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Danish Criteria-based Emergency Medical Dispatch – Ensuring 112 callers the right help in due time?

PhD dissertation

Mikkel S. Andersen

Health

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Preface

This dissertation is the result of my work during my 3-year enrolment as a PhD student at the Faculty of Health, Aarhus University and my employment as a researcher at the Research Department, Prehospital Emergency Medical Services, Central Denmark Region and the Department of Clinical Epidemiology, Aarhus University Hospital. From day one, my motivation for the project has been a profound interest in prehospital care for patients experiencing a medical emergency. Every day hundreds of ambulances and specialised prehospital units are being dispatched. The scientific evidence upon which assessment of emergency calls and subsequent dispatch of help is conducted is sparse. I decided to make an effort to do something about that.

I would like to thank my main supervisor Erika Frischknecht Christensen for believing in me, supporting me and for her unstoppable enthusiasm and encouragement. My sincere appreciation also goes to Søren Paaske Johnsen for revealing the world of clinical epidemiologic research to my, teaching me the art of scientific writing and for his always good spirit. A big thank you should also go to everyone at the Research Department, Prehospital Emergency Medical Services, Aarhus, Central Denmark Region, especially Jesper Bjerring Hansen for his unremitting help with extracting valid data from the dispatch software at the Emergency Medical Communication Centre. I would also like to thank Frank Mehnert for helping with the construction of datasets. I also owe gratitude to Thomas Deleuran for his big insight into clinical epidemiology and statistical software and for his profound interest in the local football team. Last but not least I would like to thank everyone at the involved emergency medical communication centres (in Danish; AMK-vagtcentraler), especially Jan Nørtved Sørensen and Søren Bruun Jepsen.

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Mikkel Andersen, Aarhus, June 2014

Original papers in relation to this dissertation

Andersen MS, Johnsen SP, Sorensen JN, Jepsen SB, Hansen JB, Christensen EF. Implementing a nationwide criteria-based emergency medical dispatch system: A register-based follow-up study. *Scand J Trauma Resusc Emerg Med* 2013; Jul 9;21(1):53.

Andersen MS, Johnsen SP, Hansen AE, Skjaerseth E, Hansen CM, Sorensen JN, Jepsen SB, Hansen JB, Christensen EF. Are there preventable deaths among 112 callers not considered highly urgent by the Emergency Medical Communication Centre?. *(submitted)*

Andersen MS, Christensen EF, Jepsen SB, Sorensen JN, Hansen JB, , Johnsen SP. Identifying high-risk patients among 112 callers – can information on demographic factors and hospitalisation history improve triage in Emergency Medical Dispatch?. *(submitted)*

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1. Introduction

Emergency Medical Dispatch (EMD) is in essence assessment of emergency calls, decision on the level of emergency and allocation of ambulances and specialised prehospital units. It is an essential part of the first link in the chain of survival, which consists of the alarm phase, first aid, prehospital treatment and definitive treatment in the hospital.(1) All links are considered equally important, i.e., if one link is weak, the chain is broken. This thesis focuses on the part of the chain that involves EMD, which is a central part of the alarm phase.

The organisation of care for patients with acute illnesses and injuries in Denmark is currently undergoing substantial change. Many smaller hospitals have been closed in recent years and new large emergency departments have emerged. For many citizens, this development is associated with longer distance to emergency treatment, which increases the need for quick and efficient prehospital triage, prehospital treatment and prehospital transport of patients.

The organisation of the prehospital part of the healthcare system has also changed substantially. The 112 emergency telephone number in Denmark is the common number for all emergencies both in police, fire and health-related matters. The 112 emergency number is answered by the police, except in about half of the capital area where it is answered by the Copenhagen Fire Brigade. Up until mid-2011, all emergencies, including health-related emergencies, were assessed by the police or the fire brigade, who would also decide on what kind of help or advice was needed. This system was essentially based on a first come, first served approach to emergency calls. Based on recommendations from the Danish Health and Medicines Authority and on the fact that the previous police-operated dispatch system was considered a weak link in the Danish prehospital organisation, the organisation was changed. (2) In mid-2011 five regional Emergency Medical Communication Centres (EMCCs) were established. After determination of the callers' geographical position, all calls to the 112 emergency number concerning illness or injury are now redirected to an EMCC for medical assessment. The EMCCs employ a medical staff of nurses, paramedics and doctors and all calls redirected from 112 are assessed by a member of the medical staff, and the prehospital resources (ambulances and more specialized prehospital units) are dispatched by nonmedical technical dispatchers. This organisational change has changed EMD from a completely police (and fire brigade) operated service under the jurisdiction of the Justice Department to an integrated part of the healthcare system with reference to the Ministry of Health. It has thereby become a part of the public Danish healthcare system, which is tax-funded and free of charge for all patients.

As in all other parts of the healthcare system, research is mandatory and necessary. A scientifically based investigation exploring the system´s efficiency and safety is needed. The motivation for this dissertation springs from the fact that strong evidence of the optimal way of conducting EMD is limited and that there is virtually no existing Danish research on EMD and from a profound personal interest in prehospital patient treatment.

2. Background and literature review

2.1 Historical aspects and existing Danish research concerning EMD

Some of the first records of prehospital treatment and triage systems are from the French Revolution. In 1794 the French Baron and surgeon Dominique Jean Larrey discovered that leaving wounded soldiers on the battlefield for days with no treatment was associated with high morbidity and mortality. He therefore introduced a system of on-scene treatment and transportation of severely wounded soldiers to field hospitals which yielded good results.(3, 4) These methods were reused in other wars including the American Civil War and later in the two World Wars. Around 1908 the first ambulances emerged in Denmark, operated by Sophus Falck. After World War II, more systematic ambulance services emerged in Europe and the United States.(3) The first record of direct involvement of a trained medical person in the dispatch of ambulances is from 1975 in Utah, USA. By coincidence, a paramedic was present at the dispatch central when a woman called the emergency number because her baby was unable to breathe. The paramedic gave instructions through the telephone and the baby survived. This was one of the first steps towards pre-arrival instructions and more medical involvement in the dispatching process.(5) In 1978 Dr Jeff Clawson developed a dispatch protocol with key questions, pre-arrival instructions and a way of choosing the level of response.(6, 7) This system was known as the Medical Priority Dispatch System (MPDS), and modified versions of the MPDS are today the most widespread dispatch system in the world. The MPDS is a fixed algorithm where one answer from the caller defines which next question the call-taker should ask. It is typically operated by non-healthcare dispatchers.

In 1990, a different kind of dispatch protocol, the Criteria-based Dispatch (CBD) protocol, was implemented in Kings County, Washington, USA. It was based on a set of 25 criteria representing underlying severe acute conditions.(8, 9) It was a less rigid protocol based on prompts and guidelines rather than on an algorithm. With inspiration from the Kings County model, the CBD protocol was brought to Europe by the

Norwegians.(10) In 1994 a group of Norwegian prehospital enthusiasts together with the Laerdal Medical Foundation developed the Norwegian Index for Medical Emergency Assistance, which is based on The Kings County CBD protocol with the addition of Norwegian adjustments and updates. It is still used today in Norwegian EMCCs in its third edition, and it is being operated by nurses and paramedics. Both the Norwegian organiation with regional EMCCs operated by healthcare personnel and the Norwegian Index have more or less been copied and implemented in Denmark. The Norwegian Index has been translated into The Danish Index for Emergency Care and modified according to Danish standards and the Danish prehospital organisation. Danish regional EMCCs were established during 2009 and 2010, and the technical implementation of redirection of 112 calls and the responsibility for handling all health-related 112 calls were handed over from the police to the healthcare system in May 2011. The Danish EMCCs also handle all requests for ambulances from hospitals and general practitioners. Because these requests come from healthcare professionals, they are not assessed via the Danish Index and they are not a part of this dissertation.

Research on the activities of Danish EMD prior to this PhD project is very sparse. A literature search and a review of all existing articles concerning Danish EMD yielded 13 publications of which seven contained original data, and of these only one was about the current EMCC-operated system. (11-23) Four of the six publications not reporting original data are partly political and informative statements serving as preparation of the communities for the change from police-operated EMD into an integrated part of the healthcare system. (12-14, 16) The last two publications not reporting original data are concerning the healthcare call-takers` responsibilities regarding recognition of cardiac arrest and instruction in basic life support, and they state that the EMCC is as a key player in increasing the survival of patients with out-of-hospital cardiac arrest.(17, 22) Of the seven publications containing original data, six concerns dispatch of a specialised prehospital unit, the emergency-trained anaesthesiologist-staffed vehicle and all five manuscripts originate from the era of police-operated EMD. Holler et al reported agreement in 46% of cases between police

112 operators and the hospital discharge diagnosis in suspected cardiac emergencies.(20) Andersen et al reported agreement in 45% of cases in a similar study.(19) Dahl et al reported an optimisation of use of prehospital physician-staffed car after implementation of a revised dispatch guideline.(15) Bach et al reported a sensitivity of 82%, a specificity of 72% and a positive predictive value of 39% on the assessment "unconscious" by police 112 operators. (11) Mathiesen et al reported that 32% of cardiac arrest cases were dispatched correctly.(23) The last publication, reporting original data by Andersen et al, explore the dispatch of ambulances during the current EMCC-operated EMD system and show that politically determined response time limits were met.(18) As dispatch of ambulances, not only in Denmark, but worldwide, has changed from an exclusively logistical and "first come, first served" undertaking to become an integrated part of the healthcare system and an accepted integrated part of the survival chain, it has received increasing attention in the international research community. A systematic review from 2001 of evidence supporting different methods of prioritising ambulance dispatch found very little evidence in the field.(24) Renowned journals including Circulation and Resuscitation have published recent (2009, 2011, 2014) editorials about the importance of EMD and of research within the field.(25-27) A statement from the American Heart Association recently underlined the importance of dispatcher-assisted basic cardiopulmonary resuscitation.(28) In 2011, Fevang et al stated that EMD would rank among the top five research priorities in prehospital care in the coming years.(29) In line with that statement, a new European conference focusing exclusively on EMD has been established.(30) In 2008, Castren et al. published the Utstein Guidelines about reporting in EMD research, and additional recommendations about reporting on EMD and cardiac arrest were published in 2011, also by Castren et al.(31, 32)

2.2 Existing international literature, Study I (EMD system and performance)

The search strategy was first to identify studies reporting on EMD and then to focus on studies reporting original data describing EMD systems in general and their overall performance. All queries were restricted to English and Danish language and human subjects.

The primary literature search was conducted in Medline. In Medline, the terms `dispatch` and `emergency medical dispatch` are not MESH terms (medical subheadings). A free-text search for the term `dispatch` was conducted which yielded 974 hits. The majority of the hits concerned EMD, but also Police and Fire related studies were captured. In order to narrow down the amount of hits, a free-text search for the term "emergency medical dispatch" was conducted, which yielded 592 hits. To make sure that nothing was missed, all titles from the two queries were reviewed and 282 abstracts were selected as potentially relevant. After a review of abstracts, 76 articles were selected for article review and 14 were rated relevant to our investigation.[8, 10, 33-44] In lack of a dispatch-specific MESH term, a comprehensive prehospital MESH was 'emergency medical services'. A search was also performed using this term in combination with selected subheadings and the term 'triage' as both free-text and MESH and the free-text term 'dispatch'. (Details given below).

"Emergency Medical Services/classification"[Mesh] OR "Emergency Medical Services/education"[Mesh] OR "Emergency Medical Services/etiology"[Mesh] OR "Emergency Medical Services/legislation and jurisprudence"[Mesh] OR "Emergency Medical Services/manpower"[Mesh] OR "Emergency Medical Services/methods"[Mesh] OR "Emergency Medical Services/nursing"[Mesh] OR "Emergency Medical Services/organisation and administration"[Mesh] OR "Emergency Medical Services/standards"[Mesh] OR "Emergency Medical Services/statistics and numerical data"[Mesh] OR "Emergency Medical Services/supply and distribution"[Mesh] OR "Emergency Medical Services/trends"[Mesh] OR "Emergency Medical Services/utilisation"[Mesh]) AND (dispatch[All Fields] OR ("triage"[MeSH Terms] OR "triage"[All Fields]))) AND dispatch[All Fields]

This search yielded 415 hits. After review of the titles, 150 abstracts were selected. After review of the abstracts, 85 articles were selected for review. Many of the studies were identical to the ones from the previous queries, and no additional, relevant studies were identified from this query. Similar literature searches were conducted using Embase, Cinahl, Swemed+, bibliotek.dk and the Cochrane library. One additional, relevant study was found through Embase(45) and one through Cinahl.(46) From the reference lists, one additional, relevant study was identified.(47) A list of the selected background literature for Study I is displayed in Table 2.2.

Table 2.2 Existing literature concerning description of and overall performance of EMD systems.

Author/year	Journal	Design/Country	Objective	Study population	Dispatch system	Main results
Ellensen/2014[10]	SJTREM	Cross sectional study including questionnaire/Norway	Document differences in urgency levels, Norwegian Index criteria and contact rates. Document operator use of Norwegian Index	All contacts in a 72-hour period to the 19 EMCCs of Norway (2,298)	CBD	National contact rate 51/100,000 per year, with large variation. 'Unresolved problem' constituted 20% of calls. In approx. 75% of cases, the Norwegian Index was used
Ek/2013[33]	Int Emerg Nurs	Cohort study /Sweden	Determine accuracy of Swedish CBD	Adults who received an ambulance in the County of Jamtland during 6 months of 2009	CBD	Priority 1 (35.3%), priority 2 (57.9), priority 3 6.7%). Sensitivity 94.5%, specificity 15.4%
Määttä/2012[44]	Acta Anaesthesiol Scand	Historical, before and after study/Finland	To detect changes in performance after reform of dispatch system	1,332,298 callers to 112, divided into two (2 year) periods, starting in 2003	Priority dispatch	Statistically significant (all p-values<0.00) increase in call processing time and use of category A responses
Sporer/2013[34]	J Emerg Med	Cohort study/USA	To measure the need for prehospital medication administered by paramedics	All calls to EMCC in one year (38,005)	MPDS	19% of all callers were prehospitally medicated
Sporer/2011[38]	West J Emerg Med	Cohort study/USA	Do selected MPDS categories predict prehospital interventions?	All 911 callers in San Mateo County California assigned selected dispatch codes during a 3-year period (2004-2006) (31,318)	MPDS	18% -64% received prehospital medication. Of all calls breathing problems was 12.2%; Chest pain 6%; Unknown problem 1.4%; Unconscious 9%
Andersen/2011[36]	DMB	Cross sectional study/Denmark	To report the first preliminary data after implementation of CBD	73,484 contacts to a regional EMCC, not only 112 related contacts	CBD	The distribution of A-E levels of urgency was A 28.7%, B 13.5%, C 21.0%, D 35.1% and E 1.7%
Fischer/2011[45]	Resuscitation	Cohort study/Germany, Spain, USA, UK	Comparison of EMD/ EMS systems using indicators	All patients in four cities in four different countries during a 4-year period prehospitally diagnosed with cardiac arrest, severe dyspnoea or chest pain(6,277)	MPDS and local standard	Rate of high priority responses per 100,000 inhabitants/year was 888 to 6,948. Three out of four EMCCs used MPDS.
Zakariassen/2010[41]	SJTREM	Cross sectional population based study/Norway	To obtain representative epidemiologic data on "red responses" in Norway	All emergency calls to three EMCCs during a 3-month period assessed as priority 1 "red response"	CBD	Chest pain was the most common red response (22%); Inconclusive problem 14%, Accidents 12%, Unconscious 8%
Hjälte/2007[40]	Eur J Emerg Med	Cross-sectional study including questionnaire/Sweden	Appropriateness of dispatch prioritisations	Patients receiving an ambulance in the Gothenburg area during 6 weeks of 2006	CBD	Trauma and accidents most common chief complaint. Two thirds of priority level 1 were appropriate

Garza/2007[42]	Prehosp Emerg Care	Cohort study/USA	Analysing trends between priority dispatch codes and use of "lights and sirens" *from* the scene	All calls to EMCC in 2003 (49,323)	MPDS	Priority 1; 42.6%, Priority 2; 22.0%, priority 3; 13.1% and priority 4; 22.3 Odds ratios of 'lights and sirens' *from* scene of 0.13, 0.49 and 0.58 in low priority groups. Odds ratios 1.63 and 32.11 in high priority groups.
Sporer/2006[37]	Prehosp Emerg Care	Cohort study/USA	To detect if selected MPDS categories predict prehospital interventions	911 callers in California county during 2 years starting 2003 (22.243)	MPDS	All calls' sensitivity of MPDS codes were 84% (83-85) and specificity 36% (35-36)
Kuisma/2004[47]	Resuscitation	Cohort study and audit/Finland	To report prehospital death in a four-priority dispatch system and to evaluate preventability of deaths in lower priorities.	151,928 calls to 112 in Helsinki area during 3 years (1999-2002)	Priority dispatch	Category A death: 5.%; B 1.1%; C 0.1%; D 0.03%. 1.3% avoidable deaths in lower priority groups, 32.9% potentially avoidable, 65.8% not avoidable
Nicholl/1999[46]	Pre-hospital Immediate Care	Case review/UK	To evaluate two dispatch systems operated in UK	Random sample of 1200 callers to the 999 emergency number	CBD and MPDS	CBD sensitivity 39% and positive predictive value 40%. AMPDS sensitivity 14% and positive predictive value 40%. A total of four patients from the sample constituted undertriage
Cooke/1999[35]	Pre-hospital Immediate Care	Case review/UK	To determine if patients assessed by ambulance crew as requiring immediate care were assessed as category A by dispatcher	104 patients transported as "immediate"	CBD	Overtriage in 8 of 104 cases, undertriage 20%
Calle/1995[43]	Eur J Emerg Med	A combined method and cohort study/Belgium	To describe a way of evaluating a dispatch system and to report results from the evaluation	All callers to the 100 emergency number in Gent during 5 months of 1993 (4,601)	Fire department operated, no dispatch protocol	ALS unit in combination with BLS unit in 20% of cases. Underestimation of severity by dispatcher 31%
Culley/1994[8]	Ann Emerg Med	Before and after design/USA	Determine if implementation of criteria-based dispatch improved efficiency of emergency medical system	All callers to 911 in Kings County, Washington with medical complaints before and after implementation of a criteria-based dispatch protocol	CBD	Decreased use of ALS units from 41% to 21% of turnouts for seizure and from 41% to 28% for turnouts for cerebrovascular events. No increase in call processing time
Slovis/1985[39]	Ann Emerg Med	Historical, before and after study/USA	To determine if implementation of a priority dispatch system reduced ambulance response time and changed the use of advanced life support units	Patients transported by ambulance during two periods of 2 months, before and after implementation of priority dispatch (9,905)	Priority dispatch	Ambulance response time decreased 30%, the use of advanced life support units increased.

The existing literature constitutes a heterogeneous group of studies reporting on different dispatch organisations using a variety of outcomes. Most systems use a specific dispatch protocol dividing calls into three to five levels of emergency. There is considerable variation in the proportion of patients allocated to the respective emergency levels. Chest pain, unknown problem, trauma and breathing difficulties are among the most prevalent chief complaints reported, and there is much variation between countries and EMD systems. All EMD systems report concordance between dispatcher-assessed emergency level and the severity of the patient's condition, with some variation in accuracy.

There is a lack of studies using the Utstein template (Castren et al) for reporting on EMD. Furthermore, there is a lack of studies concerning the Scandinavian (in particular the Danish) variant of CBD.

2.3 Existing literature, Study II (audit)

From the comprehensive literature review conducted in Study I, one relevant study concerning the preventability of EMD-related deaths was identified(47), and another six studies using voice-log recordings as part of their methods were found.(48-53)

In order to identity more studies concerning audit, preventability of early death and use of voice-log recordings, the search for existing literature was conducted as follows (all queries were restricted to English and Danish language and human subjects):

In MedLine:

"Clinical audit"[MESH] or "Medical audit"[MESH] and "emergency medical services"[MESH]

This query yielded 1087 hits. A total of 136 abstracts were selected for further review, 61 articles were reviewed and seven studies were selected as relevant background literature for Study II.(54-60)

Another MedLine query was also conducted:

“clinical audit”[MESH] OR “Medical audit” [MESH] AND “hospital emergency” [MESH]

This query yielded 786 hits, which provided one additional, relevant study.(61) Substituting the MESH terms “emergency medical services” and “hospital emergency” with the free-text words “emergency medical dispatch” and “dispatch” gave five and seven hits, respectively, but added no additional, relevant studies. One more query in MedLine was conducted, using the free-text words “patient record” and “preventability”, which yielded 84 hits and one additional, relevant study.(62) A similar query in the Embase yielded one relevant study. A query in Cinahl gave no further relevant studies. Through cross checking of the reference lists of the reviewed literature, four additional studies were identified.(63-66)

Table 2.3.1 Existing literature concerning audit and preventability of early death

Author/year	Journal	Design/Country	Objective	Study population	Main results
Hogan/2014[63]	Int J Qual Health Care	Patient record review (audit)/UK	To asses preventability of hospital deaths	1000 deaths in acute hospital during 1 year	5.2% preventable deaths
Saltzherr/2011[62]	Injury	Patient record review (audit)/The Netherlands	To asses preventability of hospital trauma deaths	62 deaths occurring in or after presentation to trauma centre, during 2 years	1.6% preventable deaths, 27.4% potentially preventable
Falconer/2010[64]	N Z Med J	Post-mortem record review/New Zealand	To asses preventability of pre-hospital trauma deaths	191 pre-hospital trauma deaths	10% had survivable injuries, 35% had potentially survivable injuries, 55% non-survivable
Macleod/2007[65]	Am J Surg	Patient and autopsy record review (audit)/USA	To detect possible salvageable injuries among trauma deaths	556 trauma deaths occurring within one hour after presentation to hospital	Among a subset of patients (93) with initial vital signs, 38% were assessed as possibly survivable
Nafsi/2007[61]	Emerg Med J	Patient record review (audit)/UK	To asses preventability of hospital deaths occurring after admission to ward from Emergency department.	95 deaths occurring within one week	3.15% were preventable, 3.15% were potentially preventable, 6.31 were probably preventable
Lu/2006[66]	Emerg Med J	Patient record review (audit)/Taiwan	To investigate rate of preventable deaths in an emergency department	210 deaths occurring within 24 hours after emergency admission from emergency department	25.8% preventable deaths
Kuisma/2004[47]	Resuscitation	Cohort study and audit/Finland	To report prehospital death in a four priority dispatch system and as a secondary objective to evaluate preventability of deaths in lower priorities	151,928 calls to 112 in Helsinki area during 3 years (1999-2002	1.3% avoidable deaths in lower priority groups, 32.9% potentially avoidable, 65.8% not avoidable
O´Connor/2002	Acad Emerg Med	Patient record and autopsy report review (audit)/Australia	To detect discrepancy between patient chart findings and autopsy findings	59 patients who died in the emergency department	7% could potentially have survived
Rosenfeld/2000[67]	J Clin Neurosci	Patient record review (audit)/Australia	Identification of errors and evaluation of preventability	355 road accident fatalities with head injury in the State of Victoria during a 5½ -year period	4% preventable, 30% potentially preventable. Problems identified: No prehospital intubation, prolonged scene time and no intravenous access
Lau/1998(57)	Aust N Z J Surg	Patient record review (audit)/Singapore	To determine incidence of preventable trauma death	85 trauma deaths during 2 years	7.1% "frankly preventable", 15.3 potentially preventable
Papadopoulos/1996(59)	J Trauma	Evaluation of	To identify preventable prehospital	82 trauma patients dead on	4.87% definitely preventable, 42,65

		autopsy findings	deaths, caused by trauma	arrival to hospital	possibly preventable
Maio/1996(54)	J Trauma	Patient record review (audit)/USA	To determine preventability of death in trauma	155 trauma-related deaths (1 year)	2.6% definitely preventable, 10.3% possibly preventable
Davis/1992(56)	J Trauma	Patient record review (audit)/USA	To determine preventability of death in trauma	1,295 trauma deaths in a 4-year period	5.9% were considered preventable or potentially preventable
Phair/1991(58)	Injury	Patient record review (audit)/UK	Clinical audit of performance of trauma treatment	107 trauma patients during 1 year	35 deaths of which 11 were preventable

Table 2.3.2 Existing literature concerning use of voice-log recordings from EMCCs.

