
For emergency calls and dispatch of ambulance helicopter emergency services (HEMS), there is a challenge in activating a mission when appropriate, and in not activating a mission when it appears to be not appropriate based on the information in the call. This study assessed outcomes when emergency calls in one system which were triaged to HEMS or to no HEMS.

For almost 40 years, the physician-staffed helicopter emergency medical service (HEMS) in Norway has supplemented the ground ambulance service and on-call general practitioners (GPs) in the municipalities. The HEMS covers most of the populated mainland within a 30-min flight time.

However, the capacity is limited and new dispatches can occur simultaneously with another HEMS mission. A high rate of concurrencies can be a sign of over-triage or a low capacity of the HEMS. In Norway 4–5% of HEMS missions are cancelled due to concurrent requests, an incidence that was considered acceptable until now.[1,2] An unknown proportion of these missions are completed by other HEMS bases. A Canadian study found that 3.5% of requests are aborted due to concurrent missions.[3] The effect of cancellations due to concurrency on patient outcomes is not known.

In HEMS dispatch, cooperation between the emergency medical communication centre (EMCC) and HEMS and the judgements of experienced personnel are important for appropriate use of the service.[4–6] Inter-operator variability likely affects the missions to which HEMS is dispatched.[4] Several aspects must be considered, such as the patient's condition, accessibility from a road, distance to the hospital, and the proximity of other resources. In the Norwegian system, the HEMS crew makes the final decision on whether to respond. A certain level of over-triage is, and must be, accepted in order to reduce under-triage. However, a too liberal dispatch policy will increase the probability of HEMS being unavailable if needed. In the initial phase of a mission, reliable data on the patient's physiology is often limited, and prioritisation of concurrent missions can be challenging.[7,8] To the best of our knowledge, patient outcomes after cancelled missions due to concurrent requests have not yet been described. Such information is relevant for discussions regarding the centralisation of ambulances and GP out-of-hour services, in addition to the number and location of HEMS bases. In the present study, we compared the outcomes of patients transported by ground ambulances in missions cancelled by the HEMS due to concurrent requests to the outcomes of patients in missions prioritised and completed by the HEMS.

Methods

This retrospective cohort study included missions from the three HEMS bases in Western Norway (Førde, Bergen, and Stavanger). The Norwegian emergency medical system is two-tiered. The municipalities are responsible for primary health care, including first responders and a comprehensive out-of-hours GP service; the regional health trusts are responsible for ground, boat, and air ambulances, as well as hospitals. The HEMS in our region was described previously.[2]

Data source, data management, and variables

Data are recorded for both completed and cancelled HEMS missions, providing two groups for comparison. First, all missions cancelled due to another concurrent mission during 2004–2013 were identified (AMB group). Next, we manually identified each corresponding completed mission that occupied the HEMS (HEMS group), comprising primary, inter-hospital, search-and-rescue, or other HEMS missions. If data from a cancelled mission were not found, the corresponding HEMS mission was not assessed. Patients were assessed in the nine receiving hospitals for both cancelled and completed missions. Figure 1 outlines the excluded missions.

The primary outcome was survival to hospital discharge. The secondary outcomes were physiology score in the emergency department (ED), immediate emergency interventions in the receiving hospital, type of department for patient admittance and length of hospital stay. The Worthing Physiological Scoring System (PSS) (Table 1) was used to score the physiology status in the ED.[9] An early warning score was preferred due to robustness in handling missing values, and the Worthing PSS was chosen because validation against survival during the complete hospital stay was available. Patients under 16 years of age were excluded when reporting Worthing PSS, as it is only validated for adults.