Author/year	Journal	Design/Country	Objective	Study population	Dispatch system	Main results
Clegg/2014[48]	Resuscitation	Feasibility study/UK	To pilot the use of a novel transcription technique of emergency calls for use in evaluation of dispatch-assisted CPR	50 calls to emergency number resulting in suspicion of out-of-hospital cardiac arrest	MPDS	Transcription was feasible and showed potential to identify key factors in caller-dispatcher interaction
Palma/2014[49]	J Emerg Nurs	Review of recordings of emergency calls/Italy	To detect factors associated with undertriage	839 randomly selected calls from a 1-year period	Nurse-operated system, local basic protocol	Undertriage was associated with increasing age and other individuals calling on behalf of the patient.
Meischke/2013[50]	Prehosp Emerg Care	Review of recordings of emergency calls/USA	To investigate the effect of language barriers on call processing time and assessment of level of emergency	All 911 calls to one call centre during 4 different months in Washington State	CBD	Call processing times were 33% - 43% longer when language barriers present
Gibson/2012(60)	Emerg Med J	Review of recordings of emergency calls/UK	To identify how patient's level of consciousness was described in emergency calls and interpreted by call-takers	643 emergency calls with suspected or confirmed stroke	Advanced MPDS	Consciousness level was very hard to describe, it was miscommunicated and conflated with breathing difficulties
Dami/2010[51]	Acad Emerg Med	Review of recordings of emergency calls/Switzerland	To evaluate rate and reasons for caller refusal of initiation of dispatcher-assisted CPR	264 calls where CPR was proposed by dispatcher	Nurse or paramedic operated dispatch, no dispatch protocol	Main reasons for not initiating CPR was bystanders physical condition and emotional distress
Berdowski/2009[52]	Circulation	Review of recordings of emergency calls/ The Netherlands	To study recognition of cardiac arrests in emergency calls and its influence on survival	285 calls concerning cardiac arrest + 506 randomly sampled control calls	CBD	29% of cardiac arrests were not recognised during the call. 3-month survival was 5% when a cardiac arrest was not recognised vs. 14% if recognised.
Lorem/2009[53]	Eur J Emerg Med	Survey and review of recordings of emergency calls/ Norway	Evaluation of dispatcher's handling of calls concerning intoxication	313 Norwegian dispatchers and 84 voice-log recordings of emergency calls	CBD	89% of dispatchers used the dispatch protocol. Deviation from protocol in 33% -

The existing literature concerning audits focusing on preventability of deaths in acute settings is mainly concerned with in-hospital settings (emergency departments and trauma centres), where definite preventability of death is reported at 1-10%. Many studies consider only in-hospital factors. The division of deaths into preventable, potentially preventable and non-preventable is a common approach in the listed studies. Only one audit study concerning preventability of death in EMD was identified.(46) The study focused mainly on mortality rates at the different emergency levels, but a secondary aim (not describing the method in detail) was to review the preventability of death at lower emergency levels. Review of emergency calls through listening to and analysing voice-log recordings has been used in a number of studies, which have focused mainly on cardiac arrests and the delivery of dispatcher-guided cardiopulmonary resuscitation.

There is a lack of studies concerning the preventability of deaths within the first important link of the survival chain, the assessment of the 112 call at the EMCC, in particular regarding CBD and no studies of Danish EMD were found.

2.4 Existing literature, Study III

The search strategy was to identify studies reporting on the use of demographic factors and previously assigned diagnoses in prediction of the outcome in EMD or, alternatively, prediction of outcome in other acute settings. In addition, studies regarding initiatives targeting improvement of dispatch and studies reporting about the predictive ability of EMD systems in general were included. From the wide body of literature reviewed in relation to Study I, seven relevant studies were identified.(68-74) All queries were restricted to English and Danish language and human subjects. The first query (see below) yielded 301 hits; 89 abstracts were selected for review, which yielded 30 articles for full review of which ten were selected as relevant background literature.(75-84)

International Classification of Diseases"[Mesh] OR "Demography"[Mesh] OR "Diagnosis"[Mesh]) AND "Emergency Medical Services"[Mesh] OR Emergency Medical Service Communication Systems [MESH] AND dispatch

Second query (see below) yielded 436 hits; 130 abstracts were chosen for review; 37 articles were selected for full review and seven were found to be relevant to the study.(85-91)

International Classification of Diseases"[Mesh] OR "Demography"[Mesh] OR "Diagnosis"[Mesh]) AND "Emergency Medical Services"[Mesh] OR Emergency Medical Service Communication Systems [MESH] AND prediction.

The following query was also performed adding no further studies.

International Classification of Diseases"[Mesh] OR "Demography"[Mesh] OR "Diagnosis"[Mesh]) AND "Emergency Medical Services"[Mesh] OR Emergency Medical Service Communication Systems[MESH] AND Bayesian prediction[MESH]

The Embase and Cinahl were also consulted, which added no further studies.

Table 2.4. Studies reporting on accuracy or performance of improvement efforts in EMD and studies concerning performance of prediction tools in acute settings.

Author/year	Journal	Design/Country	Objective	Study population	Dispatch system	Main results
Joosse/2014(86)	Crit Care Med	Validation cohort study/The Netherlands	Validation of the Emergency Trauma Score	Two cohorts from trauma registry originating from two different centres, in total 4,418 patients	-	Area under receiver operating curve, AUCs of 0.94 and 0.92 in the two cohorts, respectively
Hettinger/2013[74]	Prehosp Emerg Care	Cohort study/USA	Can MPDS codes predict patient outcome?	One year of 911 callers in county transported to hospital (26,846)	MPDS	Average age of cohort 46.2 years, 54% female. Subset of MPDS codes showed 90% positive predictive value. Gender not associated with outcome, age 65 or more associated with adverse outcome with OR 2.0 to 19.6
Weiser/2013(84)	Resuscitation	Cluster-randomised trial/Austria	To investigate if allowing dispatchers to use own impression of OHCA could improve dispatch times	1,500 suspected cardiac arrests	MPDS	Faster dispatch in the intervention group 143 seconds vs. 198 seconds
Lesko/2013(91)	J Neurotrauma	Prediction study	To determine GCS score association with outcome	21,657 traumatic brain injury patients from a 10-year period from trauma registry	-	AUC of 0.89 for GCS score on scene and AUC of 0.91 of GCS score upon arrival to hospital
Bala/2013(79)	SJTREM	Cohort study/Israel	To describe injuries among elderly and to analyse predictors of in-hospital death	417 trauma patients form a 5-year period	-	Chronic renal failure was the comorbidity with the highest impact on risk of in-hospital death, adjusted OR 3.49
Coventry/2013(78)	Prehosp Emerg Care	Cohort study	To detect any difference in symptoms reported between the men and women in CA cases, and to measure its effect on ambulance response times	1,681 emergency calls from patients diagnosed with myocardial infarction	Local protocol	Women less likely to report chest pain, OR 0.70.
Cildir/2012(89)	Intern Emerg Med	Prospective, observational study	To evaluate three scoring systems (The Modified Mortality in Emergency Department Sepsis (MEDS), Modified Early Warning Score (MEWS) and the Charlson Comorbidity Index (CCI)) ability to predict prognosis of sepsis patients in the ED	230 ED sepsis patients	-	Concerning 5-day mortality, the AUCs were MEDS 0.83, CCI 0.65, MEWS 0.57, respectively
Roozenbeek/2012(87)	J Neurotrauma	Validation cohort study/USA	To investigate performance of two prediction models for use with	2,513 TBI patients from trauma registry		The models showed AUCs of 0.79 and 0.83, respectively

			traumatic brain injury patients			
Sporer/2012(73)	Prehosp Disaster Med	Cohort study/USA	To investigate whether MPDS categories predict level of prehospital intervention	65,268 911 callers during 3-year period (2004-2006)	MPDS	Sensitivity of high priority dispatch codes were 83-94%, with specificities of 28-32%
Krebes/2012(71)	Stroke	Validation and before-and-after study/Germany	To introduce and validate a new dispatcher identification algorithm for stroke	207 emergency calls	No protocol, interview based	Sensitivity of new algorithm for stroke calls was 52.3% and specificity 0.97, pos. pred. value 47.8%
Seymour/2010(88)	JAMA	Cohort study&/USA	To determine prehospital predictors of critical illness and to characterise predictive ability	Two cohorts of non-trauma, non-cardiac arrest patients (4,835 and 3121)	CBD	Predictors were: Older age, lower syst. blood pressure, abnormal respiratory rate, lower GCS and lower pulse oximetry. Combined AUC was 0.77
Deakin/2009(72)	EMJ	Cohort study/UK	To evaluate ability of dispatchers to detect stroke in emergency calls	4,810 emergency callers during 6 s of 2007	AMPDS	Sensitivity 47.62%, specificity 98.68%, pos. pred. value 0.49 and neg. pred. value 0.49
Ohshige/2009(68)	BMC Emergency Med	Cohort study/Japan	To evaluate performance of a new life threat risk assessment algorithm based on logistic models, located in dispatch centre	68,692 callers during 6 months of 2008 and 2009	Local protocol	Sensitivity 80.2%, spec 96.0%, pos. pred. value 42.6%, neg pred. value 99.2%
Sporer/2008(75)	Prehosp Emerg Care	Cohort study/USA	To investigate predictive ability of dispatch system in predicting use of prehospital medication and procedures	69,541 prehospital transported patients from a 3-year period (2004-2006)	MPDS	Patients with shortness of breath, chest pain, diabetic problems, altered mental status received the most medication. 0.9% of calls resulted in procedures (intubation) being performed.
Clawson/2008(69)	Resuscitation	Cohort study/UK/	To establish emergency medical dispatcher predictability of cardiac arrest and high-acuity patients	130,091 chest pain callers during 1 year (starting Aug, 2005)	MPDS	The high-priority levels form MPDS was significantly associated with cardiac arrest outcome (P=0.03) and high acuity conditions (p<o.001)
Clawson/2008(83)	Resuscitation	Cohort study comparing before and after implementation/UK	To evaluate additional assessment questions to the MPDS to help identification of agonal breathing	"Before" cohort of 1.13 mill calls and "after" cohort of 1.2 mill calls. Both periods of 1 year	MPDS	Cardiac arrests in seizure MPDS category declined from 0.24% to 018% of cases
Clawson/2008(70)	Prehosp Disaster Med	Cohort study/UK	To describe chief complaint "breathing problem" and its outcomes	95,848 emergency callers classified as "breathing problems"	MPDS	0.38% were in cardiac arrest, 7.82% had other severe conditions
Clawson/2007(82)	Emerg Med J	Cohort study/USA	To establish accuracy of dispatcher decisions in overriding MPDS recommendations	1-year dataset starting sept 2005. In total 599,107 patients	AMPDS	Override decisions were not more accurate than regular, fixed MPDS-based decisions
Flynn/2006(76)	Prehosp Disaster Med	Cohort study/Australia	To determine ability of MPDS to detect cardiac arrest	3 months, emergency calls in from Melbourne	MPDS	Sensitivity 76.7% specificity 99.2%
Chen/2005(90)	Emerg Med J	Cohort study/Taiwan	To determine efficacy of the Mortality in Emergency Departments Sepsis score (MEDS) in predicting outcome	2 years, non-surgical sepsis patients admitted to ICU through the ER. In total 276	-	AUC 0.745

Gellerstedt/2006(81)	Eur J Emerg Med	Cohort study/Sweden	To analyse if a system including patient characteristics from interview could improve dispatch	3 months of chest pain callers to emergency number. In total 493	Local standards	New system increased sensitivity from 85.7% to 92.4% (p=0.17)
Goodacre/2005(85)	Emerg Med J	Cohort study/UK	To evaluate two hospital mortality risk scores (RAPS and REMS), based on mainly physiological parameters	5,583 patients transported by ambulance and admitted to hospital	-	REMS score AUC 0.74, RAPS score AUC 0.64
Gijsenbergh/2003(80)	Eur J Emerg Med	Cohort study/Belgium	To evaluate effect of training sessions for dispatcher	3,000 callers to two emergency numbers during three different periods in 1996 and 1997	No protocol	After two training sessions undertriage of specialised prehospital intensive care unit decreased from 64% to 55% and to 40%
Neely/1999(77)	Acad Emerg Med		To evaluate if dispatcher assessment agreed with paramedical field findings	1,040 callers to the 911 number during a 6-month period	Local protocol	Overall agreement in 65-70% of cases

The existing literature about the performance of EMD systems concerns mainly limited groups of chief complaints and the corresponding findings within the field by paramedics. Other studies have focused on the implementation of a specific intervention in the EMCC (introduction of new algorithms or key questions) and then measured sensitivity and specificity. No studies have included both demographic factors and diagnoses from previous hospitalisations in such interventions. There are many studies of risk prediction of in-hospital patients, and they all include physiological variables that are not accessible to EMCC call-takers. There is a lack of studies of risk prediction in the EMCC setting, in particular studies that utilise demography and hospitalization history.

Criteria-based EMD is a new and un-investigated part of Danish healthcare system. It affects more than 200,000 emergency patients every year, but virtually no scientific investigations of the system exist. Unfortunately, no systematic data collection allowing patient identification and follow-up was undertaken during the previous police-operated system, which makes a direct comparison of the previous and the current system impossible. There is an imminent need for investigations based on scientific methods in order to prove the system's efficiency and to deliver facts usable for the future optimisation of EMD.

As a starting point, I found it sensible to design studies providing baseline information about the overall performance of the system. This study was followed by a study about the system's safety and another study about possible further improvements of the system. The recommendations about the reporting of EMD research data, offered by Castren et al, were followed whenever technically possible.

3. Aims and hypotheses

Study I

The aim of Study I was to assess the accuracy of prehospital emergency patient triage based on the Danish criteria-based EMD system. We hypothesise that the newly implemented Danish EMD system in general triages 112 callers according to the severity of their underlying condition.

Study II

The aim was to investigate preventability of deaths occurring in close relation to a 112 call among callers not assessed to reach the highest priority, emergency level A ("blue lights and sirens"). We hypothesise that some patients not assessed as emergency level A patients die the same day as they call 112 and that a different assessment by the EMCC could have prevented or potentially prevented some of these deaths.

Study III

The aim was to investigate the impact of age, sex and hospitalisation history on short-term adverse outcomes and to investigate if information about age, sex and hospitalisation history could improve the accuracy of triage among time-critical 112 calls concerning cardiac arrest, chest pain, breathing difficulty, stroke or severe trauma, the so-called First Hour Quintet (FHQ). We hypothesise that age, sex and hospitalisation history are associated with short-term adverse outcomes for a large group of patients with time-critical FHQ conditions. We further hypothesise that age sex and hospitalisation history can be used in a prediction model to help increase the accuracy of Danish EMD.

4. Material and methods

4.1 Setting:

Prehospital emergency medical services in Denmark.

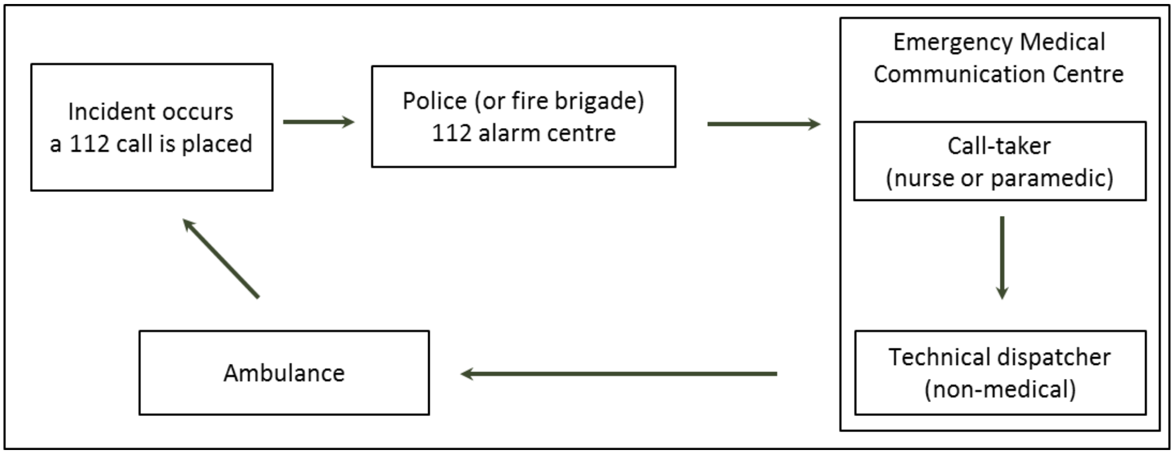
Access to acute medical help in Denmark is possible via two main access points. The most common one and the one handling the vast majority of patients is the general practitioner service (family doctors). All Danes are entitled to have a general practitioner. In general, the general practitioners' clinics are open for telephone calls and visits on weekdays during working hours. During evening and night, general practitioners are on call and available via telephone for advice or consultations; in some areas the general practitioner's involvement is preceded by a triage nurse. This system is not a part of the investigations contained in this thesis.

The second main access point is 112, the focus of this dissertation. 112 is answered by the Police (apart from approximately half of the Greater Copenhagen Capital area, where it is answered by the fire brigade). The police determine the geographical position of the caller and if the call concerns injury or illness, the call is redirected to an EMCC. The time span from answering the initial 112 by the police and until the call is received at the EMCC is not part of the reported EMD response interval of this dissertation (please see Section Four, data sources). The EMCCs are staffed with nurse and paramedic call-takers who assess all calls from 112 under supervision from medical doctors. Information about the selected emergency level is passed on from the healthcare call-takers to a non-medical, technical staff who does the actual technical dispatch of ambulances and more specialised units (Fig 4.2). The call-takers use the Danish Index for Emergency Care as a decision support and triage tool. It divides calls into five levels of emergency: A: life-threatening or potentially life-threatening condition, immediate response required (“blue lights and sirens”); B: urgent, but not life-threatening condition; C: non-urgent condition, but requires an ambulance; D: non-urgent supine patient transport; and E: other service or advice/instruction including taxi transportation (no ambulances are dispatched for emergency level E calls).The Danish Index is further divided into 37 chief complaint categories, all of which are subdivided into more specific complaint groups carrying a unique code.(92)

The Danish prehospital organisations responsible for prehospital emergency services are public and the level of service (e.g. number of ambulances, mobile emergency care units and helicopters) are determined by the regional councils. The ambulance services are mainly run by private companies on a contract with the public prehospital organisations. The prehospital service in Denmark is a two-tier system where emergency ambulances are dispatched either alone or can be dispatched in rendezvous with an anaesthesiologist-staffed mobile emergency care unit and or an anaesthesiologist-staffed helicopter.

Data for all three studies were collected from three of the five regional EMCCs in Denmark. The included regions (the Capital Region of Denmark, the Central Denmark Region and the Region of Southern Denmark) have a combined population of 4,182,613 inhabitants (2012), representing approximately 75% of the total Danish population.(93) The Capital Region consists of mainly urban areas with a population density of 665 inhabitants/km^2. The Central and Southern Regions of Denmark include both urban and rural areas and have average population densities of 99 and 96 inhabitants/km2, respectively.

Figure 4.1. The course of a 112 call concerning illness or injury in Denmark



4.2 Data sources:

EMCC dispatch software:

All patients included in the three studies were identified through logistic dispatch software used at the included EMCCs. In the Central Denmark Region and the Region of Southern Denmark, the software was a program called EVA 2000. In the Capital Region, the logistic software is called LogisCAD. These systems are administrative and logistic tools for use in everyday work at the EMCC, i.e. they are not clinical databases designed for medical research purposes. The systems mainly collect data regarding addresses (to and from), pre-hospital time intervals, patient name, civil registration number (if available) and level of emergency according to the Danish Index. Only contacts to the EMCCs from 112 were included in the study. All other contacts, e.g. from hospitals or general practitioners, were excluded.

The National Police (Study I)

Information about call processing time of 112 calls in the police-operated 112 call centres during 2012 was made available by The National Police.

Civil Registration System: (Study I-III)

The Danish Civil Registration System was established in 1968 and holds complete and daily updated records about residency, vital status (dead or alive) and exact date of death (and birth) for all residents in Denmark. At birth or immigration, all Danish residents are assigned a unique 10-digit civil registration number that allows unambiguous linkage between all Danish medical and administrative registers.(94)

The National Registry of Patients: (Study I-III)

The National Registry of Patients (NRP) was established in 1977 and holds information about all Danish hospital admissions and visits to emergency rooms and outpatient clinics. The registry includes information on several variables, including civil registration number, dates of hospital admission and discharge and diagnoses classified according to the Danish version of the WHO's International Classification of Diseases, 10th edition (ICD-10) and before 1993 according to the ICD-8. The NRP has tracked 99.4% of all discharges from Danish acute-care, non-psychiatric hospitals since 1977and all hospital outpatient and emergency department visits since 1995.(95, 96)

Danish Intensive Care Database: (Study III, FHQ)

Information about patient stay at intensive care units was obtained through the Danish Intensive Care Database. This database is based on information reported to the National Registry of Patients from all Danish intensive care units.[97, 98]

Electronic recordings of telephone interview with 112 callers: (Study II, Audit)

All telephone calls to the EMCCs are recorded in voice-log systems. Based on the date and the time of the day (and not civil registration number), this allows retrieval of recordings of the EMCC staff's telephone interviews with the 112 callers. For the purpose of Study II, recordings relevant to the audit process were retrieved from the voice-log systems of the three included EMCCs.

Medical records, Study II (Audit)

All involved hospital wards and emergency departments were contacted in order to retrieve all available medical records of the patients included in Study II. The material included hospital charts, prehospital charts (that followed the patient into the hospital), results from laboratory analyses, electrocardiograms, descriptions of x-ray and other imagining techniques. If an autopsy had been conducted, a report of this was also requested from the pathology department or the local police department.

Prehospital patient charts (Study II, Audit)

For patients included in Study II who died prehospital and were hence not admitted to a hospital, the corresponding prehospital chart was retrieved from the ambulance company. An ambulance prehospital chart is written on paper and includes information about patient identity (if known), address, prehospital time intervals, vital signs (if measured), treatment and medication administered (if any) and a very short resume of symptoms and events.

4.3 Study design:

Study I:

A register-based historical follow-up study of all patients who contacted an EMCC through the 112 number during the study period.

Study II:

An audit study, including all available patient-related material, of 112 callers not assessed as emergency level A who died on the same date as the 112 call. Review conducted by external expert panel for EMCC-related preventability of death.

Study III:

A register-based historical follow-up study of 112 callers presenting with potential time-critical conditions within the FHQ: possible cardiac arrest, chest pain, breathing difficulty, possible stroke and possibly severe trauma. A list of Danish Index codes defining the FHQ is available in the Appendix.

4.4 Study period and population:

Study I:

The study period was a 6-month period from July 1st through 31st December 2011. Included in the study were all 112 callers redirected from the police or the Copenhagen Fire Brigade to one of the three included EMCCs.

Study II:

The study period was an 18-month period from July 1st 2011 through December 31st 2012. Included in the study were all 112 callers redirected to one of the three involved EMCCs and who were not assessed as emergency level A callers and who died on the same date.

Study III:

The study period was an 18-month period from July 1st 2011 through December 31st 2012. Included in the study were all 112 callers in the study period who were redirected to one of the three involved EMCCs and who fitted the FHQ definition.

4.5 Outcomes:

Study I:

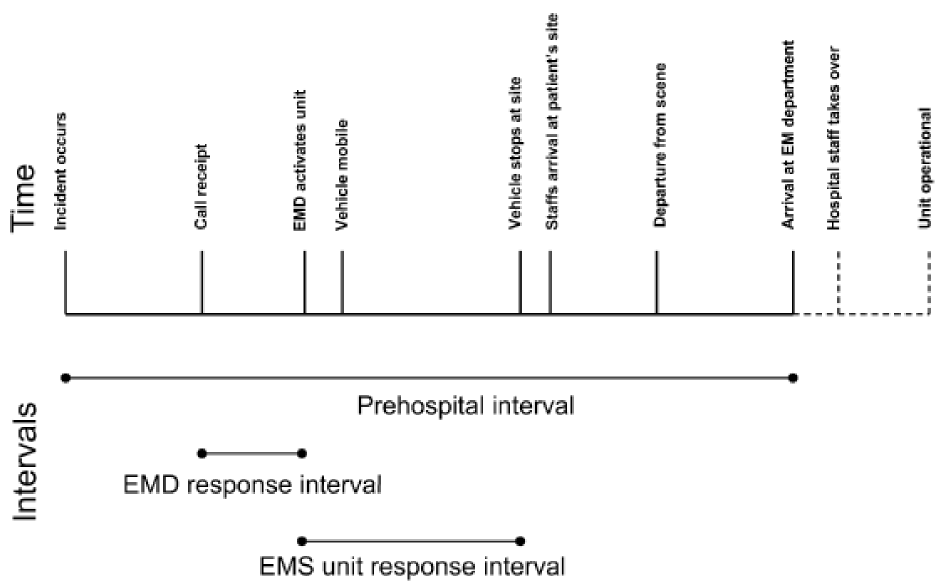
The outcomes included:

- The Danish Index code assigned to every caller, yielding information on the level of emergency, the main index group and specific subgroup symptoms.

- The prehospital time intervals of EMD and EMS response. The EMD response interval is the time interval from the 112 call is received at the EMCC until the first vehicle is dispatched. The EMS response interval is the time from dispatch of the vehicle until arrival on scene (see also Figure 4.5).

- Admission to hospital and death (within 24 h, 48 h and 30 days after the 1-1-2 call).