Emergency interventions were defined as potentially life-saving emergency procedures performed within 24 h after admittance, including endotracheal intubation to secure the airway or for breathing (but not as a routine procedure before surgery), insertion of a chest tube, emergency surgery, angiography/percutaneous coronary intervention, or thrombolysis. Admittance to an intensive care unit (ICU), high-dependency unit (HDU), or regular hospital ward was recorded. The National Advisory Committee for
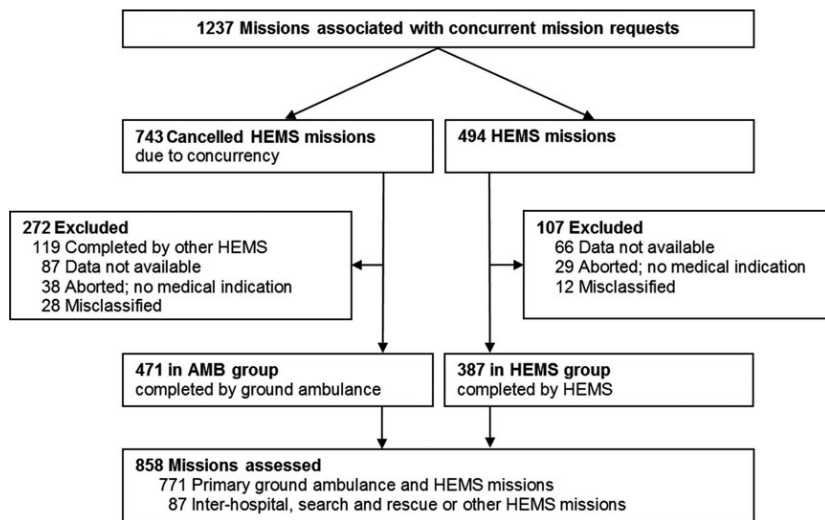
Fig. 1. Flow chart showing identified missions and selection process. During some of the completed helicopter emergency medical service (HEMS) missions, more than one other concurrent mission in the ground ambulance group (AMB) was cancelled. Reasons for exclusion were classified as being unable to identify or retrieve patient data, aborted missions with no patient data, missions misclassified as being concurrent, and AMB group patients encountered by another HEMS service.

Table 1 The Worthing Physiology Scoring System (Worthing PSS)

	Score			
	0	1	2	3
Breathing				
Respiratory rate (per min)	≤ 19	20–21	≥ 22	
Oxygen saturation in air (%)	96–100	94 or 95	92 or 93	≤ 91
Circulation				
Pulse rate (per min)	≤ 101	≥ 102		
Systolic blood pressure (mmHg)	≥ 100		≤ 99	
Temperature (°C)	≥ 35.3			≤ 35.2
Disability				
AVPU	Alert			Other

AVPU, Alert, response to Verbal stimuli, response to Pain or Unresponsive; Table is modified from Duckitt et al.[9]

Aeronautics (NACA) score (Table S1) was recorded for all HEMS missions using the most severe condition observed by HEMS.[10] For the cancelled HEMS missions in which patients were transported by ground ambulances, the NACA was scored retrospectively for the pre-hospital phase based on the patient records from the ambulance and ED, but not further examinations or discharge notes. The intention was to identify a subgroup of critically ill patients (NACA 5–6). The NACA scale is crude, but has been validated as a pre-hospital severity score useful for predicting both survival and the need for early respiratory therapy.[11]

Statistical analysis

We used descriptive methods to characterise the sample. Normally distributed data are reported as the mean and standard deviation (SD), other data as median and interquartile range (IQR). Categorical data were analysed by Pearson's chi-squared test and continuous data by the Mann–Whitney U-test. Normally distributed data were compared using t-tests for independent samples. Survival was analysed using Kaplan–Meier plots. The Breslow test was used to determine differences between the survival distributions because it is a better way to analyse a patient's chance of survival with respect to time, as the Kaplan–Meier plot displays the survival rate based on the current number of patients at risk at any given time.[12] Patients discharged alive before the current time point were censored and excluded from further survival rate analysis. $P < 0.05$ was considered significant. Data were analysed, using IBM SPSS Statistics for Windows Version 23 (IBM Corp., Armonk,

NY, USA) and Matlab 7.10 (The MathWorks Inc., Natick, MA, USA).

Ethics

The Regional Ethics Committee (REK Vest 2010/2930) examined the study protocol, had no objections to the study and waived the need for its approval. The Ministry of Health and Care Services (2011–02407), the Norwegian Data Protection Authority (12/00291–3) and the Data Protection Officials for Research at the involved hospitals approved the study. The Ministry of Health and Care Services waived the need for consent from the patients or next of kin.

Results

A total of 1237 missions involved with concurrencies were assessed; 186 (15.0%) were completed by other physician-staffed services or aborted before the patient encounter, 193 (15.6%) had missing or incorrectly registered patient identities or were misclassified as concurrent missions, and 858 (69.4%) were included in the analysis (Fig. 1). All missions in the AMB group were primary missions, whereas the HEMS group consisted of 300 primary missions, 83 inter-hospital transports and 4 other missions. Patient and mission characteristics are presented in Table 2. The HEMS group had shorter median on-scene time, more patients with a pre-hospital acute threat to life (NACA 5–6), and a larger proportion of patients admitted to a hospital than the AMB group.

Among all included patients, 589 (68.6%) were admitted to a hospital. Survival to discharge was similar in both groups (Table 3). Though the AMB group had a larger proportion of in-hospital deaths occurring during the first

Table 2 Patient and mission characteristics in 858 ground ambulance and HEMS missions

	AMB Cancelled by HEMS (n = 471)	HEMS Completed by HEMS (n = 387)	P
Mean age, years (SD)	43.9 (26.2)	46.3 (23.9)	0.162a
Age < 16 years, n (%)	72 (16.3%)	53 (14.0%)	0.367b
Female gender, n (%)	170 (37.5%)	127 (33.2%)	0.189b
Patients with pre-hospital acute threat to life (NACA 5–6), n (%)	60 (13.2%)	124 (33.2%)	**< 0.001**b
Pre-hospital mission outcome, n (%)			**< 0.001**c
Admitted to hospital	339 (72.4%)	332 (87.1%)	
Dead on scene or during transport	56 (12.0%)	36 (9.4%)	
Entrusted to GP	50 (10.7%)	9 (2.4%)	
Discharged on scene	23 (4.9%)	4 (1.0%)	
Median on-scene time, min (IQR)	18 (10–30)	12 (6–20)	**< 0.001**d
Median pre-hospital time, min (IQR)	68 (39–100)	80 (58–113)	**< 0.001**d
Conditions, n (%)			**< 0.001**e
Trauma	171 (36.4)	116 (30.0)	
Cardiac arrest	64 (13.6)	54 (14.0)	
Breathing difficulties	43 (9.1)	16 (4.1)	
Acute neurology, excl. stroke	42 (8.9)	35 (9.0)	
Chest pain	40 (8.5)	53 (13.7)	
Psychiatry, incl. intoxications	26 (5.5)	12 (3.1)	
Stroke	23 (4.9)	33 (8.5)	
Obstetrics and childbirth	11 (2.3)	13 (3.4)	
Infection	10 (2.1)	21 (5.4)	
Other	40 (8.5)	34 (8.8)	

Bold P-values indicate significant differences. [a]Independent samples t-test. [b]Pearson's chi-squared test for the 2 × 2 table. [c]Pearson's chi-squared test for the 2 × 4 table. [d]Mann–Whitney U test for independent samples. [e]Pearson's chi-squared test for the 2 × 10 table. Missing values (in AMB + HEMS): age 28 + 8, gender 18 + 4, NACA 18 + 12, pre-hospital mission outcome 3 + 6, on-scene and pre-hospital times 217 + 61 conditions 1 + 0.

Table 3 Primary and secondary outcomes for 589 patients admitted to hospital in primary missions

	All (n = 589)			Pre-hospital acute threat to life; NACA 5–6 (n = 142)		
	AMB Cancelled by HEMS (n = 339)	HEMS Completed HEMS missions (n = 250)	P	AMB Cancelled by HEMS (n = 56)	HEMS Completed HEMS missions (n = 86)	P
Discharged alive, n (%)	313 (92.3)	220 (88.0)	0.244a	33 (58.9)	59 (68.6)	**0.023**a
Time of in-hospital deathb			**0.002**c			**0.004**c
First 24 h, n (%)	21 (6.2)	12 (4.8)		19 (33.9)	11 (12.8)	
After 24 h, n (%)	5 (1.5)	18 (7.2)		4 (7.9)	16 (18.6)	
Physiology in ED, age > 15 years						
Worthing PSS > 1, n (%)	104 (37.1)	96 (46.6)	**0.036**c	42 (77.8)	60 (81.1)	0.960c
Median Worthing PSS, median (IQR)	0 (0–3)	1 (0–3)	**0.040**d	4 (2–5)	3 (2–5)	0.566d
Emergency interventions < 24 h, n (%)e	57 (17.4)	64 (26.1)	**0.011**c	25 (46.3)	32 (38.6)	0.369c
Admitted to ICU or HDU, n (%)	97 (29.9)	109 (44.5)	**< 0.001**c	28 (53.8)	61 (73.5)	**0.019**c
Length of hospital stay, median (IQR)	2 (1–5)	3 (1–8)	**< 0.001**d	4 (1–11)	8 (2–18)	0.094d
Length of hospital stay > 10 days, n (%)	32 (10.3)	45 (20.5)	**0.001**c	8 (25.0)	24 (40.7)	0.135c

Bold P-values indicate significant differences. HEMS, Helicopter Emergency Medical Services; Worthing PSS, Worthing Physiology Scoring System;[9] ICU, intensive care unit; HDU, high-dependency unit. [a]Breslow Test of different survival distributions from Kaplan–Meier plot. [b]Time of in-hospital death was reported as number (n) and proportion of all patients admitted to hospital within AMB or HEMS group (%) and tested, using 2×2 chi-squared test for the time of in-hospital deaths in the two groups. [c]Pearson's chi-squared test. [d]Mann–Whitney U test for independent samples. [e]Emergency interventions; life-saving emergency procedures performed within 24 h after admittance, e.g., endotracheal intubation (but not as a routine before surgery), insertion of a chest tube, emergency surgery, angiography/percutaneous coronary intervention (PCI) or thrombolysis.