Figure 4.5. Prehospital time intervals according to Utstein Recommendations by Castren et al.(31)



Study II:

The primary outcome was preventability of death. As the EMCC was the link of interest in the chain of survival in this study, a death was only evaluated as preventable if an alternative assessment by the EMCC could have improved the chances that the patient would have survived. The actual patient care delivered by prehospital or in-hospital medical staff was not reviewed. Preventable deaths were defined as deaths in which a different assessment by the call-taker would very likely have prevented the death. Potentially preventable deaths were defined as deaths where a different assessment potentially could have prevented the death. The audit panel consisted of three consultant anaesthesiologists all with a broad experience in prehospital assessment and treatment of emergency patients. All expert panel members were selected from external institutions. None of them were affiliated with the EMCCs of concern.

Areas with a potential for improvement of the assessment process of 112 calls were a secondary outcome.

Study III:

The main outcome was death on the day or the day after a 112 call (death day 1) was made. Secondary outcomes were death on same day as the 112 call (death day 0) and death day 30. Furthermore, the analysis included the following combined outcomes: death day 0 and/or admittance to an intensive care unit, death day 1 and/or admittance to an intensive care unit, death day 30 and/or admittance to an intensive care unit.

4.6 Covariates:

Only Study III made use of actual covariates. The covariates age, sex and comorbidity were primarily used. Comorbidity was categorised according to the Charlson Comorbidity Index (CCI) and the Iezzoni Chronic Condition categories.[99, 100]

The CCI is a commonly used approach to define and categorise comorbidity with a significant impact on patient outcome. It is used both to describe comorbidity and to control for confounding by comorbidity in studies.[101] Originally, it was constructed in order to predict 1-year mortality of patients admitted to a medical ward. It comprises 19 categories of comorbidity, each considered important in the prediction of patient outcome. All included diagnoses in the CCI are from the International Classification of

Diseases (ICD). In addition to defining specific comorbidities of importance when used in the conventional way, the CCI also assigns weights to specific diagnoses, yielding a score from one to six for each diagnosis. We categorised comorbidity according to the CCI as “yes” or “no” and assigned a Charlson score of zero, one to three and four and above.

In addition to the CCI, a list of chronic conditions constructed by Iezzoni et al. was utilised as an alternative approach to the categorisation of diagnoses from previous hospitalizations. It consists of 13 chronic condition categories influencing the risk of in-hospital death. In the original paper, Iezzoni et al. defined the list of chronic conditions based on ICD-9 codes, which is the edition of the ICD commonly used in in the United States. Since the ICD-10 is used in Demark, the list of chronic conditions was translated into ICD-10 codes (for a complete list, please consult the Appendix).

4.7 Statistical analyses:

Study I:

Descriptive statistics were used in presentation of the included cohort of patients. 95% confidence intervals (95% CIs) were given for all proportions and computed as CIs for proportions with binomial data; exact methods were used. Rates were assumed to follow a Poisson distribution and 95% CIs were calculated accordingly. Relative risk (RR) estimates were calculated as risk ratios and presented with 95% CIs. The prehospital time intervals were reported as medians with interquartile range (IQR). The Wald test was used to test for trends.

Study II:

No formal statistical comparisons or tests were made in this study**.**

Study III:

The associations between age, sex, hospitalisation history and short-term outcomes were studied using multivariable logistic regression models. The predictive ability of the models was assessed using discrimination and calibration analyses. Discrimination analyses of the model were done using the area under the receiver-operating curve (AUC). Discrimination describes the ability of the test to distinguish between those who got the outcome from those who did not. An AUC of 0.5 is equivalent to random prediction. Calibration analyses were performed using the Hosmer-Lemeshow test. The data were split into 10 groups; in each group, estimated values were compared with observed values. A statistically significant test suggests little equivalence between estimated and observed values. Estimates were reported with 95% CIs.

All statistical analyses were performed using the STATA statistical software, version 12.

4.8 Ethics

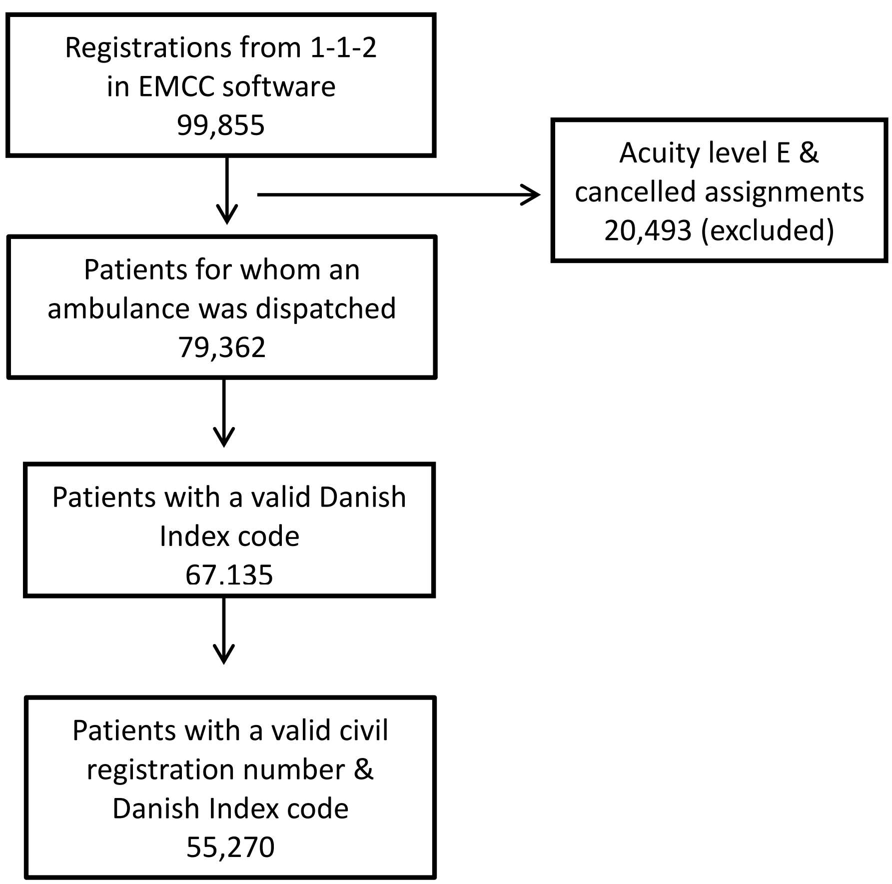
All three studies were approved by the Danish Data Protection Agency (reference number 2011-41-6326 and 2013-41-1598). According to Danish law, permission from the Ethics Committee or informed consent from individual patients is not required for studies based on routinely collected registry data. Study II (Audit) was in addition approved by the Danish Health and Medicines Authority (ref.nr. 3-3013-257/1/) with permission to access the patients' hospital and prehospital charts, including voice-log recordings.

5. Results

5.1 Study I:

A total of 99,855 registrations of 112 calls referred to the included EMCCs were identified in the 6-month study period. The lowest emergency level E, (where no ambulance was dispatched) and cancelled assignments (e.g. multiple calls regarding the same incident) were excluded because these cases were not uniformly registered in the three regions, and the patient's civil registration number was often missing. A total of 79,362 ambulances were dispatched after 112 calls; 67,135 had a registered, valid Danish Index code. A valid Danish Index code *and* a valid civil registration number was registered for 55,270 (70%) of the patients who received an ambulance (Figure 5.1.1).

Figure 5.1.1 Flow-chart of study population in study I.



The mean age of the study population was 54.9 years and 52.3% were males. In the dataset, 19.0% of individuals appeared more than once, median and minimum 1 time and maximum 23 times. Of the 67,135 112 callers with a valid Danish Index code registered, 51.4% (n = 34,489) were emergency level A, 46.3% (n = 31,116) emergency level B, 2.1% (n =1,391) emergency level C, and emergency level D patients accounted for 0.2% (n = 139). The five most often used Danish Index chief complaint groups were: 1) unclear problem; 2) chest pain, heart disease; 3) minor wound, fracture or injury; 4) accident (not traffic-related); and 5) difficulty in breathing. The distribution of the chief complaint groups stratified into levels of emergency is shown in Table 5.1.1.

Table 5.1.1 Patient distribution according to levels of emergency and chief complaint groups of the Danish Index.

Main Index Group (Chief Complaint)	All (%)	A (%)	B (%)	C (%)	D (%)
Unclear problem	11,534 (17.1)	3,909 (11.3)	7,396 (23.8)	214 (15.4)	15 (10.8)
Chest pain, heart disease	8,737 (13.0)	7,661 (22.2)	1,018 (3.3)	56 (4,0)	2 (1.5)
Minor wound, fracture, injury	7,373 (11.0)	423 (1.2)	6,494 (20.9)	384 (27.6)	72 (51.8)
Accident (not traffic-related)	6, 490 (9.6)	2,116 (6.1)	4,141 (13.3)	210 (15.1)	23 (16.6)
Difficulty in breathing	4,945 (7.3)	3,341 (9.7)	1,433 (4.6)	170 (12.2)	1 (0.7)
Impaired consciousness, paralysis	4,464 (6.6)	4,051 (11.8)	377 (1,2)	35 (2.5)	1 (0.7)
Poisoning, medications, alcohol, drugs	3,962 (5.9)	1,204 (3.5)	2,704 (8.7)	53 (3.8)	1 (0.7)
Seizure	3,420 (5.1)	1,794 (5.2)	1,626 (5,2)	.	.
Traffic accident	3,145 (4.6)	2,373 (6.9)	762 (2,5)	.	10 (7.2)
Stomach or back pain	2,950 (4.4)	659 (1.9)	2,175 (7.0)	115 (8.3)	1 (0.7)
Unconscious adult	2,342 (3.4)	2,339 (6.8)	3 (0.0)	.	.
Bleeding–non traumatic	1,227 (1.8)	689 (2.0)	494 (1.6)	44 (3.2)	.
Diabetes	1,149 (1.7)	594 (1.7)	533 (1.7)	21 (1.5)	1 (0.7)
Psychiatry, suicide	1,017 (1.5)	539 (1.6)	476 (1.5)	2 (0.1)	.
Allergic reaction	758 (1.1)	582 (1.7)	176 (0.6)	.	.
Violence, abuse	522 (0.8)	216 (0.6)	304 (1.0)	1 (0.1)	1 (0,7)
Sick child	476 (0.7)	391 (1.1)	84 (0.3)	1 (0.1)	.
Gynaecology, pregnancy	435 (0.7)	259 (0.8)	142 (0.5)	34 (2.4)	.
Headache	414 (0.6)	384 (1.1)	9 (0.0)	21 (1.5)	.
Ear, nose, throat	278 (0.4)	66 (0.2)	202 (0.7)	10 (0.7)	.
Urinary system	273 (0.4)	12 (0.0)	255 (0.8)	6 (0.4)	.
Fire or electricity injury	248 (0.4)	144 (0.4)	103 (0.3)	1 (0.1)	.
Fever	182 (0.3)	127 (0.4)	55 (0.2)	.	.
Foreign body in airway	145 (0.2)	131 (0.4)	14 (0.0)	.	.
Childbirth	120 (0.2)	96 (0.3)	13 (0.0)	.	11 (7.9)
Possible death or sudden infant death	93 (0.2)	76 (0.2)	16 (0.0)	1 (0.1)	.
Eye	83 (0.2)	37 (0.1)	41 (0.1)	5 (0.4)	.
Unconscious child	82 (0.1)	82 (0.2)	.	.	.
Animal and insect bites	74 (0.1)	57 (0.2)	13 (0.0)	4 (0.3)	.
Hypo- and hyperthermia	64 (0.1)	42 (0.1)	22 (0.1)	.	.
Chemicals and gases	54 (0.1)	32 (0.1)	20 (0.1)	2 (0.1)	.
Drowning	34 (0.1)	30(0.1)	4 (0.0)	.	.
Poisoning in children	27 (0.0)	17 (0.1)	10 (0.0)	.	.
Skin and rash	10 (0.0)	8 (0.0)	1 (0.0)	1 (0.1)	.
Diving accident	5 (0.0)	5 (0.0)	.	.	.
Large-scale accident	3 (0.0)	3 (0.0)	.	.	.
All	**67,135 (100)**	**34,489 (100)**	**31,116 (100)**	**1,391 (100)**	**139 (100)**

The median EMD response interval across all emergency levels was 2 min 34 s. In the most severe chief complaint category, “unconscious, not breathing normally”, which contains the majority of suspected cardiac arrests, the median EMD response interval was 1 min 34 s (mean, 2 min 5 s). When assessing the total patient-related time span from the dialling of the 112 number until dispatch of an ambulance, the time spent talking to a 112 operator *before* the call is redirected to an EMCC should also be taken into account. This is not part of the EMD response interval as defined by Castren et al.; but in the Danish EMD system, it is an essential measure as it increases the time interval from the initial 112 call to the arrival of the ambulance. In 2012 in the police operated 112 call centres (covering majority of the study area), this time interval was median 35 s (IQR: 21-58). Data from 2011 were not available.

The median EMS response interval for emergency level A patients was 6 min 11 s, and 75% of all emergency level A turnouts arrived on scene within 9 min 17 sec. Table 5.1.2. shows the EMD and EMS response intervals according to emergency level.

Table 5.1.2. EMD and EMS response intervals, minutes and seconds. IQR=Interquartile range.

Emergency level	No.	EMD, median (IQR)	EMS, median (IQR)
A	34,489	2:01 (1:28,2:47)	6:11 (4:18,9:17)
B	31,116	3:27 (2:20,5:38)	10:00 (6:50,14:24)
C	1,391	4:51 (3:00,10:41)	11:14 (07:44,17:27
D	139	6:46 (3:37,19:00)	13:00 (8:33,21:07)
All	67,135	2:34 (1:45,4:01)	7:53 (5.09,11:59)

Follow-up data about admission to hospital and vital status (dead or alive) could be retrieved for the 55,270 patients in whom both civil registration numbers and Danish Index codes were registered. The proportions of emergency level A and D patients admitted to hospital were 64.4% (95% CI = 63.8-64.9) and 31.2% (95% CI = 22.7-40.8), respectively. The corresponding crude RR of admission among emergency level A patients compared with emergency level B, C and D patients in combination was 1.25 (95% CI = 1.23-1.27). All results regarding risk of admission to hospital are shown in Table 5.1.3.

Table 5.1.3. Admission to hospital rates for patients in the indicated Danish Index emergency level groups.

Acuity level	No.	Admitted to Hospital	Admission rate, % (95% CI)
A	28,630	18,440	64.4 (63.8-65.0)
B	25,419	13,190	51.9 (51.3-52.5)
C	1,112	475	42.7 (39.8-45.7)
D	109	34	31.2 (22.7-40.8)
All	**55,270**	**32,139**	**58.1 (57.7-58.6)***

*Test for trend, p<0.001

The case fatality risk on the same date as the 1-1-2 call for emergency level A patients was 4.4% (95% CI = 4.13-4.60), which increased to 8.6% (95% CI = 8.28-8.94) at 30 days. The case fatality risk on the same date as the 1-1-2 call among emergency level B patients was 0.3% (95%CI = 0.23-0.37), which increased to 3.3% (95% CI =3.09-3.55) at 30 days. Emergency level A patients´ relative risk of dying the same day as the 1-1-2 call was made was 14.3 (95% CI: 11.5-18.0) compared with levels B through D combined. All results concerning case fatality risks and relative risk of death are shown in Table 5.1.4

Table 5.1.4. Case fatality risk for patients in the Danish Index emergency level groups. RR=Relative risk.

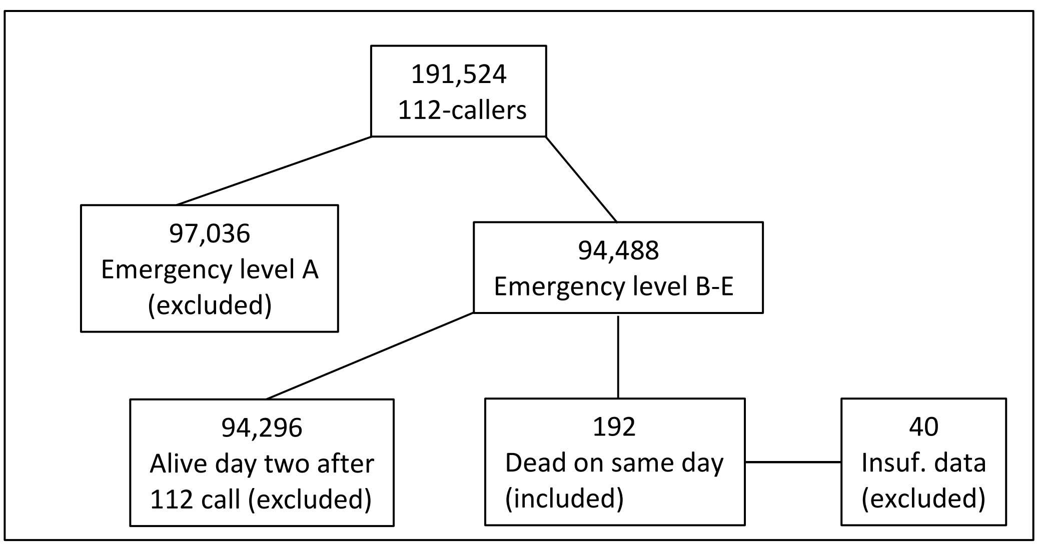
	No.	0–24 h (95% CI)	0–48 h (95% CI)	30-day (95% CI)
A	28,630	4.4 (4.13-4.60)	5.1 (4,87-5,39)	8.6 (8.28-8.94)
B	25,419	0.3(0.23-0.37)	0.6 (0.47-0.66)	3.3 (3.09-3.55)
C	1,112	0.4 (0.15-1.05)	0.5 (0.20-1.17)	3.3 (2.35-4.56)
D	109	0 (0-3.32)*	0 (0-3.32)*	0.9 (0.02-5.0)
RR A vs. B-D		14.3 (11.5-17.98)	9.2 (7.80-10.92)	2.6 (2.42-2.81)
All	**55,270**	**2.4 (2.28-2.54)**	**2.9 (2.78-3.07)**	**6.1 (5.85-6.25)**

*One-sided, 97.5% confidence interval

5.2 Study II:

During the study period of 18 months, 314,134 calls to the 112 emergency number were redirected to the three included EMCCs. Of these, 191,524 calls were registered with a valid civil registration number and a Danish Index code. A total of 94,488 were emergency level B-E calls. In total, 192 (0.2%) emergency level B-E patients died on the same date as the corresponding 112 call was made and were therefore eligible for review. Due to either lack of or insufficient information, 40 deaths were excluded. In total, 152 deaths were included in the study and reviewed, comprising 0.16% of all B-E callers. A flowchart of included and excluded patients is displayed in Figure 5.2.1

Figure 5.2.1. Flowchart of included and excluded patients.



The patients' mean age was 74.4 (range 31-100) and 54.6% were males. Table 5.2.1 displays the distribution of included patients according to the Danish Index chief complaint groups and levels of emergency.

Table 5.2.1. Distribution of patients according to Danish Index chief complaint groups.

Danish Index chief complaint group	
Emergency level B	**n**
Unclear problem	64
Difficulty in breathing	27
Stomach or back pain	15
Minor wound, fracture, injury	10
Seizure	6
Accident (not traffic-related)	6
Impaired consciousness, paralysis	6
Chest pain, heart disease	3
Poisoning, medications, alcohol, drugs	3
Urinary system	3
Diabetes	2
Bleeding–non traumatic	2
Emergency level C	
Difficulty in breathing	3
Unclear problem	1
Emergency level E	
Unclear problem	1
All	152

The reviewers unanimously found none of the 152 early deaths to be definitively (with high certainty) preventable. Eighteen (11.8% of deaths and 0.02% of total B-E callers) of the included deaths were considered potentially preventable *if* the EMCC had assessed the 112 call as more urgent, which would have resulted in the dispatch of an ambulance with shorter EMS response interval arriving faster to the scene, and possibly with the second tier of an anaesthesiologist-staffed mobile emergency care unit. The reviewers assessed 134 of the 152 deaths (88.2%) to be non-preventable. An example of a non-preventable death was 91-year-old female assessed by the EMCC to be emergency level B due to stomach pain. At the hospital, the patient was awake and orientated with normal vital signs. The patient was diagnosed with a ruptured abdominal aortic aneurism and declined further treatment. The patient died at the hospital 7 hours after the 112 call. Baseline information on potentially preventable vs. non preventable deaths is given in Table 5.2.2.

Table 5.2.2. Potentially preventable vs. non preventable deaths

Characteristics	Potentially preventable (n=18)	Non-Preventable (n=134)	Emergency level B-E survivors (n=94,336)
Female, n (%)	6 (33.3)	63 (47.0)	47,074 (49.8)
Age, mean (range)	66 (34-88)	76 (31-100)	53 (0-101)
EMD time, median (IQR) mm:ss	3:26 (3:00-5:26)	3:20 (2:10-5:11)	3:25 (2:19-5:36)
EMS time, median (IQR) mm:ss	12:23 (7:20-15:28)	9:25 (6:32-13:31)	9:51 (6:34-15:03)

The potentially preventable deaths could be divided into two groups. In one group of deaths (n=5), based on the substance of the telephone interview, the EMCC call-takers, in principle, reacted appropriately to the available information; however, it later turned out that a different response could have benefitted the patient. The second group of deaths (n=13, 0.01% of total B-E callers) shared a common characteristic, according to the expert panel's judgment, of either lack of use or incorrect use of the Danish Index. "Unclear problem" and breathing difficulty constituted the two major symptom groups among the possibly preventable deaths. An example of a potentially preventable death, where the Danish Index was followed inadequately, was a 77-year-old female found on the floor by her son. According to the voice log, the patient's son informs the EMCC that his mother might have a broken arm and mentions twice that she has severe breathing difficulties. An ambulance is dispatched as emergency level B under the criterion of a possible fracture. Upon arrival of the ambulance, the patient is in cardiac arrest. At that time, a Mobile Emergency Care Unit (MECU), staffed with an experienced anaesthesiologist with prehospital emergency medical training, is summoned by the ambulance staff. The MECU arrives 24 minutes after the 112 call and the patient is declared dead 8 minutes later. The expert panel concluded that an emergency level A “difficulty breathing” criterion should have been selected, and that a joint emergency level A response with ambulance and MECU potentially could have prevented the fatal outcome.

5.3 Study III:

During the 18-month study period (July 2011 through December 2012), a total of 82,256 calls were considered FHQ symptoms, and 69,982 (85.1) of these had a valid civil registration number, which enabled follow-up via registers and databases. Among patients appearing more than once in the FHQ group, only the first contact was included in the analyses. This returned 59,943 unique FHQ individuals for further analyses. The median age was 63 years (44-77 IQR) and 55% were males. In total, 45.5% of callers had diagnoses from previous hospitalisations fitting the CCI categories, and 44.0% had diagnoses from previous hospitalisations fitting the Iezzoni Chronic Condition categories. Patient demographics, hospitalisation history and case fatalities are shown in Table 5.3.1. The trauma group differed from the medical diseases group by fewer previous hospitalisations shown by the majority, 82%, with a Charlson score of 0.

Table 5.3.1. First Hour Quintet (stratified): Demographics, hospitalisation history and case fatality

FHQ group	Cardiac arrest	Chest Pain	Stroke	Breathing difficulties	Severe trauma	**FHQ all**
All	6.136	19,747	11,687	9.376	12.997	59,943
Age, median (IGR)	67 (51-80)	64 (49-76)	72 (59-82)	69 (53-80)	37 (21-56)	63 (44-77)
Age 0-29, n (%)	659 (10.74)	1,188 (6.02)	461 (3.94)	1,156 (12.33)	5,284 (40.66)	8,748 (14.59)
Age 30-59, n (%)	1,554 (25.33)	6,970 (35.30)	2,532 (21.67)	1,881 (20.06)	5,008 (38.53)	17,945(29.94)
Age 60-89, n (%)	3,498 (57.01)	10,762 (54.50)	7,758 (66.38)	5,808 (61.95)	2,546 (19.59)	30,372 (50.67)
Age 90-107, n (%)	425 (6.93)	827 (4.19)	936 (8.01)	531 (5.66)	159 (1.22)	2,878 (4.80)
Female (%)	2,609 (42.52)	8,767 (44.40)	5,728 (49.01)	4,863 (51.87)	5259 (40.46)	27,226 (45.42)
Hospitalisation hist. Charlson (%)	3,250 (52.97)	10,140 (51.35)	6,718 (57.48)	6,664 (71.08)	2,314 (17.80)	29,086 (45.52)
Charlson score 0 (%)	2,886 (47.03)	9,607 (48.65)	4,969 (42.52)	2,712 (28.92)	10,683 (82.20)	30,857 (51.48)
Charlson score 1-2 (%)	1,975 (32.19)	6,558 (33.21)	4,420 (37.82)	3,963 (42.27)	1,823 (14.03)	18,739 (31.26)
Charlson score 3 and above (%)	1,275 (20.78)	3,582 (18.14)	2,298 (19.66)	2,701 (28.81)	491 (3,77)	10,347 (17.26)
Hospitalisation hist. Iezzoni (%)	2,834 (46.19)	9,980 (50.54)	5,348 (45.76)	6,348 (67.70)	1,883 (14.49)	26,393 (44.03)
ICU admission, n (%)	349 (5.69)	250 (1.27)	375 (3.21)	456 (4.86)	367 (2.82)	1,797 (3.00)
Case fatality (%) Day 0	2,544 (41.46)	173 (0.88)	236 (2.02)	316 (2.7)	111 (0.85)	3,380 (5.64)
Case fatality (%) Day 1	2,662 (43.38)	235 (1.19)	372 (3.18)	478 (5.10)	133 (1.02)	3,880 (6.47)
Case fatality (%) Day 30	3,003 (48.94)	622 (3.15)	1,056 (9.04)	1,332 (14.21)	243 (1.87)	6,256 (10.44)

The adjusted OR of death among males compared with women on day one after a 112 call was 1.37 (95%CI:[1.28-1.47]) in a multivariable model containing age, sex and hospitalisation history (based on the diagnoses comprising the Charlson comorbidity categories). The adjusted OR of death day one for the age group 30-59 compared with the age group 0-29 years was 3.59 (95%CI:[2.88-4.47]). Thirteen of the 19 diagnosis groups from the CCI were also associated with an increased risk of death day one. Ten of them were statistically significant, e.g. metastatic solid tumour, mild liver disease, congestive heart failure and chronic pulmonary disease, with ORs ranging from 2.02 to 1.10. In contrast, previous myocardial infarction and cerebrovascular disease were associated with a lower risk of death at day one (OR 0.66: 95% CI [0.58-0.75] and 0.75 (95%CI [0.68-0.83]), respectively).