24 h, the HEMS group had a larger proportion of patients with deranged physiology and an increased proportion of immediate emergency interventions in the ED (e.g., intubation, surgery, or procedure). Compared to the AMB group, ICU or HDU admittance was more frequent in the HEMS group, which also had an increased length of hospital stay for patients discharged alive.

In a subgroup analysis of patients in primary missions with a pre-hospital acute threat to life (NACA 5–6), patients in the HEMS group were younger (mean age 47.5 years vs. 61.1 years in the AMB group, P = 0.001) and more often admitted to an ICU or HDU. HEMS patients in this subgroup had increased survival, based on the Breslow test for the Kaplan–Meier plot (Fig. 2).

Discussion

To the best of our knowledge, patient outcomes have not previously been reported for missions cancelled by the HEMS due to a concurrent mission request. These missions are important because they involve patients that the HEMS would like to assist if not busy with another mission. Knowledge is limited, perhaps due to the challenges of such retrospective assessments. We recommend establishing a running system for follow-up, as this may help improve the dispatch criteria and dispatch decisions, avoiding some concurrencies, and, hopefully improving patient outcomes.

The increased survival of patients with an acute threat to life in the HEMS group compared to the AMB group may indicate that HEMS treatment and/or rapid transport improves patient outcomes. The advantage of a specially trained pre-hospital anaesthesiologist performing triage and pre-hospital care is most evident when encountering critically ill patients and in incidents with long transport times. The extent to which the HEMS contributes to increased survival and better outcomes for patients has not been established. A recent study from Norway indicated that HEMS physicians are able to restore deranged physiology in the pre-hospital phase.[13] Furthermore, a 2009 review and along several other studies found that the HEMS provides a survival benefit compared to ground services in
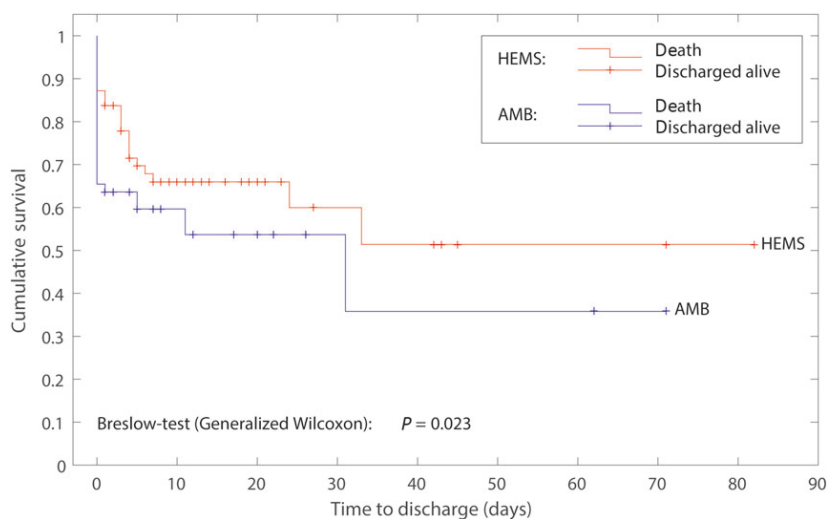
Fig. 2. Kaplan–Meier plot: patients' cumulative in-hospital survival in primary missions and patients with NACA 5–6 ($n = 142$). NACA: the National Advisory Committee for Aeronautics score (Table S1).

selected conditions; this benefit is best documented for trauma patients.[14–19] Other studies have not shown benefits of a pre-hospital emergency physician or HEMS, and a recent Cochrane review of adult trauma patients concluded that which elements provided by the HEMS are beneficial to the patients is unclear.[20–22]

The different guidelines for dispatch of the Norwegian HEMS primarily consider the need for assessment or treatment by an anaesthesiologist, rapid transport and/or the patient being less accessible (e.g., mountain rescue).[23] It is undesirable for the HEMS to be on a mission to a patient with no need for them, particularly when a severe illness or injury occurs. However, appropriate dispatch is dependent on relevant information from the scene; the HEMS crew's decision is made in collaboration with the EMCC operators. In retrospect, the HEMS is dispatched to more patients than are actually in need of this level of care. When in doubt, a lower threshold for dispatch may be appropriate to avoid cancelling missions to patients in true need of the HEMS. A lay person calling the EMCC can be misled about the severity of a given acute illness or injury. A Danish study found that 18% of calls to the EMCC presented unclear medical problems; this study emphasises the complexity of the dispatch decision.[24]

Approximately 30% of all HEMS dispatches are cancelled on the basis of no longer being medically needed.[2] Physician-staffed mobile medical teams are dispatched with a deliberately low threshold in the Netherlands, resulting in 43.5% of the missions being aborted.[25] In Nova Scotia, Canada, almost 10% of missions are declined or aborted due to air transport no longer being required.[3] If the HEMS is activated when in doubt, the response time is kept short in case the missions eventually require the HEMS, at the expense of an increased duty time for the crew. If a HEMS crew has worked 14 of the last 24 h, they will be out of service for the next 9 h due to exceeded duty time according to Norwegian HEMS regulations. It is the HEMS physician's responsibility to respond only to medically indicated missions and to turn down dispatches to non-emergency missions that can be solved by other available pre-hospital resources. The aim is to avoid overuse of the HEMS, decreasing the chance of being unavailable for a mission due to an exceeded duty time or concurrent mission. An Australian study found that a physician-staffed HEMS crew more effectively identified cases of severe paediatric trauma when screening and triaging emergency calls, than the centralised dispatch system operated by paramedics.[26] Most physicians in our HEMS have several years of experience. Live updated information regarding the patient's condition, geographic location of the incident, and other emergency resources is available on

computers at the HEMS base, as well as in the rapid response car and helicopter. However, despite careful decisions about whether to respond, concurrencies will occur.

When considering all missions, the patients in the HEMS group had a higher Worthing PSS, more often received emergency interventions, a larger proportion were admitted to the ICU or HDU, and they had an increased length of hospital stay compared to the AMB group. Thus, the HEMS crew is able to select the most severe cases when prioritising missions. Interestingly, a larger proportion of primary HEMS missions to patients with a pre-hospital acute threat to life (NACA 5–6) were admitted to the ICU/HDU compared to the AMB group even though their physiological recordings (Worthing PSS) were similar upon arrival to the ED. This may reflect a lower threshold for admitting the patient to an ICU/HDU when being transported to the hospital by the HEMS. Another possibility is that the physicians in our service have worked or are currently working in the receiving ICUs. A third possibility is that the physicians, to a larger extent than the ground ambulance personnel, were able to restore deranged physiology (e.g., a hypotensive patient receiving a pressor may have had a normal physiology score regarding blood pressure in the ED). Such patients may have had improved vital signs at the time of admittance but were actually still severely ill, leading to a normal physiology score in the ED for a given HEMS patient compared to if the patient had been transported by a ground ambulance, and an uneven distribution of condition severity between the groups. However, this was not revealed in our data. Supporting the idea of an uneven distribution is the larger proportion of early in-hospital deaths in the AMB group. The differences in ICU admittance and survival may also be due to the age difference between the groups with an acute threat to life, as the HEMS patients were almost 14 years younger than the AMB group. In the Worthing PSS validation, greater mortality was revealed for groups with increasing age.[9] The different proportion of patients admitted to the ICU or HDU may also have skewed the survival between the two groups, as increased survival is expected with ICU/HDU treatment if the patient groups are otherwise similar.

Strengths and limitations

We assessed three similar HEMS bases with a large number of missions over the same time period. As NACA scores are available for HEMS missions, it was chosen to identify severe pre-hospital conditions, and a possible difference in survival would be most evident in critically ill patients.

Regarding the limitations of our study, the retrospective study design has known weaknesses, particularly missing data or errors in data entry. We were not able to identify a number of cases due to unknown patient identity (7.3%), incomplete data in hospital records (5.1%), or misclassifications in the database (3.2%). The patient records in the hospitals were of variable quality (e.g., respiratory frequency was not recorded in ~ 40%) and the NACA score was retrospectively in the AMB group. The number of missing cases is large and, theoretically, could affect the results if most were towards one side/direction. However, we anticipate that the occurrence of these missing cases was random and most likely did not bias our results. In addition, all pre-hospital data were recorded for mission reporting and not intended for research. The missions cancelled by the HEMS and transferred to other physician-staffed helicopter services due to concurrent missions were not assessed, as they may have led to selection bias. These 119 missions were not part of the study protocol and may have characteristics different from the study groups; the threshold for the HEMS turning down missions was likely lower if another physician-staffed service was nearby. The presence of an anaesthesiologist affected the clinical assessment and use of pre-hospital advanced interventions in the HEMS group. Selection bias may have been present, as the HEMS may have been too far away from the scene in some cases to choose between missions strictly on a medical basis. In these cases, the patient in the "new mission" would be transported to the nearest hospital by a ground ambulance before the HEMS crew was able to detach from the current mission. However, because the HEMS would have already been in flight, the reaction time to a new mission may have been reduced. Large transport distances by road may have led to a reduced

threshold for HEMS dispatch and outweighed smaller differences in medical priority.