Ten out of 13 diagnosis groups among the Iezzoni Chronic Conditions were associated with an increased risk of death at day one and all of them were statistically significant. They included nutritional deficiencies, severe chronic liver disease and chronic pulmonary disease, among others, with adjusted ORs of 2.07-1.13. The three remaining diagnosis groups were associated with a decreased risk of death at day one. Two of them, functional impairment and coronary artery disease, were statistically significant with adjusted ORs of 0.80 (95%CI [0.70-0.90]) and 0.55 (95%CI [0.50-0.60]), respectively. All results regarding the association between the primary outcome (death day one) and age, sex and hospitalisation history are displayed in Table 5.3.2.

Table 5.3.2. Mutually adjusted odds ratios (OR) of the association between hospitalisation history categorised according to Charlson and Iezzoni, sex and age and risk of death day 1.

Charlson

Hospitalization history, OR [95 % CI](n)	
Metastatic solid tumour (806)	2.02 [1.65-2.49] (137)
Mild liver disease (1,250)	1.68 [1.36-2.07] (136)
Hemiplegia (282)	1.84 [1.22-2.77] (27)
Moderate to severe renal disease (2,209)	1.30 [1.13-1.50] (262)
Peripheral vascular disease (4,418)	1.31 [1.18-1.46] (492)
Moderate to severe liver disease (378)	1.30 [0.92-1.83] (50)
Dementia (1,661)	1.29 [1.10-1.52] (184)
Congestive heart failure (5,638)	1.25 [1.13-1.38] (604)
Any tumour (5,826)	1.24 [1.12-1.37] (655)
Ulcer (2,443)	1.16 [1.01-1.34] (246)
Chronic pulmonary disease (9,325)	1.10 [1.01-1.20] (810)
Diabetes I+II (5,263)	1.10 [0.97-1.25] (502)
Diabetes with end organ damage (3,035)	1.05 [0.90-1.24] (306)
Connective tissue disease (2,054)	0.95 [0.80-1.12] (156)
Lymphoma (381)	0.91 [0.63-1.31] (33)
Cerebrovascular disease (8,119)	0.75 [0.68-0.83] (594)
Leukaemia (184)	0.72 [0.40-1.31] (12)
AIDS (67)	0.72 [0.22-2.30] (3)
Myocardial infarction (4,823)	0.66 [0.58-0.75] (327)
Sex	
Male (32,717)	1.37 [1.28-1.47] (2,338)
Female (27,226)	1.00 [ref] (1,542)
Age group	
0-29 (8,748)	1.00 [ref] (92)
30-59 (17,945)	3.59 [2.88-4.47] (698)
60-89 (30,372)	8.40 [6.79-10.39] (2,733)
90- (2,878)	13.21 [10.41-16.76] (357)

Iezzoni

Hospitalization history, OR [95 % CI](n	
Nutritional deficiencies (294)	2.07 [1.47-2.92] (42)
Severe chronic liver disease (554)	2.02 [1.57-2.59] (77)
Metastatic cancer (872)	1.95 [1.61-2.37] (153)
Cancer with a poor Prognosis (1,491)	1.77 [1.52-2.07] (235)
Chronic renal failure (1,492)	1.56 [1.33-1.83] (201)
Congestive heart failure (6,035)	1.42 [1.28-1.57] (632)
Peripheral vascular disease (3,102)	1.40 [1.24-1.59] (356)
Dementia (1,902)	1.28 [1.10-1.49] (207)
Diabetes with end organ damage (6,043)	1.24 [1.13-1.37] (588)
Chronic pulmonary disease (9,289)	1.13 [1.04-1.23] (805)
Functional impairment (4,215)	0.80 [0.70-0.90] (314)
AIDS (78)	0.80 [0.29-2.24] (4)
Coronary artery disease (11,996)	0.55 [0.50-0.60] (783)
Sex	
Male (32,717)	1.40 [1.30-1.50] (2,338)
Female (27,226)	1.00 [ref] (1,542)
Age group	
0-29 (8,748)	1.00 [ref] (92)
30-59 (17,945)	3.69[2.96-4.60] (698)
60-89 (30,372)	8.82 [7.14-10.90] (2,733)
90- (2,878)	14.09 [11.12-17.86](357)

The association between the covariates age, sex and hospitalisation history and the secondary outcomes (death day 0, death day 30, death day 0/ICU, death day 1/ICU and death day 30/ICU) were in general similar in direction to the results concerning death day one. The risk of death increased from day one to day 30, e.g. the OR of death among carriers of chronic pulmonary disease rose from 1.10 [1.01-1.20] to 1.35 [1.26-1.44]; and for the age group 30-59, it rose from 3.59 [2.88-4.47] to 4.08 [3.31-5.02]. The results concerning the outcomes combining death and ICU admittance showed a more uneven pattern. Some diagnosis groups showed decreased risk when ICU was included in the outcome measure, e.g. dementia showed ORs of 1.01 [0.87-1.17] (Charlson) and 0.99 [0.86-1.13] (Iezzoni) for death day one/ICU compared with an OR for death day one alone of 1.29 [1.10-1.52] (Charlson) and 1.28 [1.10-1.49] (Iezzoni).

The ability of age, sex and hospitalisation history to predict patient outcome was tested via discrimination and calibration analyses. Concerning the main outcome, death day one, the full model including age sex and hospitalisation history showed areas under the receiver operator curve of 0.70 (Charlson) and 0.69 (Iezzoni) with p-values from the Hosmer-Lemeshow test of 0.00. When considering the individual contribution of the covariates to the prediction model, sex showed an area under the receiver operator curve of 0.53 (Hosmer-Lemeshow test, p-value 0.00). Age showed an area under the receiver operating curve of 0.65 (Hosmer-Lemeshow test, p-value 0.00). Hospitalisation history (Charlson) alone showed an area under the receiver operator curve of 0.61 (Hosmer-Lemeshow test, p-value 0.72). Hospitalisation history (Iezzoni) alone showed an area under the receiver operator curve of 0.61 (Hosmer-Lemeshow, test p-value 0.00). A p-value from the Hosmer-Lemeshow test below 0.05 indicates little overlap between which patients the model *predicted* would get an adverse outcome and which patients were *observed* to actually have an adverse outcome; this equals poor calibration. A high p-value indicates large overlap between observed and predicted outcomes, equalling good calibration. All results of discrimination and calibration analyses regarding death day one are displayed in Table 5.3.3.

Table 5.3.3. Results of discrimination and calibration analyses concerning the total FHQ, and after stratification into FHQ groups, showing predictive ability of all covariates independently and in combination (day 1). AUC = Area under the receiver operating curve. HL = Hosmer-Lemeshow p-value.

Covariate(s)	FHQ	Cardiac arrest	Chest pain	Stroke	Breathing difficulties	Severe trauma
Sex , AUC/HL	0.53/0.00	0.53/0.00	0.55/0.00	0.50/0.00	0.53/0.00	0.61/0.00
Age, AUC/HL	0.65/0.00	0.63/0.00	0.66/0.00	0.60/0.00	0.64/0.00	0.67/0.00
Charlson, AUC/HL	0.61/0.72	0.63/0.00	0.62/0.00	0.63/0.92	0.65/0.04	0.58/0.00
Iezzoni, AUC/HL	0.61/0.00	0.62/0.00	0.61/1.0	0.62/1.00	0.64/0.02	0.57/0.58
Age, sex & Charlson, AUC/HL	0.69 / 0.00	0.69 /0.00	0.73 /0.00	0.67 /0.23	0.71 /0.00	0.73 /0.00
Age, sex & Iezzoni, AUC/HL	0.70 / 0.00	0.69 /0.00	0.73 /0.00	0.67 /0.00	0.71 /0.00	0.74 /0.99

Discrimination and calibration analyses of the full model including age, sex and hospitalisation history were also performed concerning the secondary outcomes, both on the total FHQ and after stratification into the five FHQ main groups. Concerning the secondary outcomes of close, timely relation to the 112 call (death day 0, death day0/ICU and death day 1/ICU), were between 0.61 and 0.73. They were lowest among the combined outcome and highest concerning death day 0 in the trauma group. The majority of p-values from the Hosmer-Lemeshow tests regarding the secondary outcomes were below 0.01. In the trauma group, the p-values were generally higher with death day 0 as the highest with a p-value of 1.0.

6. Discussion

The accuracy of patient triage, the preventability of early deaths and the impact of age, sex and hospitalisation among a group of time-critical conditions was studied in the new EMD system implemented in May 2011 in Denmark. We demonstrated that the majority of 1-1-2 callers in contact with the Danish EMCCs were assessed as Danish Index emergency level A or B. The most frequent chief complaints presented by callers were unclear problem, chest pain, minor wounds and injuries, accidents and difficulties in breathing. The EMD and EMS response intervals were shortest for emergency level A patients. The risk of admission to hospital and case-fatality risks were considerably higher for emergency level A patients than for emergency level B–D patients.

No same day deaths among 112 callers not assessed as emergency level A patients were considered definitively preventable by an expert panel; however, a number of deaths considered potentially preventable by a different call assessment in the EMCC were found. They constituted a small proportion of all non-high-acuity patients. A common characteristic among the majority of potentially preventable same-day deaths was no use or inadequate use of the criteria-based dispatch protocol.

This dissertation also demonstrates that age, sex and certain groups of diagnoses obtained during previous hospitalisations are associated with short-term adverse outcomes for patients with the time-critical conditions within the FHQ. For patients with chest pain and severe trauma, information on previous hospitalisation showed a potential for prediction of outcome.

6.1 Methodological considerations

When interpreting the results presented in this dissertation, it is necessary to consider the methodological strengths and limitations of the studies, including their selection and information bias, confounding and statistical precision.

6.1.1 Selection bias:

Selection bias is defined as a systematic error originating from the procedures used to select subjects and from factors that influence study participation.(102) (Rothmann KJ. Biases in study design. Epidemiology: An introduction. 1st ed. Oxford University Press; 2002. 94-112). This bias occurs when the association between outcome and exposure/covariate differs between participants and non-participants in a study. All three studies in this dissertation were based on population-based data sources, which reduce the risk of selection bias. Still, missing data and subsequent missing patients exist in all three studies of this dissertation. This may potentially have introduced selection bias into all studies. The most important causes for missing data or patients were mainly two issues concerning registration procedure at the EMCCs. One, Emergency level E patients were not registered with a civil registration number in the Capital Region and in the Region of Southern Denmark; and in the Central Denmark Region, the civil registration number was registered in less than 50% of category E cases. This registration procedure explained a very large part of the missing data. Second, the civil registration numbers registered in the EMCCs were mostly reported to the EMCC by the ambulance services after a turnout was finished. This procedure was not always followed (and the civil registration number could be typed incorrectly into the EMCC software). This was another substantial cause of missing data. Furthermore, some patients were unidentified and some were unwilling or unable to report their personal data. In Study II (audit), patient data were also missing due to missing patient charts, mainly because the filing system was incomplete in some parts of the geographical area in 2011. It could be speculated that patients with inadequately registered data differ from the included patients in terms of outcomes and covariates. If that were the case, selection bias exists in this dissertation. In order to explore the risk of bias, patients with missing Index code or missing civil registration number were compared to patients with complete data. No substantial differences in distribution of chief complaints, fatality risk or admission risk where discovered (data not shown).

6.1.2 Information bias

Information bias is systematic errors that happen because the information collected about the patients (exposure / covariates and outcome) is in some way flawed.(102). For all three studies, the data were prospectively registered, which reduces the risk of information bias

Information about patients included in this dissertation was mainly considered in terms of categories, e. g. emergency level A patients or patients who died on a specific day. If any information error existed in these variables, the patients would have been misclassified. Misclassification can be differential or non-differential. Differential misclassification arises if the classification of either outcome or exposure/covariate is dependent of its counterpart, e.g. more emergency level A patients were registered as dead *because* they were emergency level A. This kind of misclassification seems unlikely in this dissertation. Non-differential misclassification happens when outcome or exposure/covariate is coded wrongly, but independently of the counterpart. It could simply be typing a turnout as emergency level B into the EMCC dispatch software even though the ambulance was dispatched as level A. This kind of misclassification cannot be ruled out in the present dissertation. However concerning one of the primary outcomes, death, it has been shown that this is coded in the Civil Registration System essentially without errors.(94) In Study II (audit), we relied on the external expert panel´s professional opinion about preventability as the main outcome measure. If a death should be considered preventable, it was stated to the reviewers that it should be with a high probability according to their professional clinical judgment based on all the patient -related material presented to them. This method includes a risk of non-differential misclassification if an actually preventable death is not judged (and coded) as such. The use of an expert panel also includes the possibility that two experts review the same case and come to different conclusions. We tried to counter this problem by having three experts on the panel so that a majority decision could be made. It turned out that the result of zero preventable deaths was a unanimous decision by the expert panel.

Incorrect coding of hospital discharge diagnoses may be a concern in Study III where comorbidity indices are used to categorise hospitalisation history. It has been shown that especially Charlson Comorbidity Index is reliable with high positive predictive values of the diagnoses.(103) A number of physical and psychiatric diseases are omitted in both indices, which leaves out the possible predictive power of these conditions.

6.1.3 Confounding

Confounding is, in essence, a mixing or confusion of effects. Since confounding is mainly a concern in aetiological and causal studies, it is not a major concern in the present dissertation. However, possible confounding (e.g. by age and sex) may be a concern in Study I where we (cautiously) use admission and case fatality rate as surrogate measures of severity of the patient's condition. In Study III (FHQ), additional factors like current medication or socio-economic status could, in principle, have been included in order to create a theoretically optimal model. Our approach to the study was more pragmatic in the sense that the included variables should be easily available in the EMCC setting and not require a list of additional questions that should be presented to the caller.

6.1.4 Statistical precision and chance

The statistical precision of associations and proportions was reflected in the 95% confidence intervals of the dissertation. The statistical precision was generally high in most of the analyses. The large size of Study I and Study III is in this respect a strength of the dissertation. In subgroups containing fewer patients, the estimates tended to be more imprecise, leaving more room for chance.

Another strength of the present dissertation is its ability to report variables like EMD and EMS response intervals according to the Utstein recommendations, which improves the possibility of comparing our results with up-to-date international literature.

6.2 Comparison with the existing literature

6.2.1 Study I

The key role of EMD in cardiac arrest as well as in other time-critical conditions is underlined by a number of studies and by recent recommendations. However, EMD systems are not uniform throughout the countries and every system contains local elements. This makes comparisons between studies difficult. The international guidelines for reporting on EMD, proposed by Castren et al., represent a step in the right direction towards uniform, comparable reporting, but they have only existed for few years.(31, 32) One major difference between EMD systems is the approach to assessment of calls: the fixed algorithm protocol-based MPDS system often used by non-health care staff as oppose to the criteria-based system (CBD) that provides guidelines for the call-taker with room for clinical judgment.

Chief complaints and prehospital time intervals in 112 calls

Ek et al. reported a patient distribution of 35.3% priority one, 57.9% priority two and 6.7% priority three from the three priority CBD system in Sweden.(33) In a Finnish study of a priority dispatch system containing four emergency levels, (47), Kuisma et al. reported that callers were distributed as follows: A, 5.7%; B, 27.0%; C, 47.4%, and D, 19.9%. The Finnish study included *all* requests for ambulances (including requests from hospitals, doctors and nursing homes), which may explain some of the differences from our results. In a US study by Garza et al. reporting on a MPDS-operated system, the authors found the highest priority in 42.6% of turnouts and 22.0%, 13.1% and 22.3% in the following lower-priority groups respectively. Concerning call distribution on chief complaint categories, Zakariassen et al. reported from the Norwegian EMD system, which resembles the Danish system in many ways. Regarding emergency level A, they found the five most frequent chief complaints to be chest pain (22%), patient transport (ordered by hospitals and general practitioners) (18%), unclear problem (14%), accidents and traffic accidents (12%) and unconscious adult or child (8%).(41) Apart from patient transports ordered by hospitals and general practitioners, which were not a part of our study, these results were close to our findings. In another Norwegian study, Ellensen et al. reported unclear problems in up to 20% of calls.(10) Reporting from a US MPDS-operated system, Sporer et al. found that 12.2% of all calls concerned breathing problems, chest pain constituted 6.0%, unclear problems 1.1%, seizures 3.4%, falls 8.7% and fainting/unconsciousness 8.7%.(38). Especially the smaller proportion of unclear problems and the high proportion of breathing problems stand out in comparison with our results. The chief complaint "unclear problem" was found to constitute 5–8% of all calls in other studies of MPDS-operated EMD.(104, 105) Breathing problems constituted 12.2% in the US study compared with 7.3% in our study. This difference may be explained by several factors. Firstly, the construction with fixed algorithms of the MPDS and absence of emergency level E (no ambulance dispatch) could partly explain this. Secondly, many patients attend the well-established general practitioner system in Denmark, which accordingly covers the majority of emergency calls of lesser severity, including milder respiratory problems, which may not be the case in the United States.

We found a median EMD response interval for suspected cardiac arrests of 1 min 34s (mean, 2 min 5 s). A Finnish study by Kuisma et al. reported an EMD response interval of 77.1 ± 44s among confirmed out-of-hospital cardiac arrest callers.(106) In a Dutch context, Berdowski et al. reported out-of-hospital cardiac arrests with a mean EMD response interval of 1.88 minutes (1 min 53 s), which was a result similar to our findings.(52) In an editorial, Ornato stated that high-performance MPDS-operated EMD systems produced EMD response intervals of 30 seconds or less.(25) In a comparison of how two systems (one CBD and one MPDS) handled cardiac arrests, Hardeland et al. reported a call processing time between 15 and 33 seconds.(107) This is much faster than the times we and others have reported. Whether Hardeland et al. used the EMD response interval definition presented by Castren et al. is unclear. (31) A short EMD response interval does not necessarily equal high-quality triage, but a short EMD response interval must evidently be a priority concerning suspected cardiac arrest callers (and other high-acuity callers). According to the Utstein Recommendations for reporting EMD data, the EMD response interval does not include the time span from police receipt of 112 call until redirection of the call to an EMCC. But in the Danish organisation, this is an important additional time interval. Our data regarding this time interval do not stem from study period for Study I, but from the year after. The police data are not referable to single patient level as no civil registration numbers are collected at police 112 call centres.

Accuracy of patient triage

Emergency level A callers suffered the greatest risk of being admitted to a hospital in our study, and a clear trend towards a lower admission risk with lower levels of emergency was observed. In a Canadian study, Blanchard et al. reported that 32.4% of low-emergency patients were admitted to the hospital as compared with 39.5% of high-emergency level patients. This trend lies in the same range as the trend seen in our findings.(108). A similar relationship with emergency level was observed concerning risk of death. The case fatality risk in our study was significantly higher for emergency level A callers than for lower emergency levels. Kuisma et al. reported a similar trend in Finland with a case fatality risk of 5.2% for emergency level A patients, 1.1% for level B, 0.1% for level C and 0.03% for level D patients.(47)

6.2.2 Study II

The main focus in EMD is to secure immediate help for life-threatening conditions, and missing identification of a life- threatening condition is the main risk and represents serious undertriage. Study I overall confirmed adequate risk assessment by showing decreasing case fatality rate with decreasing level of emergency. However, early deaths among the patients assessed to belong to lower levels of emergency than the highest, A, might represent failure of identification of life-threatening conditions. This was investigated in Study II by audit of deaths to assess preventability at the EMD among 112 patients with emergency levels lower than A. In order to achieve a minimum of 100 deaths, we extended the data collection period from 6 months in Study I to 18 months in Study II. Most studies on preventable deaths focus on in-hospital treatment and give only little attention to the prehospital on-scene care and en-route care. We identified only one previous study that investigated the preventability of early death after a 112 call as a secondary outcome. In lower-priority groups, Kuisma et al. reported 1.3% preventable deaths, 32.9% potentially avoidable deaths and 65.8% non-preventable deaths.(47) These findings must raise concern in comparison with the conclusions from our study concerning the preventability of death. Audit studies utilising similar methods and outcome measures concerning early mortality related to emergency departments have also been conducted. Thus, Lu et al. conducted a chart review of deaths occurring within 24 hours after admission to a ward from the emergency department and reported that 25.8% of early deaths were preventable.(66) O`Connor et al. conducted a study in an Australian emergency department. Comparing patient charts with autopsy findings, they found that 7% of deaths within the emergency department were potentially preventable.(55) In an audit study of deaths occurring within 7 days of admission to the emergency department, Nafsi et al. reported that 3.15% were definitely preventable and 9.46% where possibly or probably preventable early deaths.(61) Saltzherr et al. conducted an audit study about the preventability of early death of trauma patients attending a Dutch trauma centre. They reported that 2% of the deaths were preventable and 27% were classified as potentially preventable.(62) A number of other audit studies concerning trauma patients and preventability of trauma centre-related deaths have been conducted.(54, 56-58, 65) They reported preventability proportions between 2.8% and 31.4% and potential preventability proportions between 5.9% and 38%.

Compared with the above summarised audit studies, our result of zero definitively preventable deaths is quite impressive and indicates a high level of safety in the new Danish EMD system. The longer patient contact in an emergency department or a trauma centre admission than in a short telephone interview should be taken into consideration when making this comparison.

An important finding in our study was that 13 of 18 potentially preventable deaths were associated with non-compliance with the dispatch protocol. This is in accordance with other studies of a similar EMD system. In a Norwegian study, Ellensen et al. reported that the Norwegian criteria-based dispatch protocol was used on average in only 75% of emergency calls. Lorem et al. reported, also from Norway, that 89% of dispatchers used the CBD protocol with deviations from the protocol in 33% of calls included in the study.(10, 53)

6.2.3 Study III

112 calls include calls from patients with chronic diseases with acute exacerbation or new symptoms or injuries; and in our Study I, almost one fifth called 112 more than once during a 6-month period. It may be important to obtain information on previous hospitalisation in the assessment of the chief complaint presented during the 112 call. In Study III, we investigated previous hospitalisation´s (plus age and sex) impact on adverse outcomes, among a group of suspected time-critical conditions, the FHQ of possible cardiac arrest, chest pain, breathing difficulty, possible stroke and possible severe trauma. We found that almost half of these patients had diagnoses from previous hospital admissions. No other studies known to the authors have added demographic factors *and* past hospitalisation history to the EMD process. One study by Hettinger et al. looked at age and sex (and MPDS) in relation to emergency department outcome.(74) They found no association between sex and adverse outcomes (death or admission from emergency room to hospital), but they reported an increased risk of adverse outcomes with increasing age. Adding various initiatives to existing dispatch systems in order to improve performance has been attempted in several studies. In an Austrian study of an MPDS-operated EMD system, Weiser et al. reported a shortening of the EMD response interval from a median 198 seconds to a median of 143 seconds when call-takers were allowed to divert from the strict MPDS algorithm and dispatch an ambulance immediately upon suspicion of a cardiac arrest.(84) Clawson et al. did not reproduce these findings in a US study of MPDS. They found no difference in accuracy comparing strict algorithm adherence with overriding the MPDS recommendations.(82) A German study of a no-protocol EMD system by Krebes et al. reported a sensitivity of 52.3% and a specificity of 0.97% for detection of stroke after implementation

of a dispatcher algorithm for detection of stroke.(71) In a Japanese study from a local dispatch protocol-operated EMD system where an algorithm was constructed to assess life threat risk in emergency calls, Oshige et al. reported a sensitivity of 80.2% and a specificity of 96.0%.(68) No area under receiver operating curve was presented, but it must be acceptable considering the sensitivity and specificity reported. Gijsenbergh et al. attempted to increase the accuracy of dispatch by introducing training sessions in a Belgian EMCC, which yielded a decrease in undertriage to a specialised prehospital intensive care unit from 64% to 40%. In summary, various approaches to improvement of dispatch exist and a combination of methods may be a way of the future.