Even though the patients with a pre-hospital acute threat to life were almost identical in the two groups, differences may have been present that were not revealed in our; thus, the results must be interpreted with caution. Many factors affect the rate of cancellation due to concurrent missions. Dispatch criteria and priority decisions between missions are important to avoid concurrencies, but the approach varies between HEMSs, EMCCs and countries.[27] Geography, population density and flight distances are also factors influencing the incidence of concurrencies, as the many fjords and mountains make the HEMS preferable in many cases due to a significant reduction in transport time.

In conclusion, the patients in missions cancelled by HEMS due to concurrent requests, who were then transported by ground ambulances, had a similar survival rate as patients treated and transported by the HEMS. The HEMS patients were more often critically ill and received more emergency interventions. In a subgroup analysis, patients with a pre-hospital acute threat to life had increased survival after being transported by the HEMS but were younger and more often admitted to an ICU. This retrospective assessment was challenging. Continuous registration and follow-up is recommended to improve dispatch criteria and the appropriate selection of missions; not only would this be useful as a quality indicator, but it may improve the HEMS physicians' ability to prioritise between missions and contribute to a reduction in patient morbidity and mortality.

Authors' contributions

Ø.Ø.: conceived and designed the study, conducted the data analysis, drafted, interpreted the data, critically revised the manuscript, read and approved the final manuscript.

J.-K.H.: conceived and designed the study, interpreted the data, critically revised the manuscript, read and approved the final manuscript.

K.T.: conceived and designed the study, interpreted the data, critically revised the manuscript, read and approved the final manuscript.

G.B.: conceived and designed the study, interpreted the data and critically revised the manuscript, read and approved the final manuscript.

References

1. Norwegian Air Ambulance Service Annual Reports 2009–15. [Web site in Norwegian]. Available at: http://www.luftambulanse.no/%C3%A5rsrapport (accessed 16 June 2017).
2. Østerås Ø, Brattebø G, Heltne JK. Helicopter-based emergency medical services for a sparsely populated region: a study of 42,500 dispatches. Acta Anaesthesiol Scand 2016; 60: 659–67.
3. Lawless J, Tallon JM, Petrie D. Aborted air medical missions: a 4-year quality review of a Canadian province-wide air medical program. Air Med J 2005; 24: 79–82.
4. McQueen C, Smyth M, Fisher J, Perkins G. Does the use of dedicated dispatch criteria by Emergency Medical Services optimise appropriate allocation of advanced care resources in cases of high severity trauma? A systematic review Injury 2015; 46: 1197–206.
5. Harmsen AMK, Giannakopoulos G, Franschman G, Christiaans H, Bloemers F. Limitations in prehospital communication between trauma helicopter, ambulance services, and dispatch centers. J Emerg Med 2017; 52: 504–12.
6. Wilmer I, Chalk G, Davies GE, Weaver AE, Lockey DJ. Air ambulance tasking: mechanism of injury, telephone interrogation or ambulance crew assessment? Emerg Med J 2015; 32: 813–6.
7. Palumbo L, Kubincanek J, Emerman C, Jouriles N, Cydulka R, Shade B. Performance of a system to determine EMS dispatch priorities. Am J Emerg Med 1996; 14: 388–90.
8. Giannakopoulos GF, Bloemers FW, Lubbers WD, Christiaans HMT, van Exter P, de Lange-de Klerk ESM, Zuidema WP, Goslings JC, Bakker FC. Criteria for cancelling helicopter emergency medical services (HEMS) dispatches. Emerg Med J 2012; 29: 582–6.
9. Duckitt RW, Buxton-Thomas R, Walker J, Cheek E, Bewick V, Venn R, Forni LG. Worthing physiological scoring system: derivation and validation of a physiological early-warning system for medical admissions. An observational, population-based single-centre study. Br J Anaesth 2007; 98: 769–74.

10. Tryba M, Brüggemann H, Echtermeyer V. Klassifizierung von Erkrankungen und Verletzungen in Notarztrettungssystemen. Notfallmedizin 1980; 6: 725–7.

11. Raatiniemi L, Mikkelsen K, Fredriksen K, Wisborg T. Do pre-hospital anaesthesiologists reliably predict mortality using the NACA severity score? A retrospective cohort study. Acta Anaesthesiol Scand 2013; 57: 1253–9.