Risk prediction tools exist in various settings of the healthcare system. Many published studies on performance of risk prediction tools in acute settings use survival at discharge or death at 14-30 days after initial assessment as an outcome measure.(86, 87, 89-91) They reported areas under the receiver operating curve between 0.75 and 0.84, which in general was a better discriminative ability than achieved by us concerning very early mortality (day zero and one). Other risk prediction tools like the Euroscore, the Apache II and the Simplified Acute Physiology Score II (SAPS II) score offer AUCs from 0.79 to 0.88, but they do not attempt to predict an outcome as close to onset of symptoms as we do. [(109-111)] Concerning 30-day mortality, though, our results are quite compatible with those presented by others. In triage at the EMCC, it is important to know if deciding to let the patient wait more than ten minutes for the ambulance is associated with a significantly increased risk of an adverse outcome. In this respect, 30-day mortality is not as relevant an outcome measure as same-day death or death the day after because the patient's prognosis is influenced by many factors other than EMD. Two studies use outcome measures closer in time to the initial assessment and they show AUCs of 0.77-0.80, which is closer to our day-zero and day-one findings.(85, 88) All of the above-mentioned studies use risk prediction models that include vital signs or findings that are only accessible through hands-on measurements or examination of the patient, which is not feasible through a telephone interview.

Not all diagnosis groups from previous hospitalisations were associated with an increased risk of adverse events. In fact, a history of myocardial infarction or cerebrovascular disease was associated with a statistically significantly decreased risk of early death in our study. This may partly be explained by the fact that patients with these diseases receive lifelong antiplatelet treatment, which reduces the risk of future infarctions. A study furthermore suggests that the survivors of the initial acute phase of a myocardial infarction live longer than the background population. (112)

7. Conclusions

7.1 Study I

Emergency level A and B are the most frequently used assessments of 112 calls in Danish EMD. Using case fatality and hospital admission risks as indicators of case severity, the new Danish criteria-based dispatch system seems to triage patients with high risk of admission and death to the highest level of emergency.

7.2 Study II

Among non-high acuity 112 callers, an expert audit panel identified no definitively preventable early deaths. A small proportion of early deaths among non-high-acuity 112 callers were assessed as potentially preventable by the independent audit panel. A better alignment with the dispatch protocol may be a way of further improving safety of the dispatching process.

7.3 Study III

Diagnoses from prior hospitalisations are prevalent among FHQ 112 callers. Age, sex and a wide variety of hospital discharge diagnoses from prior hospitalisations are associated with an increased short-term adverse outcome for these patients. As part of a tool for predicting outcome among 112 callers, age sex and hospitalization history has limited impact on the system’s performance, but it may prove useful for subgroups.

8. Perspectives

The investigations presented in this dissertation add to the existing literature with respect to several important aspects of EMD. First, we have demonstrated that CBD, in general, triage callers according to severity levels matching severity of their underlying condition. The high proportion of "unclear problems" reported has resulted in an increased focus on more meticulous questioning in order to assign a more precise criterion of chief complaint group to callers. The results concerning the EMD response interval have resulted in the intent, that all emergency level A responses should be dispatched within 90 seconds, something that may become a national requirement. Future studies concerning the overall accuracy of dispatch and accuracy in subgroups will be able to benefit from two imminent upcoming technological advances: the implementation of an electronic prehospital patient chart system and the implementation of a new dispatch software (in four of five Danish regions). These two systems will limit the amount of missing data and they will furthermore allow for large studies utilising vital sign data collected on-scene for all patients. Calls assessed as emergency level E constitute a substantial limitation in our knowledge about EMD. It must be a priority in future studies to investigate this group of patients, preferably in a study design using prospectively collected data in order to secure completeness of data.

Second, we have demonstrated that serious undertriage in terms of preventable deaths is very limited in Danish EMD. In this respect, the system can be regarded as safe. More exact adherence to the dispatch protocol is a way of upholding and improving safety. We have not investigated the impact of call-taker communication skills. This is an unexplored and important topic for future EMD-related research. We have demonstrated that the use of voice-log recordings in Danish EMD is feasible, and the use of voice-log may be an important tool in future communication-related EMD research.

Third, we have demonstrated that in some categories of 112 callers, the use of demographic information and information about past hospitalisation history can be useful for identifying callers suffering from severe injury and illness. Such information could be valuable when deciding if specialised physician-manned units should be allocated to these callers. This aspect of EMD needs further investigation. An obvious starting point would be to explore exactly which diagnoses are strong predictors of an adverse outcome among chest pain and trauma patients. Further investigations should not only be restricted to the FHQ, but should also embrace other major chief complaint categories. If adding demographic factors and previous hospital discharge diagnoses shows promising results in future studies, it could be worth implementing such information into a computer-based risk assessment tool at the EMCC. All countries with reliable civil registration systems and complete health registries, such as the Scandinavian countries, among others, are in an ideal position to implement such a system.

9. Summary in English

Emergency Medical Dispatch (EMD) is triage and assessment of health-related calls to the 112 emergency telephone number and dispatch of ambulances. EMD as the first link in the chain of survival plays a key role for patient outcome, but research into EMD is scarce and has only recently gained momentum. In May 2011, a new nationwide EMD system was implemented in Danish healthcare. Until mid-2011, all calls to the joint 112 emergency telephone number in Denmark were handled by the police or fire brigade. Emergency Medical Communication Centres (EMCCs) have been established, and 112 calls concerning illness and injury are now redirected to an EMCC. The EMCCs are staffed with nurses, paramedics and doctors, and callers are categorised into five (A-E) levels of emergency according to a criteria-based dispatch protocol, the Danish Index for Emergency Care.

This dissertation is based on three studies concerning the new EMD system from mid-2011 through 2012. Data for all three studies were collected from three of the five regional Danish EMCCs, Central, Southern and Capital, covering 75% of the Danish population and from national population-based administrative and medical registries. Study 2 also involved information from individual patients' medical records.

The aims of this dissertation were to (1) investigate the newly implemented EMD system in Denmark and to assess the accuracy of the triage of 112 calls according to the severity of the caller's condition; (2) examine for preventability of same-day deaths among callers not assessed as belonging to the most urgent category; and (3), among callers with potentially time-critical conditions, examine a possible association between age, sex and hospitalisation history and short-term adverse outcomes. Furthermore, the aim was to investigate if this possible association was useful when attempting to predict the caller's outcome.

In Study I, we found that 51.4% of 67,135 calls were assessed as emergency level A, 46.3% were assessed as level B and 2.3% as levels C and D. The proportion of emergency level A callers admitted

to hospital was 64.4%, and admission declined statistically significantly with decreasing levels of emergency (p<0.001). In Study II, we found 152 callers who were not assessed as being among the most urgent callers, but who died on the same day as the corresponding 112 call was made. None of the deaths were considered preventable by an external expert panel. Of the included cases, 18 (11.8%) were considered potentially preventable by the reviewers if the EMCC had assessed the 112 call as a higher emergency level call. In 13 of the potentially preventable deaths, lack of or incorrect use of the Danish Index was a common characteristic. A total of 134 (88.2%) fatalities were considered non-preventable by reviewers. In Study III, we included a cohort of 59,943 potentially time-critical patients. Age 30-59 (OR 3.59 [2.88-4.47]), male sex (OR 1.37 [1.28-1.47]), and the hospitalisation history categories nutritional deficiencies (OR 2.07 [1.47-2.92]), severe chronic liver disease (OR 2.02 [1.57-2.59]) and metastatic solid tumour (OR 1.95 [1.61-2.37]) had the largest adjusted ORs of death same day or the day after a 112 call. Discrimination with an area under the receiver operating curve of 0.74 and 0.73 was found for trauma patients and chest pain patients, respectively, regarding the outcome, death same or the day after the 112 call.

In conclusion, the work presented in this dissertation shows that the Danish EMD system in general triages callers according to the severity of their condition. Deaths in the lower emergency categories due to factors preventable at the EMCC are very few. Age, sex and a variety of hospital discharge diagnoses from previous hospitalisations are associated with an increased risk of short-term adverse outcomes and have a possible place in future risk assessment of 112 callers.

10. Summary in Danish / dansk resumé

Triagering og hastegradsvurdering af 112-opkald har stor betydning for overlevelse og forløbet for potentielt livstruende akut syge og tilskadekomne. Alligevel er forskning inden for dette område kun sparsom og er først de senere år blevet fremhævet som vigtig. I maj 2011 blev triagering og hastegradsvurdering af 112-opkald for første gang en ny opgave i det danske sundhedsvæsen. Vurdering af hastegrad af 112-opkald og disponering af den præhospitale indsats foretages nu på landets fem Akut Medicinsk Koordination (AMK)-vagtcentraler. Indtil for tre år siden vurderede politiet størstedelen af alle 112 opkald, herunder også hvilken hjælp der skulle tilbydes syge og tilskadekomne. 112-opkald, der omhandler sygdom og tilskadekomst, omstilles nu til en AMK-vagtcentral, hvor sygeplejersker og reddere superviseret af læger vurderer opkaldene. Hastegradsvurderingen foretages ved hjælp af en kriteriebaseret protokol, Dansk Indeks for Akuthjælp, der bl.a. inddeler i fem hastegrader A-E, hvor A er den mest hastende.

Denne afhandling er baseret på tre studier blandt patienter (eller andre) som har ringet 112 i perioden medio 2011 til udgangen af 2012. Information er indhentet fra AMK-vagtcentralerne i Region Midtjylland, Region Syddanmark og Region Hovedstaden, samt fra centrale administrative registre (Studium 1-3). Til studium 2 er der endvidere anvendt oplysninger fra patientjournaler. Formålet med denne afhandling er: (1) at undersøge de nye danske AMK-vagtcentraler og om patienterne triageres i henhold til alvorligheden af deres underliggende tilstand, (2) at karakterisere dødsfald, hvor død indtraf inden for 24 timer blandt de patienter, der blev vurderet som mindre hastende og identificere evt. undgåelige dødsfald, (3) i en gruppe af formodet tidskritiske patienter at undersøge sammenhængen mellem alvorlige udfald som død eller intensivindlæggelse og alder, køn og udskrivelses diagnoser fra tidligere hospitaliseringer. Endvidere var formålet at undersøge, om en sådan association kan anvendes til at forudsige, hvilke patienter der har størst risiko for et alvorligt udfald.

I studium I fandt vi, at 51,4% af 112 opkald, hvor der disponeredes en ambulance, kategoriseredes som hastegrad A, 46,3% som B og resten som C eller D (E ekskluderet). Indlæggelsesraten for hastegrad A var 64,4% og viste et statistisk signifikant (P<0,001) fald med faldende hastegrad. Blandt hastegrad A patienter døde 4,4% samme dag som 112-opkaldet, mens 0,4-0,0% døde i de lavere hastegrader. I studium II fandt vi 152 patienter, som døde samme dag, der blev ringet 112, men som ikke blev hastegradsvurderet blandt de mest hastende. Ifølge et eksternt ekspertpanel kunne ingen af disse dødsfald med stor sikkerhed være undgået, hvis pågældende AMK-vagtcentral havde vurderet anderledes. 18 dødsfald kunne potentielt være undgået, og 134 dødsfald kunne ikke være undgået. I studium 3 inkluderede vi 59,943 potentielt tidskritiske patienter. Stigende alder (odds ratio(OR) 3,59 [95% sikkerhedsinterval:2,88-4,47]) samt mandligt køn (OR 1,37 [1,28-1,47]) viste sig at være associeret med forøget risiko for død og/eller intensiv indlæggelse umiddelbart i efterforløbet at et 112-opkald. Endvidere viste store grupper af diagnoser fra tidligere hospitaliseringer sig også at være associeret med forøget risiko for tidlig død og/eller intensiv indlæggelse i tidsrummet efter et 112-opkald. Til eksempel viste ernæringsmæssige mangeltilstande (OR 2,07 [1,47-2,92]), alvorlig kronisk leversygdom (OR 2,02 [1,57-2,59]) og metastaserende cancer (OR 1,95 [1,61-2,37]) størst risiko for fatale udfald. De påviste sammenhænge viste størst evne til forudsigelse af udfald blandt 112 indringere med brystsmerter og alvorlige fysiske traumer.

Samlet viser studierne, at der overordnet er god sammenhæng mellem alvorligheden af patientens tilstand og den hastegrad, de tildeles. Alvorlig undertriage i form dødsfald som følge af uhensigtsmæssig hastegradsvurdering ser ud til at være yderst minimal. Alder, køn og visse typer af diagnoser fra tidligere hospitaliseringer er associeret med alvorlige udfald som død og intensivindlæggelse i umiddelbar forlængelse af et 112 opkald og kan have en plads i fremtidig vurdering af 112 opkald.

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12 Appendix

1. Danish Index chief complaint groups defining the First Hour Quintet.

FHQ	Danish Index chief complaint groups defining the First Hour Quintet. (Emergency level) (Index code)		
Cardiac arrest	Unconscious adult (A)(01.00)	Unconscious child (A) (02.xx)	Possible death or Sudden Infant Death (A)(25.xx)
Chest pain	Chest pain, heart disease (A & B)(10.xx)		
Stroke	Impaired consciousness, paralysis (A & B)(26.xx)		
Breathing difficulties	Difficulty in breathing (A & B) (28.xx)		
Severe trauma	Accident, not traffic related) (A) (31.xx)	Wound, fracture, injury (A) (32.xx)	Traffic accident (A) (33.xx) & Violence (A) (35.xx)

Xx: All numbers in specified section

2. Translations of the Iezzoni Chronic Conditions ICD-9 codes to ICD-10 codes.

	ICD-9 diagnosis codes		**ICD-10 diagnosis codes**
	Cancer with a Poor Prognosis		**Cancer with a Poor Prognosis**
1500	Malignant neoplasm of cervical esophagus	DC153	Malignant neoplasm upper third of oesophagus
1501	Malignant neoplasm of thoracic esophagus	DC154	Malignant neoplasm middle third of oesophagus
1502	Malignant neoplasm of abdominal esophagus	DC155	Malignant neoplasm lower third of oesophagus
1503	Malignant neoplasm of upper third of esophagus	DC153	Malignant neoplasm upper third of oesophagus
1504	Malignant neoplasm of middle third of esophagus	DC154	Malignant neoplasm middle third of oesophagus
1505	Malignant neoplasm of lower third of esophagus	DC155	Malignant neoplasm lower third of oesophagus
1508	Malignant neoplasm of other specified part	DC158	Malignant neoplasm overlapping lesion of oesophagus
1509	Malignant neoplasm of esophagus, unspecified	DC159	Malignant neoplasm Oesophagus, unspecified
1510	Malignant neoplasm of cardia	DC160	Malignant neoplasm of stomach, Cardia
1511	Malignant neoplasm of pylorus	DC164	Malignant neoplasm of stomach, Pylorus
1512	Malignant neoplasm of pyloric antrum	DC163	Malignant neoplasm of stomach, Pyloric antrum
1513	Malignant neoplasm of fundus of stomach	DC161	Fundus of stomach
1514	Malignant neoplasm of body of stomach	DC168	Overlapping lesion of stomach
1515	Malignant neoplasm of lesser curvature, unspecified	DC165	Lesser curvature of stomach, unspecified
1516	Malignant neoplasm of greater curvature, unspecified	DC166	Greater curvature of stomach, unspecified
1518	Malignant neoplasm of other specified sites of stomach	DC168	Overlapping lesion of stomach
1519	Malignant neoplasm of stomach, unspecified	DC169	Stomach, unspecified
1550	Malignant neoplasm of liver, primary	DC220	Malignant neoplasm of liver and intrahepatic bile ducts, Liver cell carcinoma
1551	Malignant neoplasm of intrahepatic bile ducts	DC221	Intrahepatic bile duct carcinoma
1552	Malignant neoplasm of liver, not specified as primary or secondary	DC227 , DC222, DC223, DC224, DC229	Other specified carcinomas of liver, Hepatoblastoma, Angiosarcoma of liver; Other sarcomas of liver; Malignant neoplasm of liver, unspecified
1570	Malignant neoplasm of head of pancreas	DC250	Malignant neoplasm of pancreas, Head of pancreas
1571	Malignant neoplasm of body of pancreas	DC251	Malignant neoplasm of pancreas, Body of pancreas
1572	Malignant neoplasm of tail of pancreas	DC252	Malignant neoplasm of pancreas, Tail of pancreas

1573	Malignant neoplasm of pancreatic duct	DC253	Malignant neoplasm of pancreas, Pancreatic duct
1574	Malignant neoplasm of islets of Langerhans	DC254	Malignant neoplasm of pancreas, Endocrine pancreas
1578	Malignant neoplasm of other specified sites of pancreas	DC257	Malignant neoplasm of pancreas, Other parts of pancreas
1579	Malignant neoplasm of pancreas, part unspecified	DC259, DC258	Malignant neoplasm of pancreas, unspecified and Overlapping lesion of pancreaslokalisationer
1580	Malignant neoplasm of retroperitoneum	DC480	Malignant neoplasm of retroperitoneum and peritoneum, Retroperitoneum
1588	Malignant neoplasm of specified parts of peritoneum	DC481	Malignant neoplasm of retroperitoneum and peritoneum, Specified parts of peritoneum
1589	Malignant neoplasm of peritoneum, unspecified	DC482, DC488	Malignant neoplasm of retroperitoneum and peritoneum, Peritoneum, unspecified; Overlapping lesion of retroperitoneum and peritoneum
1620	Malignant neoplasm of trachea	DC339	Malignant neoplasm of trachea
1622	Malignant neoplasm of main bronchus	DC340	Malignant neoplasm of bronchus and lung, Main bronchus
1623	Malignant neoplasm of upper lobe, bronchus or lung	DC341	Upper lobe, bronchus or lung
1624	Malignant neoplasm of middle lobe, bronchus or lung	DC342	Middle lobe, bronchus or lung
1625	Malignant neoplasm of lower lobe, bronchus or lung	DC343	Lower lobe, bronchus or lung
1628	Malignant neoplasm of other parts of bronchus or lung	DC348	Overlapping lesion of bronchus and lung
1629	Malignant neoplasm of bronchus and lung, unspecified	DC349	Bronchus or lung, unspecified
1630	Malignant neoplasm of parietal pleura	DC450	Malignant neoplasms of mesothelial and soft tissue, Mesothelioma
1631	Malignant neoplasm of visceral pleura	DC450	Malignant neoplasms of mesothelial and soft tissue, Mesothelioma
1638	Malignant neoplasm of other specified sites of pleura	DC450	Malignant neoplasms of mesothelial and soft tissue, Mesothelioma
1639	Malignant neoplasm of pleura, unspecified	DC384	Malignant neoplasm of heart, mediastinum and pleura, Pleura
1830	Malignant neoplasm of ovary	DC569	Malignant neoplasm of ovary
1832	Malignant neoplasm of fallopian tube	DC570	Malignant neoplasm of Fallopian tube
1833	Malignant neoplasm of broad ligament	DC571	Malignant neoplasm of Broad ligament
1834	Malignant neoplasm of parametrium	DC573	Malignant neoplasm of Parametrium
1835	Malignant neoplasm of round ligament	DC572	Malignant neoplasm of Round ligament
1838	Malignant neoplasm of other specified sites of uterine adnexa	DC577	Malignant neoplasm of Other specified female genital organs
1839	Malignant neoplasm of uterine adnexa, unspecified	DC579	Malignant neoplasm of Female genital organ, unspecified
1910	Malignant neoplasm of cerebrum, except lobes and ventricles	DC710	Malignant neoplasm of brain, Cerebrum, except lobes and ventricles
	1911 Malignant neoplasm of frontal lobe	DC711	Malignant neoplasm of brain, Frontal lobe
1912	Malignant neoplasm of temporal lobe	DC712	Malignant neoplasm of brain, Temporal lobe
1913	Malignant neoplasm of parietal lobe	DC713	Malignant neoplasm of brain, Parietal lobe
1914	Malignant neoplasm of occipital lobe	DC714	Malignant neoplasm of brain, Occipital lobe
1915	Malignant neoplasm of ventricles	DC715	Malignant neoplasm of brain, Cerebral ventricle
1916	Malignant neoplasm of cerebellum not otherwise specified	DC716	Malignant neoplasm of brain, Cerebellum
1917	Malignant neoplasm of brain stem	DC717	Malignant neoplasm of brain, Brain stem
1918	Malignant neoplasm of other parts of brain	DC718	Malignant neoplasm of brain, Overlapping lesion of brain
1919	Malignant neoplasm of brain, unspecified	DC719	Malignant neoplasm of brain, Brain, unspecified
20400	Acute lymphoid leukemia without mention of	DC910-	Covered by Lymphoid leukemia

	remission	DC919	
20410	Chronic lymphoid leukemia without mention of remission	DC910-DC919	Covered by Lymphoid leukemia
20420	Subacute lymphoid leukemia without mention of remission	DC910-DC919	Covered by Lymphoid leukemia
20480	Other lymphoid leukemia without mention of remission	DC910-DC919	Covered by Lymphoid leukemia
20490	Unspecified lymphoid leukemia without mention of remission	DC910-DC919	Covered by Lymphoid leukemia
20500	Acute myeloid leukemia without mention of remission	DC920-DC929	Covered by Myeloid leukemia
20510	Chronic myeloid leukemia without mention of remission	DC920-DC929	Covered by Myeloid leukemia
20520	Subacute myeloid leukemia without mention of remission	DC920-DC929	Covered by Myeloid leukemia
20530	Myeloid sarcoma without mention of remission	DC920-DC929	Covered by Myeloid leukemia
20580	Other myeloid leukemia without mention of remission	DC920-DC929	Covered by Myeloid leukemia
20590	Unspecified myeloid leukemia without mention of remission	DC920-DC929	Covered by Myeloid leukemia
20600	Acute monocytic leukemia without mention of remission	DC930	Acute monoblastic/monocytic leukaemia
20610	Chronic monocytic leukemia without mention of remission	DC931	Chronic myelomonocytic leukaemia
20620	Subacute monocytic leukemia without mention of remission	DC930	Acute monoblastic/monocytic leukaemia
20680	Other monocytic leukemia without mention of remission	DC937	Other monocytic leukaemia
20690	Unspecified monocytic leukemia without mention of remission	DC939	Monocytic leukaemia, unspecified
20700	Acute erythremia and erythroleukemia without mention of remission	DC940	Acute erythroid leukaemia, Acute myeloid leukaemia M6 (a)(b)
20710	Chronic erythremia without mention of remission	DC940A	Erythroleukaemia
20720	Megakaryocytic leukemia without mention of remission	DC942	Acute megakaryoblastic leukaemia
20780	Other specified leukemia without mention of remission	DC947	Other specified leukaemias
20800	Acute leukemia of unspecified cell type without mention of remission	DC950	Acute leukaemia of unspecified cell type
20810	Chronic leukemia of unspecified cell type without mention of remission	DC951	Chronic leukaemia of unspecified cell type
20820	Subacute leukemia of unspecified cell type without mention of remission		
20880	Other leukemia of unspecified cell type without mention of remission	DC957	Other leukaemia of unspecified cell type
20890	Unspecified leukemia without mention of remission	DC959	Leukaemia, unspecified
	Metastatic Cancer		**Metastatic Cancer**
1960	Secondary and unspecified malignant neoplasm of lymph nodes of head, face, and neck	DC770	Secondary and unspecified malignant neoplasm of lymph nodes of head, face and neck
1961	Secondary and unspecified malignant neoplasm of intrathoracic lymph nodes	DC771 Secondary and unspecified malignant neoplasm of Intrathoracic lymph nodes	
1962	Secondary and unspecified malignant neoplasm of intra-abdominal lymph nodes	DC772 Secondary and unspecified malignant neoplasm of Intra-abdominal lymph nodes	
1963	Secondary and unspecified malignant neoplasm of lymph nodes of axilla and upper limb	DC773	Secondary and unspecified malignant neoplasm of Axillary and upper limb lymph nodes
1965	Secondary and unspecified malignant neoplasm of lymph nodes of inguinal region and lower limb	DC774	Secondary and unspecified malignant neoplasm of Inguinal and lower limb lymph nodes
1966	Secondary and unspecified malignant neoplasm of intrapelvic lymph nodes	DC775	Secondary and unspecified malignant neoplasm of Intrapelvic lymph nodes
1968	Secondary and unspecified malignant neoplasm of lymph nodes of multiple sites	DC778	Secondary and unspecified malignant neoplasm of lymph nodes of multiple regions