12. Kleinbaum DG, Klein M. Kaplan-Meier survival curves and the log-rank test. In: Dietz K, Gail M, Samet JM, Singer B, Tsiatis A, eds. Survival Analysis: A Self-Learning Text, 3rd edn. New York, NY: Springer New York, 2012: 55–96.

13. Reid BO, Rehn M, Uleberg O, Krüger AJ. Physician-provided prehospital critical care, effect on patient physiology dynamics and on-scene time. Eur J Emerg Med 2016. https://doi.org/10.1097/me j.0000000000000432. [Epub ahead of print].

14. Bøtker MT, Bakke SA, Christensen EF. A systematic review of controlled studies: do physicians increase survival with prehospital treatment? Scand J Trauma Resusc Emerg Med 2009; 17: 12.

15. Andruszkow H, Lefering R, Frink M, Mommsen P, Zeckey C, Rahe K, Krettek C, Hildebrand F. Survival benefit of helicopter emergency medical services compared to ground emergency medical services in traumatized patients. Crit Care 2013; 17: R124.

16. McVey J, Petrie DA, Tallon JM. Air versus ground transport of the major trauma patient: a natural experiment. Prehosp Emerg Care 2010; 14: 45–50.

17. Giannakopoulos GF, Kolodzinskyi MN, Christiaans HMT, Boer C, de Lange-de Klerk ESM, Zuidema WP, Bloemers FW, Bakker FC. Helicopter Emergency Medical Services save lives: outcome in a cohort of 1073 polytraumatized patients. Eur J Emerg Med 2013; 20: 79–85.

18. Hesselfeldt R, Steinmetz J, Jans H, Jacobsson MLB, Andersen DL, Buggeskov K, Kowalski M, Præst M, Øllgaard L, Höiby P, Rasmussen LS. Impact of a physician-staffed helicopter on a regional trauma system: a prospective, controlled, observational study. Acta Anaesthesiol Scand 2013; 57: 660–8.

19. Lossius HM, Søreide E, Hotvedt R, Hapnes SA, Eielsen OV, Førde OH, Steen PA. Prehospital advanced life support provided by specially trained physicians: is there a benefit in terms of life years gained? Acta Anaesthesiol Scand 2002; 46: 771–8.

20. Bieler D, Franke A, Lefering R, Hentsch S, Willms A, Kulla M, Kollig E, TraumaRegister DGU. Does the presence of an emergency physician influence pre-hospital time, pre-hospital interventions and the mortality of severely injured patients? A matched-pair analysis based on the trauma registry of the German Trauma Society (TraumaRegister DGU(R)). Injury 2017; 48: 32–40.

21. Butler DP, Anwar I, Willett K. Is it the H or the EMS in HEMS that has an impact on trauma patient mortality? A systematic review of the evidence. Emerg Med J 2010; 27: 692–701.

22. Galvagno SM Jr, Thomas S, Stephens C, Haut ER, Hirshon JM, Floccare D, Pronovost P. Helicopter emergency medical services for adults with major trauma. Cochrane Database Syst Rev 2013; 3: CD009228.

23. Ministry of Health and Care Services. [Regulation (2015), document in Norwegian] Forskrift om krav til og organisering av kommunal legevaktordning, ambulansetjeneste, medisinsk nødmeldetjeneste mv. (akuttmedisinforskriften). Available at: https:// lovdata.no/dokument/SF/forskrift/2015-03-20-231 (accessed 09 May 2017)

24. Møller TP, Kjærulff TM, Viereck S, Østergaard D, Folke F, Ersbøll AK, Lippert FK. The difficult medical emergency call: a register-based study of predictors and outcomes. Scand J Trauma Resusc Emerg Med 2017; 25: 22.

25. Giannakopoulos GF, Lubbers WD, Christiaans HMT, van Exter P, Bet P, Hugen PJC, Innemee G, Schubert E, de Lange-Klerk ESM, Goslings JC, Jukema GN. Cancellations of (helicopter-transported) mobile medical team dispatches in the Netherlands. Langenbecks Arch Surg 2010; 395: 737–45.

26. Garner AA, Lee A, Weatherall A. Physician staffed helicopter emergency medical service dispatch via centralised control or directly by crew – case identification rates and effect on the Sydney paediatric trauma system. Scand J Trauma Resusc Emerg Med 2012; 20: 82.