1969	Secondary and unspecified malignant neoplasm of lymph nodes, site unspecified	DC779	Secondary and unspecified malignant neoplasm of lymph node, unspecified
1970	Secondary malignant neoplasm of lung	DC780	Secondary malignant neoplasm of lung
1971	Secondary malignant neoplasm of mediastinum	DC781	Secondary malignant neoplasm of mediastinum
1972	Secondary malignant neoplasm of pleura	DC782	Secondary malignant neoplasm of pleura
1973	Secondary malignant neoplasm of other respiratory organs	DC783	Secondary malignant neoplasm of other and unspecified respiratory organs
1974	Secondary malignant neoplasm of small intestine, including duodenum	DC784	Secondary malignant neoplasm of small intestine
1975	Secondary malignant neoplasm of large intestine and rectum	DC785	Secondary malignant neoplasm of large intestine and rectum
1976	Secondary malignant neoplasm of retroperitoneum and peritoneum	DC786	Secondary malignant neoplasm of retroperitoneum and peritoneum
1977	Secondary malignant neoplasm of liver, specified as secondary	DC787	Secondary malignant neoplasm of liver and intrahepatic bile duct
1978	Secondary malignant neoplasm of other digestive organs and spleen	DC788	Secondary malignant neoplasm of other and unspecified digestive organs
1980	Secondary malignant neoplasm of kidney	DC790	Secondary malignant neoplasm of kidney and renal pelvis
1981	Secondary malignant neoplasm of other urinary organs	DC791	Secondary malignant neoplasm of bladder and other and unspecified urinary organs
1982	Secondary malignant neoplasm of skin	DC792	Secondary malignant neoplasm of skin
1983	Secondary malignant neoplasm of skin	DC793	Secondary malignant neoplasm of brain and cerebral meninges
1984	Secondary malignant neoplasm of other parts of nervous system	DC794	Secondary malignant neoplasm of other and unspecified parts of nervous system
1985	Secondary malignant neoplasm of bone and bone marrow	DC795	Secondary malignant neoplasm of bone and bone marrow
1986	Secondary malignant neoplasm of ovary	DC796	Secondary malignant neoplasm of ovary
1987	Secondary malignant neoplasm of adrenal gland	DC797	Secondary malignant neoplasm of adrenal gland
19881	Secondary malignant neoplasm of breast		*(kan ikke findes)
19882	Secondary malignant neoplasm of genital organs		*(kan ikke findes)
19889	Secondary malignant neoplasm of other	DC798	Secondary malignant neoplasm of other specified sites
1990	Malignant neoplasm without specification of site: disseminated	DC809	Malignant neoplasm, unspecified
1991	Malignant neoplasm without specification of site: other	C80.0	Malignant neoplasm, primary site unknown, so stated
	Acquired Immunodeficiency Syndrome (AIDS)		**Acquired Immunodeficiency Syndrome (AIDS)**
0420	HIV infection with specified infection	DB201-DB207	Human immunodeficiency virus [HIV] disease resulting in infectious and parasitic diseases
0421	HIV infection causing other specified infections	DB208	HIV disease resulting in other infectious and parasitic diseases
0422	HIV infection with specified malignant neoplasms	DB210 - DB213	Human immunodeficiency virus [HIV] disease resulting in malignant neoplasms
0429	HIV infection with AIDS, unspecified	DB24	Unspecified human immunodeficiency virus [HIV] disease
0431	HIV infection causing specified diseases of the CNS	DB201-DB207	Human immunodeficiency virus [HIV] disease resulting in infectious and parasitic diseases
0432	HIV infection causing other disorders involving the immune mechanism	DB232	HIV disease resulting in haematological and immunological abnormalities, not elsewhere classified
0433	HIV infection causing other specified conditions	DB22	Human immunodeficiency virus [HIV] disease resulting in other specified diseases
0440	HIV infection causing specified acute infections	DB209	HIV disease resulting in unspecified infectious or parasitic disease
1363	Pneumocystosis	DB206	HIV disease resulting in Pneumocystis jirovecii pneumonia
1760	Kaposi's sarcoma skin	DB210	HIV disease resulting in Kaposi sarcoma
1761	Kaposi's sarcoma soft tissue		HIV disease resulting in Kaposi sarcoma
1762	Kaposi's sarcoma palate		HIV disease resulting in Kaposi sarcoma

1763	Kaposi's sarcoma gastrointestinal sites		HIV disease resulting in Kaposi sarcoma
1764	Kaposi's sarcoma lung		HIV disease resulting in Kaposi sarcoma
1765	Kaposi's sarcoma lymph nodes		HIV disease resulting in Kaposi sarcoma
1768	Kaposi's sarcoma other specified sites		HIV disease resulting in Kaposi sarcoma
1769	Kaposi's sarcoma unspecified		HIV disease resulting in Kaposi sarcoma
	Chronic Pulmonary Disease		**Chronic Pulmonary Disease**
4911	Mucopurulent chronic bronchitis	DJ40-DJ47	Covered by Chronic lower respiratory diseases
49120	Obstructive chronic bronchitis without mention of acute exacerbation	DJ40-DJ47	Covered by Chronic lower respiratory diseases
49121	Obstructive chronic bronchitis with acute exacerbation	DJ40-DJ47	Covered by Chronic lower respiratory diseases
4918	Other chronic bronchitis	DJ40-DJ47	Covered by Chronic lower respiratory diseases
4919	Unspecified chronic bronchitis	DJ40-DJ47	Covered by Chronic lower respiratory diseases
4920	Emphysematous bleb	DJ40-DJ47	Covered by Chronic lower respiratory diseases
4928	Other emphysema	DJ40-DJ47	Covered by Chronic lower respiratory diseases
49310	Intrinsic asthma without mention of status asthmaticus	DJ40-DJ47	Covered by Chronic lower respiratory diseases
49311	Intrinsic asthma with status asthmaticus	DJ40-DJ47	Covered by Chronic lower respiratory diseases
49390	Asthma, unspecified without mention of status asthmaticus	DJ40-DJ47	Covered by Chronic lower respiratory diseases
49391	Asthma, unspecified with status asthmaticus	DJ40-DJ47	Covered by Chronic lower respiratory diseases
494	Bronchiectasis	DJ40-DJ47	Covered by Chronic lower respiratory diseases
496	Chronic airway obstruction, not elsewhere classified	DJ40-DJ47	Covered by Chronic lower respiratory diseases
501	Asbestosis	DJ40-DJ47	Covered by Chronic lower respiratory diseases
5064	Chronic respiratory conditions due to fumes and vapors	DJ40-DJ47	Covered by Chronic lower respiratory diseases
515	Pulmonary fibrosis	DJ40-DJ47	Covered by Chronic lower respiratory diseases
	Coronary Artery Disease		**Coronary Artery Disease**. (Covered by the four diagnostic groups listed below)
4111	Intermediate coronary syndrome	DI20.0-9	Angina pectoris
4118	Other acute and subacute forms of ischemic heart disease	DI23.0-8	Certain current complications following acute myocardial infarction
41181	Acute ischemic heart disease without myocardial infarction	DI24.0-9	Other acute ischaemic heart diseases
41189	Coronary insufficiency, subendocardial ischemia	DI25.0-9	Chronic ischaemic heart disease
412	Old myocardial infarction		
4130	Angina decubitus		
4139	Other and unspecified angina pectoris		
4140	Coronary atherosclerosis		
4148	Other specified forms of chronic ischemic heart disease		
4149	Chronic ischemic heart disease, unspecified		
	Congestive Heart Failure		**Congestive Heart Failure**
4280	Congestive heart failure	DI500	Congestive heart failure
4281	Left heart failure	DI501	Left ventricular failure
4289	Heart failure, unspecified	DI509	Heart failure, unspecified

40201	Malignant hypertensive heart disease with CHF	DI110	Hypertensive heart disease with (congestive) heart failure
40211	Benign hypertensive heart disease with CHF	DI110	Hypertensive heart disease with (congestive) heart failure
40291	Unspecified hypertensive heart disease with CHF	DI110	Hypertensive heart disease with (congestive) heart failure
39891	Rheumatic heart failure (congestive)	DI500	Congestive heart failure
40401	Malignant hypertensive heart and renal disease with CHF	DI130	Hypertensive heart and renal disease with (congestive) heart failure
40411	Benign hypertensive heart and renal disease with CHF	DI130	Hypertensive heart and renal disease with (congestive) heart failure
40413	Benign hypertensive heart and renal disease with CHF and renal failure	DI131	Hypertensive heart and renal disease with renal failure
40491	Unspecified hypertensive heart and renal disease with CHF	DI139	Hypertensive heart and renal disease, unspecified
40493	Unspecified hypertensive heart and renal disease with CHF and renal failure	DI132	Hypertensive heart and renal disease with both (congestive) heart failure and renal failure
	Peripheral Vascular Disease		**Peripheral Vascular Disease**
4400	Atherosclerosis of aorta	DI70.0-9	Covered by Atherosclerosis
4401	Atherosclerosis of renal artery	DI70.0-9	Covered by Atherosclerosis
44020	Atherosclerosis of arteries of the extremities, unspecified	DI70.0-9	Covered by Atherosclerosis
44021	Atherosclerosis of arteries of the extremities with intermittent claudication	DI70.0-9	Covered by Atherosclerosis
44022	Atherosclerosis of arteries of the extremities with rest pain	DI70.0-9	Covered by Atherosclerosis
44023	Atherosclerosis of arteries of the extremities with ulceration	DI70.0-9	Covered by Atherosclerosis
44024	Atherosclerosis of arteries of the extremities with gangrene	DI70.0-9	Covered by Atherosclerosis
4408	Atherosclerosis of other specified arteries	DI70.0-9	Covered by Atherosclerosis
4409	Generalized and unspecified atherosclerosis	DI70.0-9	Covered by Atherosclerosis
4410	Dissecting aortic aneurysm	DI710	Dissection of aorta [any part]
4411	Thoracic aortic aneurysm, ruptured	DI711	Thoracic aortic aneurysm, ruptured
4412	Thoracic aortic aneurysm without mention of rupture	DI712	Thoracic aortic aneurysm, without mention of rupture
4413	Abdominal aortic aneurysm, ruptured	DI713	Abdominal aortic aneurysm, ruptured
4414	Abdominal aortic aneurysm without mention of rupture	DI714	Abdominal aortic aneurysm, without mention of rupture
4415	Aortic aneurysm of unspecified site, ruptured	DI718	Aortic aneurysm of unspecified site, ruptured
4419	Aortic aneurysm of unspecified site without mention of rupture	DI719	Aortic aneurysm of unspecified site, without mention of rupture
4439	Peripheral vascular disease, unspecified	DI739	Peripheral vascular disease, unspecified
	Severe Chronic Liver Disease		**Severe Chronic Liver Disease**
5712	Alcoholic cirrhosis of liver	DK703	Alcoholic cirrhosis of liver
5715	Cirrhosis of liver without mention of alcohol	DK746	Other and unspecified cirrhosis of liver
5716	Biliary cirrhosis	DK743	Primary biliary cirrhosis
5723	Portal hypertension	DK766	Portal hypertension
	Diabetes with End Organ Damage		**Diabetes with End Organ Damage**
	The following fifth-digit subclassification is for use with category 250:		
0	Type II [Non-insulin dependent type][NIDDM type][Adult-onset type] or unspecified type, not stated as uncontrolled	DE10-DE14	Covered by Diabetes Mellitus(DM)

1	Type I [Insulin dependent type][IDDM type][Juvenile type], not stated as uncontrolled	DE10-DE14	Covered by DM
2	Type II [Non-insulin dependent type][NIDDM type][Adult-onset type], or unspecified type, uncontrolled	DE10-DE14	Covered by DM
3	Type I [Insulin dependent type][IDDM type][Juvenile type], uncontrolled	DE10-DE14	Covered by DM
2504(0,1, 2,3)	Diabetes with renal manifestations	DE10-DE14	Covered by DM
2505(0,1, 2,3)	Diabetes with ophthalmic manifestations	DE10-DE14	Covered by DM
2506(0,1, 2,3)	Diabetes with neurological manifestations	DE10-DE14	Covered by DM
2507(0,1, 2,3)	Diabetes with peripheral circulatory disorders	DE10-DE14	Covered by DM
2509(0,1, 2,3)	Diabetes with unspecified complication	DE10-DE14	Covered by DM
3572	Polyneuropathy in diabetes	DE10-DE14	Covered by DM
36641	Diabetic cataract	DE10-DE14	Covered by DM
36201	Background diabetic retinopathy	DE10-DE14	Covered by DM
36202	Proliferative diabetic retinopathy	DE10-DE14	Covered by DM
	Chronic Renal Failure		**Chronic Renal Failure**
40301	Malignant hypertensive renal disease with renal failure	DN181-9	Covered by Chronic Renal Failure
40311	Benign hypertensive renal disease with renal failure	DN181-9	Covered by Chronic Renal Failure
40391	Unspecified hypertensive renal disease with renal failure	DN181-9	Covered by Chronic Renal Failure
585	Chronic renal failure	DN181-9	Covered by Chronic Renal Failure
V451	Renal dialysis status	DN181-9	Covered by Chronic Renal Failure
V560	Aftercare involving intermittent extracorporeal dialysis	DN181-9	Covered by Chronic Renal Failure
V568	Aftercare involving intermittent other dialysis	DN181-9	Covered by Chronic Renal Failure
	Nutritional Deficiencies		**Nutritional Deficiencies; Malnutrition**
260	Kwashiorkor	DE40-47	Covered by Malnutrition
261	Nutritional marasmus	DE40-47	Covered by Malnutrition
262	Other severe protein-calorie malnutrition	DE40-47	Covered by Malnutrition
2630	Malnutrition of moderate degree	DE40-47	Covered by Malnutrition
2638	Other protein-calorie malnutrition	DE40-47	Covered by Malnutrition
2639	Unspecified protein-calorie malnutrition	DE40-47	Covered by Malnutrition
7834	Lack of expected normal physiological development	DE40-47	Covered by Malnutrition
7994	Cachexia	DR64	Cachexia
7830	Anorexia	DF500-9	Eating disorders
	Dementia		**Dementia**
2900	Senile dementia, uncomplicated	DF000-9, DF03	Dementia in Alzheimer disease; Unspecified dementia
29010	Presenile dementia, uncomplicated	DF000-9, DF03	Dementia in Alzheimer disease; Unspecified dementia
29011	Presenile dementia with delirium	DF000-9, DF03	Dementia in Alzheimer disease; Unspecified dementia

29012	Presenile dementia with delusional features	DF000-9, DF03	Dementia in Alzheimer disease; Unspecified dementia
29013	Presenile dementia with depressive features	DF000-9, DF03	Dementia in Alzheimer disease; Unspecified dementia
29020 s	Senile dementia with delusional feature	DF000-9, DF03	Dementia in Alzheimer disease; Unspecified dementia
29021	Senile dementia with depressive features	DF000-9, DF03	Dementia in Alzheimer disease; Unspecified dementia
29041	Arteriosclerotic dementia with delirium	DF000-9, DF03	Dementia in Alzheimer disease; Unspecified dementia
29042	Arteriosclerotic dementia with delusional features	DF000-9, DF03	Dementia in Alzheimer disease; Unspecified dementia
29043	Arteriosclerotic dementia with depressive features	DF000-9, DF03	Dementia in Alzheimer disease; Unspecified dementia
2908	Other specified senile psychotic conditions	DF000-9, DF03	Dementia in Alzheimer disease; Unspecified dementia
2909	Unspecified senile psychotic condition	DF000-9, DF03	Dementia in Alzheimer disease; Unspecified dementia
2940	Other organic psychotic conditions (chronic)	DF000-9, DF03	Dementia in Alzheimer disease; Unspecified dementia
2941	Dementia in conditions classified elsewhere	DF02.0-8	Dementia in other diseases classified elsewhere
2948	Other specified organic brain syndromes (chronic)	DF068	Other specified mental disorders due to brain damage and dysfunction and to physical disease
2949	Unspecified organic brain syndrome (chronic)	DF069	Unspecified mental disorder due to brain damage and dysfunction and to physical disease
3310	Alzheimer's disease	DG30.0-9	Alzheimer disease DG 30.0-9
3312	Senile degeneration of brain	DG311	Senile degeneration of brain, not elsewhere classified
797	Senility without mention of psychosis	DR549	Senility
2903	Senile dementia with delirium	DF051	Delirium superimposed on dementia
29040	Arteriosclerotic dementia, uncomplicated	DF010-9	Vascular dementia DF01.0-9
	Functional Impairment		**Functional Impairment**
7993	Debility, unspecified		Not included
438	Late effects of cerebrovascular disease	DI69.0-8	Sequelae of cerebrovascular disease
3420	Flaccid hemiplegia	DG810	Flaccid hemiplegia
3421	Spastic hemiplegia	DG811	Spastic hemiplegia
3429	Hemiplegia, unspecified	DG819	Hemiplegia, unspecified
3440	Quadriplegia	DG823, DG824	Flaccid tetraplegia; Spastic tetraplegia Spastisk tetraplegi
3441	Paraplegia	DG820, DG821	Flaccid paraplegia; Spastic paraplegia Spastisk paraplegi
3442	Diplegia of upper limbs	DG830	Diplegia of upper limbs
3443	Monoplegia of lower limb	DG831	Monoplegia of lower limb
3444	Monoplegia of upper limb	DG832	Monoplegia of upper limb
3445	Unspecified monoplegia	DG833	Monoplegia, unspecified
34481	Other specified paralytic syndromes, locked-in state	DG838	Other specified paralytic syndromes
34489	Other specified paralytic syndromes	DG838	Other specified paralytic syndromes
3449	Paralysis, unspecified	DG839	Paralytic syndrome, unspecified
34460	Cauda equina syndrome without mention of neurogenic bladder	DG834	Cauda equina syndrome
34461	Cauda equina syndrome with neurogenic bladder	DG834A	Neurogenic bladder due to cauda equina syndrome
V440	Tracheostomy	DZ930	Tracheostomy status
V441	Gastrostomy	DZ931	Gastrostomy status

V460	Aspirator	DZ990	Dependence on aspirator
V461	Dependence on respirator	DZ991	Dependence on respirator
V468	Other enabling machines	DZ998	Dependence on other enabling machines and devices

Study I

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Implementing a nationwide criteria-based emergency medical dispatch system: A register-based follow-up study

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Abstract

Background: A criteria-based nationwide Emergency Medical Dispatch (EMD) system was recently implemented in Denmark. We described the system and studied its ability to triage patients according to the severity of their condition by analysing hospital admission and case-fatality risks.

Methods: This was a register-based follow-up study of all 1-1-2 calls in a 6-month period that were triaged according to the Danish Index – the new criteria-based dispatch protocol. Danish Index data were linked with hospital and vital status data from national registries. Confidence intervals (95%) for proportions with binomial data were computed using exact methods. To test for trend the Wald test was used.

Results: Information on level of emergency according to the Danish Index rating was available for 67,135 patients who received ambulance service. Emergency level A (urgent cases) accounted for 51.4% (n = 34,489) of patients, emergency level B for 46.3% (n = 31,116), emergency level C for 2.1% (n = 1,391) and emergency level D for 0.2% (n = 139). For emergency level A, the median time from call receipt to ambulance dispatch was 2 min 1 s, and the median time to arrival was 6 min 11 s. Data concerning admission and case fatality was available for 55,270 patients. The hospital admission risk for emergency level A patients was 64.4% (95% CI = 63.8-64.9). There was a significant trend ($p < 0.001$) towards lower admission risks for patients with lower levels of emergency. The case fatality risk for emergency level A patients on the same day as the 1-1-2 call was 4.4% (95% CI = 4.1-4.6). The relative case-fatality risk among emergency level A patients compared to emergency level B–D patients was 14.3 (95% CI: 11.5-18.0).

Conclusion: The majority of patients were assessed as Danish Index emergency level A or B. Case fatality and hospital admission risks were substantially higher for emergency level A patients than for emergency level B–D patients. Thus, the newly implemented Danish criteria-based dispatch system seems to triage patients with high risk of admission and death to the highest level of emergency. Further studies are needed to determine the degree of over- and undertriage and prognostic factors.

Keywords: Emergency medical dispatch, Criteria-based dispatch, Emergency medical services, Case fatality risk, Implementation

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Background

Emergency medical dispatch (EMD) systems aim to match response resources with patient needs. However, the organization of EMD systems varies substantially across healthcare systems, and there is no consensus regarding the optimal organization [1]. Emergency medical service calls are typically handled by an emergency medical communication centre (EMCC), which assesses the urgency of the call in order to determine the priority level of the response. Depending on country or area, the EMCC can be staffed by lay-persons that have received some training or by firemen, paramedics, nurses and doctors. EMD is usually carried out in accordance with a predefined framework of instructions, with Criteria-Based Dispatch (CBD) and Medical Priority Dispatch System® (MPDS) being the most widespread.

In Denmark, the handling of all out-of-hospital medical emergencies has recently been reorganized. This was done by a nationwide introduction of EMCCs and the implementation of a criteria-based dispatch protocol termed the Danish Index for Emergency Care (Danish Index). Danish EMCCs are staffed by nurses, paramedics and doctors who assess and prioritize 1-1-2 calls. These tasks were previously performed mainly by the police. All Danish residents have free access to health care, including emergency medical services (EMS) and hospitals as a tax-financed service.

We aimed to describe the new Danish emergency medical dispatch system. Accordingly, this paper reports the first data on the distribution of the levels of emergency of 1-1-2 calls and the corresponding prehospital time intervals. We also aimed to investigate the EMD systems ability to triage patients according to severity, by using admission risk and case fatality risk as proxies for severity of patient condition.

Methods

Setting

In Denmark, the 1-1-2 emergency number is used for all emergencies, including those that require police-, fire- and health-related responses. All 1-1-2 calls are answered by the police or fire brigade. In mid-2011, five regional EMCCs were introduced in Denmark to provide EMD service to the entire country. The assessment and prioritization of citizens with medical problems who called the 1-1-2 number was done previously by the police (or, in part of the capital, by the fire brigade). After determining the caller's location, the 1-1-2 operator now transfer all health-related calls to the appropriate EMCC where the calls are assessed. The EMCC staff determines the level of emergency and decides on a response using the Danish Index, a criteria-based dispatch protocol for assessing the calls, making decisions about the emergency level and determining the appropriate responses [2,3]. The Danish Index has 37 main symptom groups that are each subdivided into five levels of emergency; each level of emergency contains a number of more specific symptoms. The five levels of emergency are as follows: A: life-threatening or potentially life-threatening condition, immediate response required; B: urgent, but not life-threatening condition; C: non-urgent condition that needs an ambulance; D: non-urgent supine patient transport; and E: other service or advice/instruction including taxi transportation (no ambulances are dispatched for emergency level E calls). The Danish Index also suggests supplementary questions to ask the caller and advice for lay bystanders and for health care professionals. 1-1-2 calls that are answered by an EMCC are assigned a Danish Index criteria code that corresponds to the level of emergency, main symptom and specific subgroup symptom.

Population and study design

We conducted a register-based follow-up study of all patients that contacted an EMCC through the 1-1-2 number. Data were collected during the last 6 months of 2011 from three of the five regional EMCCs in Denmark. The combined population of the three regions (the Capital Region of Denmark, the Central Region of Denmark and the Region of Southern Denmark) is 4,165,361 inhabitants, representing approximately 75% of the total Danish population [4]. The Capital Region consists of mainly urban areas with a population density of 665 inhabitants/km^2. The Central and Southern Regions of Denmark include both urban and rural areas and have lower population densities of 99 and 96 inhabitants/km^2, respectively [4].

Data sources and variables

The EMCC dispatch software was used to identify all 1-1-2-related assignments. The study variables extracted from the dispatch software for each assignment included the patient's civil registration number, the Danish Index code and prehospital time intervals. The prehospital time intervals obtainable from the EMCC software included the EMD response interval and the EMS response interval as defined in Utstein style by Castren et al. [5]. The EMD response interval is the time from registration of a call by the EMCC software until activation of the first responding ambulance. The EMS response interval is the time from activation of the first ambulance until its arrival on scene.

In order to retrieve additional follow-up data we utilized the fact that each Danish citizen is assigned a unique 10-digit civil registration number. This number is used in all Danish registries and enables unambiguous linkage among these registries [6]. If a patient had no civil registration number registered in the EMCC software we were unable to retrieve register-based follow-up data. For this study we used two national registries, the Danish Civil Registration System (CRS) and the Danish National Registry of Patients (NRP). The NRP was established in 1977 and has records of all Danish hospital visits and admissions. The registry includes information on numerous variables, including civil registration number, dates of hospital admission and discharge and discharge diagnoses classified according to the Danish version of the WHO's International Classification of Diseases, 10th edition (ICD-10). The NRP has tracked 99.4% of all discharges from Danish acute care non-psychiatric hospitals since 1977 and all hospital outpatient and emergency department visits since 1995 [7]. For this study, the hospital admission date and the discharge date were retrieved from the NRP.

The Danish Civil Registration System was established in 1968 and registers all persons living in Denmark [6]. For this study we retrieved data on gender, date of birth and changes in vital status (dead or alive) from the CRS. The vital status data was used to calculate case fatality risk.

Statistics

The outcomes included the Danish Index level of emergency, the main index group, the EMD and EMS response intervals, admission to hospital and death (within 24 h, 48 h and 30 days after the 1-1-2 call). Proportions were reported with 95% confidence intervals (95% CI) computed as CIs for proportions with binomial data using exact methods. Rates per 1,000 were assumed to follow a Poisson distribution and 95% CIs were computed according to that. Relative risk (RR) estimates were calculated as risk ratios comparing emergency level A patients with combined emergency level B through D and RR estimates are presented with the 95% CI. Time intervals were reported as medians with interquartile range (IQR). We used the Wald test to test for trends. All analyses were performed using STATA statistical software, version 12.

Ethics

The study was approved by the Danish Data Protection Agency. According to Danish law, permission from the Ethics Committee or from individual patients is not required for register-based studies.

Results

In the six-month study period from July 2011 to December 2011, a total of 99,855 1-1-2-related registrations were identified in the three included EMCCs. Of these, 20,493 did not lead to dispatch of an ambulance, mainly because they were assessed as emergency level E or were cancelled for other reasons (e.g. multiple calls regarding the same incident). A total of 79,362 ambulances were dispatched i.e. one ambulance per patient. A valid Danish Index code was registered for 67,135 of these, a valid Danish Index code *and* a valid civil registration number was available for 55,270 (70%) of the patients receiving an ambulance (Figure 1). The mean patient age was 54.9 years, and 47.7% were female and 52.3% male. Of the patients receiving an ambulance in the study period, 81.0% appeared in the dataset only once.

Out of the total 67,135 patients with a valid Danish Index code registered, emergency level A accounted for 51.4% (n = 34,489) , emergency level B patients for 46.3% (n = 31,116), emergency level C patients for 2.1% (n = 1,391) and emergency level D patients for 0.2% (n = 139). That corresponds to a total rate of 32.2 ambulance turnouts per 1,000 inhabitants per year in the three regions. The capital region had 32.9 turnouts per 1.000 inhabitants, the southern region 36.4 and the central region had 27.3. The rates of turnouts per 1.000 inhabitants are shown on

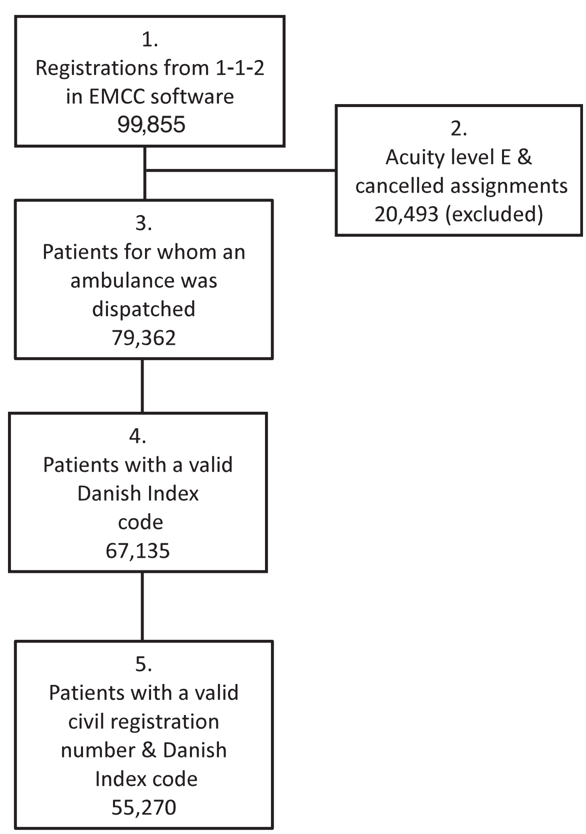

Figure 1 Included patients and patients lost to follow-up due to incomplete registration. Box **1**: Total number of 1-1-2 registrations in the study period. Box **2**: Excluded patients. Emergency level E and cancelled assignments. Box **3**: All patients that received an ambulance via a 1-1-2 call. Box **4**: Patients, that received an ambulance via a 1-1-2 call, with a valid Danish Index code registered. Box **5**. Patients that received an ambulance via a 1-1-2 call, with a valid Danish Index code *and* a valid civil registration number registered (making complete follow-up possible).

a regional level in Table 1. The five most frequently used Danish Index main symptom groups were: 1) unclear problem; 2) chest pain, heart disease; 3) minor wound, fracture or injury; 4) accident (not traffic-related); and 5) difficulty in breathing. The distribution of the main symptom groups according to level of emergency is shown in Table 2.

The overall median EMD response interval was 2 min 34 s. The median EMD response interval for the most urgent emergencies within all main symptom groups was 1 min 46 s. For the most severe main symptom category (A.01.01), "unconscious, not breathing normally", a group containing the majority of suspected cardiac arrests, the median EMD response interval was 1 min 34 s (mean, 2 min 5 s). The median EMS response interval for emergency level A patients was 6 min 11 s, and 75% of all emergency level A turnouts arrived on scene within 9 min 17 sec. Table 3 shows the EMD and EMS response intervals according to emergency level.

Follow-up data on admission to hospital and vital status (dead or alive) were available for the 55.270 patients with both a Danish Index code *and* a civil registration number registered. The admission risks among emergency level A and D patients were 64.4% (95% CI = 63.8-64.9) and 31.2% (95% CI = 22.7-40.8), respectively. The relative risk (RR) of admission among emergency level A patients compared to emergency level B, C and D patients combined was 1.25 (95% CI = 1.23-1.27). Admission risk data is shown in Table 4. Patients not admitted to the hospital as inpatients received either sufficient treatment on-scene (by EMS staff or prehospital physician), or received treatment for minor injuries in the Emergency Department and then sent home. Among emergency level A patients with complete follow-up data available, the case fatality risk on the same date as the 1-1-2 call was 4.4% (95% CI = 4.13-4.60), and the risk increased to 8.6% (95% CI = 8.28-8.94) after 30 days. Among emergency level B patients, the case fatality risk on the same date as the 1-1-2 call was 0.3% (95% CI = 0.23-0.37), and the risk increased to 3.3% (95% CI = 3.09-3.55) after 30 days. Emergency level A patients had a relative risk of dying of 14.3 (95% CI: 11.5-18.0) the same day as the 1-1-2 call compared to levels B through D combined. The case fatality risks and RR of death are shown in Table 5.

Table 1 Number of patients receiving an ambulance per 1,000 inhabitants per year in the three included regions

	All N = 67,135 (95% CI)	Capital (n = 28,030) (95% CI)	Central (n = 17,233) (95% CI)	Southern (21,872) (95% CI)
A	16.6 (16.38-16,74)	13.1 (12,86-13,34)	16,7 (16,38-17,02)	21.3 (20,94-21,68)
B	14.9 (14,78-15,1)	19.4 (19,06-19,66)	10,4 (10,12-10,62)	13.5 (13,18-13,78)
C	0.7 (0,64-0,7)	0.5 (0,40-0,5)	0.2 (0,16-0,24)	1.5 (1,38-1,58)
D	0.07 (0,06-0,08)	0.02 (0.2-0,04)	0.04 (0,04-0,06)	0.2 (0,12-0,2)
All	32.2 (32.0-32,48)	32.9 (32,54-33,32)	27.3 (26,9-27,72)	36.4 (35,94-36,92)

The study contains data from a 6 months period, the estimates in this table has been extrapolated to one year.

Discussion

This study showed that the majority of 1-1-2 callers in contact with the Danish EMCCs were assessed as being Danish Index emergency level A or B. The symptoms reported most frequently by callers were unclear problem, chest pain, minor wounds and injuries, accidents and difficulties in breathing. Both the EMD and EMS response intervals were shortest for emergency level A patients. Admission and case-fatality risks were substantially higher for emergency level A patients than for emergency level B–D patients.

The new EMD system enables linkage between dispatch data and patient outcome data. The previous system, which was staffed by police, did not register each patient's civil registration number; therefore there are no comparable Danish data at the individual level before the introduction of EMCCs. Comparisons with results reported by other EMD systems are warranted, but hampered by several factors. First, EMD organization differs considerably in different countries. Secondly, uniform guidelines for EMD reporting have only been available for a few years [5,8].

Kuisma et al. reported on an EMD system in the Helsinki area of Finland [9]. In a four emergency levels system, the distribution of calls according to emergency was: A, 5.7%; B, 27.0%; C, 47.4%, and D, 19.9%. These numbers are quite different from ours; however, the differences can probably be explained by the fact that not only assignments originating from 1-1-2 calls, but also other ambulance requests were included in the Finnish study.

Norway has an EMD system and a prehospital organization that is very similar to the recently implemented Danish system. In a study by Zakariassen et al. of the Norwegian Index, which served as the basis of the Danish Index, they found a rate of emergency level A turnouts in Norway of 25 per 1,000 inhabitants per year. [10] That is a higher rate than the 16.6 in our study. A part of the difference can be explained by missing data in our study. Based on our data the rates per 1,000 inhabitants underestimates by approximately 18%. Some of the regional differences in rates per 1.000 inhabitants observed in our study can be explained by differences in demographics between the regions. Zakariassen et al. also reported a patient distribution in the main symptom

Table 2 Level of emergency and main symptom groups

Main Index Group	All (%)	A (%)	B (%)	C (%)	D (%)
Unclear problem	11,534 (17.1)	3,909 (11.3)	7,396 (23.8)	214 (15.4)	15 (10.8)
Chest pain, heart disease	8,737 (13.0)	7,661 (22.2)	1,018 (3.3)	56 (4,0)	2 (1.5)
Minor wound, fracture, injury	7,373 (11.0)	423 (1.2)	6,494 (20.9)	384 (27.6)	72 (51.8)
Accident (not traffic related)	6, 490 (9.6)	2,116 (6.1)	4,141 (13.3)	210 (15.1)	23 (16.6)
Difficulty in breathing	4,945 (7.3)	3,341 (9.7)	1,433 (4.6)	170 (12.2)	1 (0.7)
Impaired consciousness, paralysis	4,464 (6.6)	4,051 (11.8)	377 (1,2)	35 (2.5)	1 (0.7)
Poisoning, medications, alcohol, drugs	3,962 (5.9)	1,204 (3.5)	2,704 (8.7)	53 (3.8)	1 (0.7)
Seizure	3,420 (5.1)	1,794 (5.2)	1,626 (5,2)	.	.
Traffic accident	3,145 (4.6)	2,373 (6.9)	762 (2,5)	.	10 (7.2)
Stomach or back pain	2,950 (4.4)	659 (1.9)	2,175 (7.0)	115 (8.3)	1 (0.7)
Unconscious adult	2,342 (3.4)	2,339 (6.8)	3 (0.0)	.	.
Bleeding–non traumatic	1,227 (1.8)	689 (2.0)	494 (1.6)	44 (3.2)	.
Diabetes	1,149 (1.7)	594 (1.7)	533 (1.7)	21 (1.5)	1 (0.7)
Psychiatry, suicide	1,017 (1.5)	539 (1.6)	476 (1.5)	2 (0.1)	.
Allergic reaction	758 (1.1)	582 (1.7)	176 (0.6)	.	.
Violence, abuse	522 (0.8)	216 (0.6)	304 (1.0)	1 (0.1)	1 (0,7)
Sick child	476 (0.7)	391 (1.1)	84 (0.3)	1 (0.1)	.
Gynaecology, pregnancy	435 (0.7)	259 (0.8)	142 (0.5)	34 (2.4)	.
Headache	414 (0.6)	384 (1.1)	9 (0.0)	21 (1.5)	.
Ear, nose, throat	278 (0.4)	66 (0.2)	202 (0.7)	10 (0.7)	.
Urinary system	273 (0.4)	12 (0.0)	255 (0.8)	6 (0.4)	.
Fire or electricity injury	248 (0.4)	144 (0.4)	103 (0.3)	1 (0.1)	.
Fever	182 (0.3)	127 (0.4)	55 (0.2)	.	.
Foreign body in airway	145 (0.2)	131 (0.4)	14 (0.0)	.	.
Childbirth	120 (0.2)	96 (0.3)	13 (0.0)	.	11 (7.9)
Possible death or Sudden Infant Death	93 (0.2)	76 (0.2)	16 (0.0)	1 (0.1)	.
Eye	83 (0.2)	37 (0.1)	41 (0.1)	5 (0.4)	.
Unconscious child	82 (0.1)	82 (0.2)	.	.	.
Animal and insect bites	74 (0.1)	57 (0.2)	13 (0.0)	4 (0.3)	.
Hypo- and hyperthermia	64 (0.1)	42 (0.1)	22 (0.1)	.	.
Chemicals and gases	54 (0.1)	32 (0.1)	20 (0.1)	2 (0.1)	.
Drowning	34 (0.1)	30(0.1)	4 (0.0)	.	.
Poisoning in children	27 (0.0)	17 (0.1)	10 (0.0)	.	.
Skin and rash	10 (0.0)	8 (0.0)	1 (0.0)	1 (0.1)	.
Diving accident	5 (0.0)	5 (0.0)	.	.	.
Large scale accident	3 (0.0)	3 (0.0)	.	.	.
All	**67,135 (100)**	**34,489 (100)**	**31,116 (100)**	**1,391 (100)**	**139 (100)**

All patients with a valid Danish Index code (67.135) distributed according to main symptom group and level of emergency, as defined by The Danish Index for Emergency Care.

groups similar to our findings. Specifically, for emergency level A, the five most frequent main symptoms were chest pain (22%), patient transport (ordered by hospitals and general practitioners) (18%), unclear problem (14%), accidents and traffic accidents (12%) and unconscious adult or child (8%). The corresponding emergency level A data in our study (Table 2) were chest pain (22.2%), accidents and traffic accidents (13%), unclear problem (11.3%) and unconscious adult or child (7.0%). Patient transports ordered by hospitals and general practitioners were not a part of our study since they are not handled by the Danish 1-1-2 system. The Danish

Table 3 Emergency medical dispatch and emergency medical services response intervals in minutes and seconds

Emergency Level	No.	EMD, median (IQR)	EMS, median (IQR)
A	34,489	02:01 (1:28,2:47)	6:11 (4:18,9:17)
B	31,116	03:27 (2:20,5:38)	10:00 (6:50,14:24)
C	1,391	04:51 (3:00,10:41)	11:14 (07:44,17:27
D	139	6:46 (3:37,19:00)	13:00 (8:33,21:07)
All	67,135	02:34 (1:45,4:01)	7:53 (5.09,11:59)

Interquartile range (IQR).
EMD response interval: Time spend from reception of 1-1-2 call at the EMCC, until activation of the ambulance. EMS response interval: Time spend from ambulance activation until arrival on scene. Patients with a valid Danish Index code (67,135) are included in the table.

Table 5 Case fatality risk for patients in the indicated Danish Index emergency level groups

	No.	0–24 h (95% CI)	0–48 h (95% CI)	30-day (95% CI)
A	28,630	4.4 (4.13-4.60)	5.1 (4,87-5,39)	8.6 (8.28-8.94)
B	25,419	0.3(0.23-0.37)	0.6 (0.47-0.66)	3.3 (3.09-3.55)
C	1,112	0.4 (0.15-1.05)	0.5 (0.20-1.17)	3.3 (2.35-4.56)
D	109	0 (0–3.32)*	0 (0–3.32)*	0.9 (0.02-5.0)
RR A vs. B-D		14.3 (11.5-17.98)	9.2 (7.80-10.92)	2.6 (2.42-2.81)
All	**55,270**	**2.4 (2.28-2.54)**	**2.9 (2.78-3.07)**	**6.1 (5.85-6.25)**

*One-sided, 97.5% confidence interval.
Case fatality risk for patients in the indicated Danish Index emergency level groups and the relative risk (RR) of dying for group A patients compared to group B, C and D patients combined. Analysis based on 55.270 patients with Danish Index code *and* civil registration number registered (a prerequisite for follow-up data from national registries).

Index is a new feature of a very young organization, which may explain the high proportion of patients with unclear problems in our study. When a serious condition is suspected, health care personnel probably tend to rapidly deploy the desired response team rather than spending time determining the relevant main symptom group. However, the similar finding of a high proportion of unclear problems in Norway, where the criteria-based EMD organization is well established, identifies a possible inadequacy in the Danish and Norwegian Indexes. In a study in the US, Sporer et al. found breathing problems reported in 12.2% of all calls, chest pain in 6.0%, unclear problems in 1.1%, seizures in 3.4%, falls in 8.7% and fainting/unconsciousness in 8.7% [11]. Sporer et al. reported on an MPD system that uses slightly different main symptom groups; nevertheless, the small proportion of unclear problems and the high proportion of breathing problems stands out compared to our results. Other studies of MPD systems have typically reported unclear problems in 5–8% of patients [12,13] The fixed algorithm structure of the MPDS may explain some of the difference in the proportion of breathing problems. In Denmark all citizens have 24 hr access to a general practioner, which may also explain some of the differences.

Table 4 Admission to hospital risk for patients in the indicated Danish Index emergency level groups

Emergency level	No.	Admitted to hospital	Admission risk, % (95% CI)
A	28,630	18,440	64.4 (63.8-65.0)
B	25,419	13,190	51.9 (51.3-52.5)
C	1,112	475	42.7 (39.8-45.7)
D	109	34	31.2 (22.7-40.8)
All	**55,270**	**32,139**	**58.1 (57.7-58.6)***

*Test for trend, $p < 0.001$.
All patients with Danish Index code and civil registration number (55.270) registered (a prerequisite for follow-up data from national registries). Patients hospitalized for one day or more are regarded as admitted.

The median EMD response interval for potential cardiac arrests (unconscious, not breathing normally) was 1 min 34 s (mean, 2 min 5 s) in our study. For 373 known out-of-hospital ventricular fibrillation cases in Finland, Kuisma et al. found an EMD response interval of 77.1 ± 44 s [14]. In an EMD system resembling the Danish CBD system, Berdowski et al. examined the handling of out-of-hospital cardiac arrests in the Amsterdam area [15]. They found a mean EMD response interval for suspected cardiac arrests of 1.88 minutes (1 min 53 s), a result similar to our findings. These results raise the question of whether this amounts to a fast or a slow processing of calls concerning potentially serious emergencies. A recent *Circulation* editorial stated that high performance Medical Priority Dispatch Systems typically have vehicles rolling ≤ 30 seconds from call receipt [16]. Compared with our > 90 seconds, this seems very fast. Since EMD systems aim to balance response resources with patient needs, it is worth considering whether a short EMD response interval in itself is an indicator of high quality in dispatching. Except for cardiac arrest where a quick dispatch is of major importance, the time spent clarifying the situation may help uphold high quality dispatching. Data regarding the time interval from a 1-1-2 call is received by the police and until it is passed on to the EMCC was not available for this study.

The EMS response interval, which is often described as the ambulance response time, is a topic that receives much attention from researchers, health care professionals, administrators, politicians and the general public. Many EMS systems have a target response time of less than 8 - minutes for acute response. There is robust evidence for an association between short EMS response interval and increased survival only for cardiac arrest patients [17]. In a study of North American trauma patients with field-based physiological abnormalities, Newgard et al. found no association between the response time (or other prehospital time interval) and mortality. For 3,656 ambulance dispatches they reported an impressive median EMS response interval of 4.28 min with an IQR of 3.0–6.3 min [18]. In a study in the US, Pons et al. reported a median EMS response interval of 5.8 min (IQR 4.3–7.7 min) [19]. Many North American studies are conducted in areas that include very large cities. The three regions included in our study contained a mixture of urban and rural areas with different locally-determined target values for EMS response intervals. The target values concerning acuity level A turnouts was a median of 8 min in one region, a mean of 10 min in another and 75% below 10 min in the third region. All regional target values were met during the study period.

The hospital admission risk was highest among emergency level A patients and correlated directly with emergency level. Specifically, we found a clear trend of lower admission risk for lower levels of emergency (Table 4). If we consider admission risk to be a proxy for the severity of the patient's condition, this trend indicates that the new Danish EMD system triages severely ill patients appropriately. A similar trend was found in a Canadian study by Blanchard et al. in which 7,603 of 23,442 (32.4%) of lower emergency level patients were admitted as inpatients and 3,141 of 7,943 (39.5%) of higher emergency level patients were admitted as inpatients [20]. In our study, a similar pattern was observed regarding case fatality risk, which was much higher among patients assessed as emergency level A compared with patients assessed as having a lower emergency level (Table 5). In a Finish study, Kuisma et al. observed a similar trend in the prehospital case fatality risk, which was of 5.2% among emergency level A patients and 1.1% for level B, 0.1% for level C and 0.03% for level D patients [9].

We had no data on the physiological status of the patients at the time of ambulance arrival on scene or upon arrival at the hospital. Precise estimates of over- and undertriage in terms of sensitivity, specificity and predictive values were therefore not possible to make. However our results do allow considerations about triage precision. The results regarding admission to hospital suggests a degree of overtriage among emergency level A patients of about 35%, since their condition could be treated on scene or in the emergency department. On the other hand, a part of the 35% non-admitted emergency level A patients, may have been in severe distress, but treated sufficiently on scene or in the emergency room. A part of the admitted patients in the lower emergency level groups may represent undertriage, especially the emergency level B and C patients dying on the same day as the 1-1-2 call may represent undertriage. But the case fatality risks in these groups are quite small, indicating that undertriage is not extensive. In all systems some degree of mistriage is unavoidable. When looking at e.g. trauma patients, the American College of Surgeons states that 5–10% undertriage is probably inevitable and overtriage of 30–50% is common in trauma-triage systems [21]. Some quantity of overtriage is definitely needed to avoid oversights of severe conditions.

The strengths of our study include the population-based design and its representation of 75% of the Danish population. Other strengths include the large study volume, which allowed statistically precise estimates and the ability to follow-up patients to determine hospital admission and case-fatality risks. One limitation is that a part of the patients had missing data due to incomplete registration of either the Danish Index code, civil registration number or both. The entry of index codes and civil registration numbers into the EMCC software is based mainly on manual typing by the EMCC staff. This is a large part of the explanation for the missing data. There are also situations where patients are unable to inform their civil registration number, or the caller is a third party with no knowledge about patient identity. Other reasons for missing civil registration numbers are foreign patients, patients unwilling to inform identity and oversights by EMCC or EMS staff. When looking at the rate of missing data in smaller clusters (e.g. comparing the three EMCCs, comparing shorter time periods) we found no indications of selection bias. The missing registration of about 15% of all Danish Index codes makes our results regarding rates of turnouts per 1,000 inhabitants underestimates of the true values.

Conclusions

Using case fatality and hospital admission risks as indicators of case severity, the new Danish criteria-based dispatch system seems to triage patients with high risk of admission and death to the highest level of emergency. Further studies are needed to determine the degree of over- and undertriage and studies of the Danish Index as a predictor of death or severe illness and injury are warranted.

Abbreviations

CBD: Criteria-based dispatch; CI: Confidence interval; CRS: Civil registration system; EMCC: Emergency Medical Communication Centre; EMD: Emergency medical dispatch; EMS: Emergency medical services; IQR: Interquartile range; MPDS: Medical priority dispatch system; NRP: National registry of patients; RR: Relative risk.

Competing interests

The authors declared that they have no competing interests.

Authors' contributions

MSA, SPJ and EFC have designed the study. MSA, JNS, SBJ, JBH have made substantial contributions to the acquisition of data. All authors have contributed substantially in the analysis and interpretation of data, drafting the manuscript and have given final approval of this version.

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Study II

Are there preventable deaths among 112 callers not considered highly urgent by the Emergency Medical Communication Centre? – An audit study

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Abstract

Background: For callers to the 112 emergency number, triage can be error prone because rapid decisions must be made based on limited information. Here we investigated the preventability and common characteristics of same-day deaths among patients who called 112 and were not assigned an ambulance with lights and sirens by the Emergency Medical Communication Centre (EMCC).

Methods: An audit was performed by an external panel of experienced prehospital consultant anaesthesiologists. The panel focused exclusively on the role of the EMCC, assessing whether same-day deaths among 112 callers could have been prevented if the EMCC had assessed the situations as highly urgent. The panels' assessments were based on review of patient charts and voice-log recordings of 112 calls. The study was conducted in three of five regions in Denmark, which include 75 % of the population. The study period was 18 months, from mid-2011 to the end of 2012.

Results: Linkage of prospectively collected EMCC data with population-based registries resulted in the identification of 94,488 non-high-acuity 112 callers. Among these callers, 152 (0.16 % of all) died within 24 hours of their 112 call, and were included in this study. The mean age of included patients was 74.4 years (range, 31–100 years) and 45.4 % were female. The audit panel found no definitively preventable deaths; however, 18 (11.8 %) of the analysed same-day deaths (0.02 % of all non-high-acuity callers) were found to be potentially preventable. In 13 of these 18 cases, the dispatch protocol was either not used or not used correctly.