27. Ellensen EN, Hunskaar S, Wisborg T, Zakariassen E. Variations in contact patterns and dispatch guideline adherence between Norwegian emergency medical communication centres – a cross-sectional study. Scand J Trauma Resusc Emerg Med 2014; 22: 2.
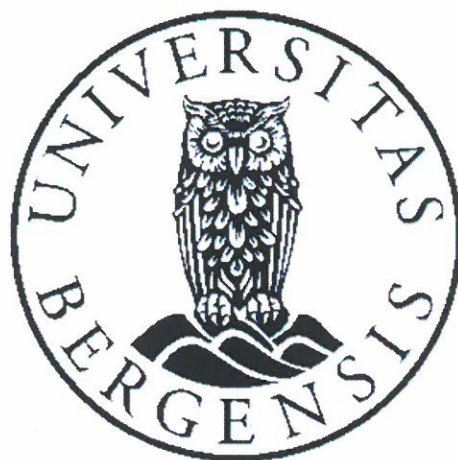
Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Table S1. The NACA scale: a severity scoring used by the Norwegian Air Ambulance Service
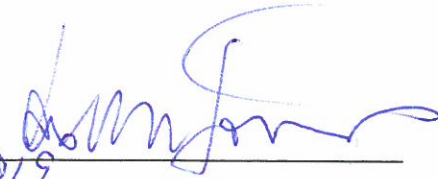
Errata for
Helicopter-based Emergency Medical Service: dispatches, decisions and patient outcome

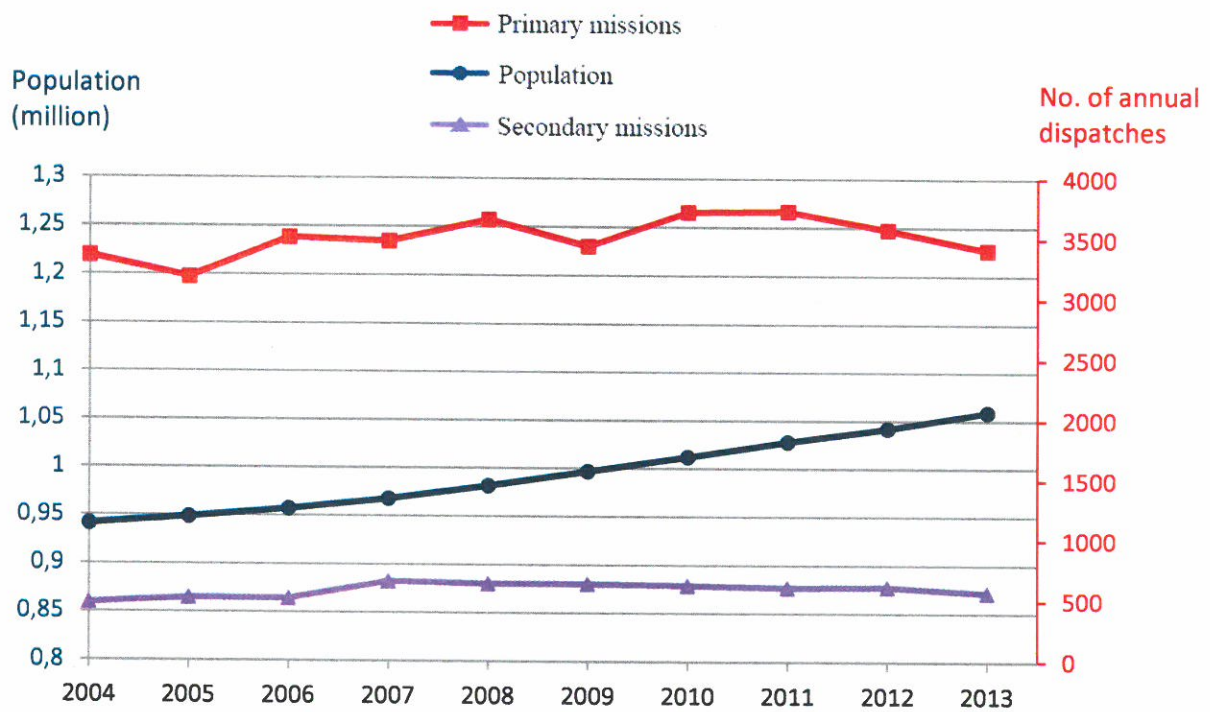*HEMS in Western Norway*

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Thesis for the degree philosophiae doctor (PhD)

at the University of Bergen

3/9-2019   *Øyvind Østerås*   3/9 2019

(date and sign. of candidate)   (date and sign. of faculty)

Errata

Page 29   Corrected Figure 3 according to figure title

Figure 3 Population and the number of annual HEMS dispatches to primary and secondary missions in Western Norway in the study period.

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