Conclusion: Same-day death rarely occurred among 112 callers whose situations were assessed as not highly urgent. No same-day deaths were found to be definitively preventable by a different EMCC call assessment, but a minority of same-day deaths could potentially have been prevented with more accurate triage. Better adherence with dispatch protocol could improve the safety of the dispatch process.

Keywords: Emergency medical dispatch, audit, preventable deaths.

Introduction

In Emergency Medical Communication Centres (EMCC), patient triage is susceptible to errors since decisions must be made rapidly based on limited information. Such errors can impact patient outcome, resulting in increased morbidity or death. Previous studies have investigated the preventability of deaths among acutely ill and injured patients admitted to emergency departments and among trauma patients.[1-4] Only one previous audit study examined, as a secondary endpoint, the preventability of death in Emergency Medical Dispatch.[5]

The last three years have seen considerable changes to the organization of Emergency Medical Dispatch in Denmark. The system was formerly mainly police operated—but with the opening of EMCCs staffed with nurses, paramedics, and doctors to assess all 112 calls, it has become an integrated part of public health care. Ten years ago, a survey of prehospital care in the Nordic countries highlighted the former police-operated system as a weak link in Danish prehospital care. [6] A statement that was stressed by studies showing moderate to low accuracy of the system. [7, 8] The recent reorganization was intended to improve the initial assessment and triage of callers to the 112 emergency telephone number; however, it has not yet been evaluated whether this goal has been accomplished. The Danish EMCCs assess all incoming calls using a criteria-based dispatch protocol (the Danish Index for Emergency Care), which divides patients into five levels of emergency (A–E) based on their main symptoms. [9-11]

The first study of the new EMD system in Denmark revealed a group of 112 callers who were not assessed as highly urgent but who died on the day of their 112 call. [10] These patients potentially represent serious undertriage and, therefore, warrant further more detailed investigation. The primary objective of the present study was to determine the proportions of preventable and potentially preventable same-day deaths among the 112 callers who were not assessed as highly urgent. Secondly, we wanted to identify common characteristics among preventable deaths, in order to detect areas for improvement of the EMD process.

Methods

Setting

In Denmark, criteria-based EMD is conducted in five regional EMCCs. The common number for fire, police, and health-related emergencies is 112, which is answered by the police (or by the fire brigade in part of the capital area). Following establishment of the caller's geographical position, all calls concerning illness and injury are redirected to an EMCC. According to the Danish Index for Emergency Care (Danish Index), the EMCC staff categorizes calls into one of 37 chief complaint groups that are each subdivided into five levels of emergency: A: life-threatening or potentially life-threatening condition requiring immediate response ("blue lights and sirens"); B: urgent but not life-threatening condition; C: non-urgent condition that requires an ambulance; D: non-urgent condition requiring supine patient transport; and E: condition requiring other service or advice/instruction, including taxi transportation (no ambulances are dispatched for emergency level E calls). Each level of emergency contains a number of more specific symptoms, each with a specific index code.

Population and study design

This study was conducted in the three largest regions of the country (Central, Southern, and Capital), which have a combined population of 4,182,613 inhabitants (1st of January, 2012), equalling 75 % of the total Danish population (n = 5,580,516). [12] The study population comprised all 112 callers who were registered by the EMCCs as emergency level B–E, and who died on the same date as the corresponding emergency call. The study period was from July 1st 2011 to the end of 2012 (18 months).

The study was designed as a medical audit performed by an external expert panel and carried out as a retrospective review of all patient-related material as described by Lembcke et al., Mainz et al., and

Nakano et al. [13-15] The expert panel consisted of three consultant anaesthesiologists with extensive prehospital experience and with no affiliation to the evaluated EMCCs.

Data sources

Patients were identified through the EMCC dispatch software. All contacts to the EMCC from the 112 system were identified, and the patient's civil registration number and Danish Index code (including level of emergency) were documented. The unique 10-digit civil registration number assigned to all Danish residents enables unambiguous linkage to public registries and hospital chart systems. [16] From the Civil Registration System, we obtained information on age, gender, and change in vital status (dead or alive). Callers who received a Danish Index code consistent with emergency level B or lower *and* who died on the same date as their 112 call were included in the present investigation (fig. 1). For each included patient, we recorded the patient's prehospital time interval, which included the EMD response interval (from receipt of a call at the EMCC until dispatch of the first ambulance) and the EMS response interval (from ambulance dispatch to arrival on scene). We utilized the National Registry of Patients (NRP) to obtain data on hospital admissions. The NRP hold records of 99.4 % of all discharges from Danish hospitals since 1977, and on all in- and out-patient hospital visits since 1995. [17] For each patient, we retrieved the prehospital medical records from the ambulance services, the record from the involved hospital, and the post-mortem report when available. From the involved EMCCs, we also obtained voice log recordings of the telephone conversations between the 112 callers and the EMCC.

The audit process

All material was retrieved and reviewed by a member of the study group (Andersen MS). After initial review patients with inadequate and missing information on circumstance surrounding their death were excluded (fig. 1). Summaries of all included deaths were produced by Andersen MS. Table 1 presents the content of the patient summary. Material relating to the deaths—including all charts, voice logs, post-mortems, and summaries—was uploaded to a secure server accessible only to the expert panel. The external reviewers (Hansen AE, Skjaerseth E, Hansen CM) were asked to evaluate the material before a two-day meeting, during which all death-related material was jointly reviewed with Andersen MS as the facilitator.

The reviewers were asked to determine whether each patient's death was preventable, potentially preventable, or non-preventable. In the judgement of preventability, the reviewers were asked to state what the EMCC should or could have done differently. The reviewers were instructed to exclusively focus on factors related to the EMCC call-taker. Preventable death in this study was defined as a death that could have been prevented if the EMCC had assessed the call differently, such that an ambulance with blue lights and sirens was dispatched to the patient, as well as a supplemental prehospital doctor in the most severe cases. The quality of care provided by ambulance staff, and prehospital or in-hospital doctors was not subjected to review in this study. Preventability was determined according to the experts' professional judgment of each included death, based on thorough review of all available patient-related material before and during the two-day audit meeting, as well as on the reviewers' considerable experience with prehospital emergency care. A death was deemed preventable deaths if there was a high certainty that a different assessment by the EMCC could have prevented the death. Potentially preventable deaths were cases in which a different assessment by the EMCC could have potentially prevented the death. These preventability categories were inspired by audit studies by Kuisma et al., Lu et al., and Nafsi et al. [1, 2, 5] Any dissent between the three experts was resolved by discussion and, if any disagreement remained, it was settled with majority decision.

Statistics

Descriptive statistics of the included patients were presented. No formal statistical comparisons or tests were made**.**

Ethics

This study was approved by the Danish Data Protection Agency (reference number 2011-41-6326 and 2013-41-1598). Permission to inspect patient charts was granted by the Danish Health and Medicines Authority (ref. nr.3-3013-257/1/). Permission from the Ethics Committee is not required for studies using routinely accumulated data according to Danish law.

Results

During the study period, a total of 314,134 calls to the 112 number were redirected to the three EMCCs included in the study. Of these callers, 191,524 were registered in the EMCC dispatch software with a valid civil registration number and Danish Index code. A total of 94,488 were assessed as emergency level B–E. Of these callers, 192 (0.2 %) died on the same date as calling the 112 number and were hence eligible for review. Forty of these deaths were excluded due to insufficient information. One half of the exclusions were due to a failed filing system of prehospital records in one region during the first part of the study period. The other half were due to very sparse information noted on pre- and in-hospital charts combined with missing voice-log recordings, which together left too little information available to assess preventability. A total of 152 deaths were included in the study, comprising 0.16 % of all B–E callers. The mean age of the callers at the time of death was 74.4 (range, 31–100) and 45.4 % were female. Table 2 displays the distribution of included patients according to the Danish Index level of emergency and chief complaint groups. The majority was assessed as urgency level B, and the remainder as lower emergencies of which one patient was emergency level E. The most frequently entered chief complaint "unclear problem" (66 of 152) followed by "difficulty in breathing" (27 of 152).

None of the 152 deaths included in the study were considered definitively preventable by any of the reviewers. Eighteen of the included deaths (11.8 % of the included deaths and 0.02 % of total B–E callers) were considered potentially preventable *if* the EMCC had assessed the 112 call as more urgent and this had led to an ambulance dispatch with a shorter response time and possible rendezvous with a physician-staffed mobile emergency care unit (MECU). The reviewers rated 134 deaths (88.2 %) as non-preventable. One example of a non-preventable death was that of a 91-year-old female assessed by the EMCC as emergency level B due to stomach pain. At the hospital, the patient was awake and orientated with normal vital signs. The patient was diagnosed with a ruptured abdominal aortic aneurism and declined further treatment. The patient died at the hospital 7 hours after the 112 call. Another non-preventable death was that of a 56-year-old male who was assessed by the EMCC to be emergency level B after a minor seizure. The patient was admitted to the hospital where he recovered to his normal state with normal vital signs; however, eight hours later, the patient developed hematemesis and died.

The median EMD response interval was 3 min 26 sec among the potentially preventable deaths and 3 min 20 sec among the non-preventable deaths. The median EMS response interval was 12 min 23 sec among the potentially preventable deaths and 9 min 25 sec among the non-preventable deaths. Table 3 presents the characteristics of the patients who experienced potentially preventable or non-preventable deaths and of the survivors.

The potentially preventable deaths fell in two groups. In one group (n = 5), the EMCC call-takers, in principle, reacted adequately to the inquiry based on the content of the telephone interview; however, it later turned out that a different response could have benefitted the patient. One example of such a death occurred in a 62-year-old female with difficulty breathing. Her husband was the caller, and it was possible to hear the patient talk and yell in the background. The EMCC nurse chose a priority B “difficulty breathing, gradually deteriorating” criterion. At ambulance arrival, the patient was cyanotic and in severe respiratory distress. The patient went into cardiac arrest and a MECU was summoned and arrived after 10 minutes. Fifty-two minutes after the onset of cardiac arrest, the patient was declared dead in the emergency department. The review panel concluded that the EMCC nurse reacted adequately according to the Danish Index and the content of the telephone interview, but that the immediate dispatch of an emergency level A ambulance and a MECU could potentially have prevented the fatal outcome for the patient.

In the second group of potentially preventable deaths (n = 13; 0.01 % of total B–E callers), the expert panel determined that either the Danish Index was not used or it was used incorrectly by the call-taker. An example of a potentially preventable death in this second group was that of a 77-year-old female who was found on the floor by her son. On the voice log, the patients’ son is heard to inform the EMCC that his mother might have a broken arm and to mention twice that she had severe breathing difficulties. An ambulance was dispatched as emergency level B under the criterion of a possible fracture. At ambulance arrival, the patient was in cardiac arrest. At that time, the ambulance staff summoned a MECU staffed with an experienced anaesthesiologist with prehospital emergency medical training. The MECU arrived 24 minutes after the 112 call, and the patient was declared dead 8 minutes later. The expert panel determined that the patient should have been assigned a “difficulty breathing” criterion and assessed as emergency level A. They concluded that a joint response with ambulance and MECU was justified based on the content of the 112 call, and that such a response could have potentially prevented the fatal outcome.

Among the potentially preventable deaths, most EMD response intervals were between 1 and 4 minutes. In two cases, the EMD response interval was above 10 minutes. The EMS response intervals were between 6 and 13 minutes in most cases. In four cases, the EMS response intervals were between 17 and 38 minutes. Table 4 presents information on all potentially preventable deaths.

Discussion

Same-day deaths occurring among 112 callers who were not assessed by the EMCC to have a life-threatening condition could represent very serious undertriage. The present independent expert review of telephone call recordings and patient charts found that none of these same-day deaths were definitively preventable with high certainty—i.e. in no case was there a high probability that the death could have been avoided if the EMCC had made a different assessment. Our review identified a number of potentially preventable deaths that could possibly have been averted if the EMCC had made a different call assessment; however, these constituted a very small proportion of all non-high-acuity patients (one potentially preventable death for every 5,249 non-high-acuity 112 caller). The majority of cases in which death was deemed potentially preventable involved incorrect use or no use of dispatch protocol. Most of the potentially preventable deaths occurred with an EMS response interval of around 13 minutes or less. These were not extremely long intervals, but they would likely have been markedly shorter if the calls had been assessed as emergency level A and "blue lights and sirens" had been used. Four of the potentially preventable deaths showed EMS response intervals of 17 minutes and up to 38 minutes, which constitute time-spans that may have substantially influenced patient prognosis.

One earlier study investigated preventability of death occurring in close relation to a 112 call.[5] Among deaths occurring in lower-priority groups in Finland, Kuisma et al. reported that 1.3 % were preventable, 32.9 % were potentially avoidable, and 65.8 % were non-preventable. These proportions of preventable and potentially preventable deaths are markedly higher compared to our present findings; however, it is unclear whether the review process and definitions of preventability were the same as in our study. The previously published chart review was a secondary aim of a Finnish study, and thus the audit process was not described in detail. A number of other audit studies have investigated early mortality related to emergency departments and trauma centres. Lu et al. performed a chart review of deaths occurring within 24 hours after admission to a ward from the emergency department (ED).[2] They found that 25.8 % of early deaths were preventable. In an audit with external patient chart review, Nafsi et al. evaluated deaths that occurred within 7 days of admission to an ED, and found that 3.15 % were definitely preventable and 9.46 % were either possibly or probably preventable.[1] In a Dutch trauma centre audit, Saltzherr et al. reported that 2 % of deaths were preventable and 27 % were potentially preventable.[3] Compared to these previous studies, our present results were fairly good, with zero definitively preventable deaths and 11.8 % potentially preventable deaths. This comparison must take into account the longer duration of patient contact in an ED admission compared to the short prehospital time interval. A higher proportion of deaths are likely to occur due to suboptimal treatment during the hours or days of a hospital admission than as a consequence of actions during the shorter time from a 112 call until the arrival of an ambulance and/or doctor to the patient.

For investigating whether deaths or other adverse events are avoidable, a well-planned chart review by an expert panel is a reliable method that also provides opportunity for identifying possible areas of future improvement.[1, 2, 13, 14, 18] One limitation of the present study was the incomplete registration of civil registration numbers and Danish Index codes into the EMCC software. We examined the rate of missing data in smaller clusters (e.g. comparing between the three EMCCs and between shorter time periods), which revealed no indications of selection bias. Another limitation of the study was the exclusion of some patients whose pre- and in-hospital charts were missing or insufficient, which could introduce selection bias. However, the authors had no reason to believe that the group of excluded patients contained a higher proportion of preventable deaths than the included patients.

In daily clinical practice at the EMCC, it is a general impression that 112 calls that end with a suboptimal outcome for the patient or a complaint from the caller are often the result of the dispatcher failing to comply with the dispatch protocol. This impression was confirmed by the present study, as 13 of the 18 potentially preventable deaths were associated with non-compliance with the dispatch protocol. In a study of the Norwegian criteria-based dispatch protocol, Ellensen et al. reported large variations between the EMCCs regarding adherence to the dispatch protocol.[19] On average, the Norwegian dispatch protocol was followed by call-takers in 75 % of calls. In a Norwegian study of EMCC handling of calls concerning intoxication, Lorem et al. reported that 89% of dispatchers used the CBD protocol, but that 33 % of the calls included in the study showed deviations from the protocol.[20]

Our present findings that none of the same-day deaths among non-high-acuity 112 callers were considered preventable and that few were potentially preventable, are encouraging results regarding the new EMD system in Denmark—especially when considering the young age of the system, and the almost 200,000 calls that this study was based on. A limited number of patients among the potentially preventable deaths may have suffered serious consequences of the EMCC triage. There exists room for improvement in terms of systematic protocol adherence.

Conclusion

No preventable same-day deaths were identified among non-high-acuity 112 callers. A small proportion of same-day deaths among all non-high-acuity 112 callers were assessed as potentially preventable by audit panel. Better alignment with dispatch protocol may further improve the safety of the dispatching process.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

MSA, SPJ and EFC have designed the study. MSA, JNS, SBJ, JBH have made substantial contributions to the acquisition of data, patient charts and voice-log recordings. AEH, ES and CMH conducted the audit, facilitated by MSA. All authors have contributed substantially in the interpretation of results, drafting the manuscript and have given final approval of this version.

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Tables

Table 1. Information included in patient summary used by audit panel.

Date and time of 112 call referred to EMCC:
Danish Index criteria (index code):
Additional information, if any, in dispatch software visible in ambulance:
EMD response interval (min:sec):
EMS response interval (min:sec):
Vital signs:
Summary of pre- and in-hospital charts and tests results:
Short summary of prior medical history (if any):
Age:
Time of death:

Min, minutes; sec, seconds.

Table 2. Distribution of Danish Index chief complaint groups among the included patients.

Chief complaint group	
Emergency level B	**n**
Unclear problem	64
Difficulty in breathing	27
Stomach or back pain	15
Minor wound, fracture, injury	10
Seizure	6
Accident (not traffic related)	6
Impaired consciousness, paralysis	6
Chest pain, heart disease	3
Poisoning, medications, alcohol, drugs	3
Urinary system	3
Bleeding, non-traumatic	2
Diabetes	2
Emergency level C	
Difficulty in breathing	3
Unclear problem	1
Emergency level E	
Unclear problem	1
Total	152

Table 3. Potentially preventable vs. non-preventable deaths.

Characteristics	Potentially preventable (n = 18)	Non-preventable (n = 134)	Emergency level B–E survivors (n = 94,336)
Female, n (%)	6 (33.3)	63 (47.0)	47,074 (49.8)
Age, mean (range)	66 (34–88)	76 (31–100)	53 (0–101)
EMD time in min:sec, median (IQR)	3:26 (3:00–5:26)	3:20 (2:10–5:11)	3:25 (2:19–5:36)
EMS time in min:sec, median (IQR)	12:23 (7:20–15:28)	9:25 (6:32–13:31)	9:51 (6:34–15:03)

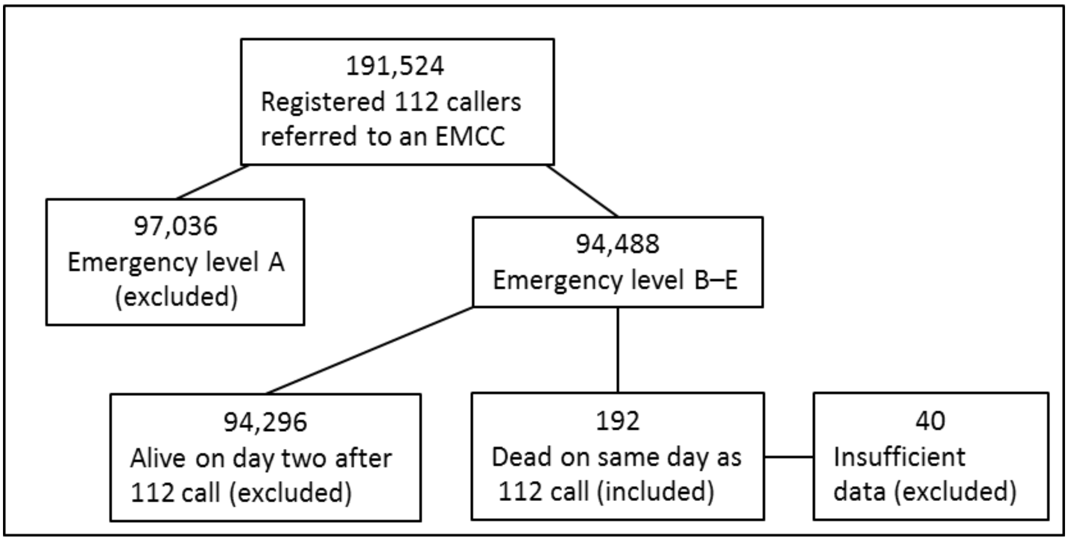
Min, minutes; sec, seconds.

Table 4. Summary of potentially preventable deaths.

Patient	Danish Index chief complaint	Age (sex)	EMD response interval	EMS response interval
1	Unclear problem	63 (M)	03:44	13:47
2	Unclear problem	66 (F)	04:17	12:43
3	Unclear problem	69 (M)	12:01	06:41
4	Unclear problem	83 (M)	02:08	06:45
5	Unclear problem	74 (M)	03:26	07:33
6	Unclear problem	61 (M)	07:37	08:27
7	Unclear problem	73 (M)	05:08	12:25
8	Difficulty in breathing	56 (F)	01:41	12:32
9	Difficulty in breathing	62 (F)	03:36	06:34
10	Difficulty in breathing	34 (F)	04:31	17:42
11	Difficulty in breathing	68 (F)	11:19	15:47
12	Chest pain, heart disease	74 (M)	.	13:00
13	Chest pain, heart disease	88 (M)	01:51	38:31
14	Poisoning, medications, alcohol, drugs	44 (M)	15:33	24,45
15	Poisoning, medications, alcohol, drugs	70 (M)	03:00	04:10
16	Seizure	52 (M)	01:39	17:58
17	Accident (not traffic related)	77 (F)	03:24	11:09
18	Urinary system	76 (M)	05:43	12:51

Figures

Figure 1. Flowchart of patients included in and excluded from the study.



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Study III

Identifying high-risk patients among 112 callers: can information on demographic factors and hospitalization history improve triage in Emergency Medical Dispatch?

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Abstract

Background: Limited information is available to Emergency Medical Dispatch. We investigated whether demographic and hospitalization history information improved the identification of high-risk patients on time-critical emergency calls.

Methods: This follow-up study analyzed data from emergency calls in three Danish regions. ‘Time-critical’ was defined as suspected First Hour Quintet (FHQ) (cardiac arrest, chest pain, stroke, difficulty breathing, trauma). The association of age, sex, and hospitalization history with adverse outcomes was examined using logistic regression modeling. The predictive ability of the model was assessed via area under the curve (AUC) and Hosmer-Lemeshow (HL) tests.

Results: Of 59,943 FHQ patients (median age 63 years, 45% female), 44–45.5% had at least one chronic condition, and 3,880 (6.47%) died the day or the day after (day 1) calling 112. Age 30–59 years was associated with an increased adjusted odds ratio (OR) of death on day 1 of 3.59 [2.88–4.47]. Male sex was associated with an increased adjusted OR of death on day 1 of 1.37 [1.28–1.47]. Previous hospitalization with nutritional deficiencies (adjusted OR 2.07 [1.47–2.92]) and severe chronic liver disease (adjusted OR 2.02 [1.57–2.59]) was associated with a higher risk of death. For trauma patients, a prediction model including age, sex, and previous diagnoses showed discrimination with an AUC of 0.74 for death on day 1.

Conclusion: Age, sex, and hospitalization history was associated with increased risk of death on day 1 for FHQ 112 callers. This information shows promise as a prediction tool for trauma patient triage.

Introduction

Triage systems must balance patient needs and available resources. With the trend toward fewer larger emergency departments, along with increasing demand for prehospital emergency medical services in many health care systems, the design of triage systems has been the subject of debate and several research initiatives.[1, 2] Widely-used in-hospital triage systems like the Medical Emergency Triage and Treatment System, the Canadian Emergency Department Triage and Acuity Scale, and Adaptive Process Triage are based on information about the chief complaint combined with vital signs information.[3, 4] Emergency medical services also use systems that include vital signs information. Emergency Medical Dispatch triage systems that are used in Emergency Medical Communication Centers (EMCCs) face a distinct challenge. Specifically, unlike the in-hospital and prehospital triage in the ambulance, EMCCs do not have access to reliable clinical or para-clinical information. Rather, they rely exclusively upon information obtained by a telephone interview with patients, bystanders, or relatives.

Accurate triage is especially important for critically ill and severely injured patients. First Hour Quintet (FHQ) is a term that describes a group of emergency conditions for which the first hour after injury or debut of symptoms is considered to be essential. The FHQ consists of cardiac arrest, chest pain, stroke, breathing difficulties, and severe trauma.[5] The aim of this study was to investigate whether information about demographic factors and hospitalization history could improve the identification of high-risk patients in the triage of critically ill and severely injured patients as performed by EMCCs. Accordingly, we examined the association between age, sex, and hospitalization history and the risk of short-term adverse outcomes. Furthermore we determined the extent to which these factors predicted patient outcomes.

Methods

Setting

The telephone number used for all emergencies in Denmark is 112, and 112 calls are answered by the police or, in part of the capital, by the Fire Brigade. Calls concerning illness and injury are redirected to one of five regional EMCCs, which are staffed with nurses and paramedics as call-takers, technical staff as dispatchers, and medical doctors as supervisors. The call-takers use a criteria-based dispatch protocol, namely the Danish Index for Emergency Care.[(6)*] This protocol divides patients into five emergency levels and into 37 chief complaint groups. Assessment is based on systematic questioning of the callers according to the Danish Index for Emergency Care.

Study design and population

The study was designed as a historical follow-up study based on prospectively collected registry data. The study was conducted in three of the five EMCCs in Denmark; these EMCCs cover a combined population of 4,182,613 inhabitants (approximately 75.0% of the total Danish population).[†] Data were collected from mid-2011 through the end of 2012.

The study population was restricted to patients with symptoms of FHQ. The concept of FHQ was introduced by the European Resuscitation Council in 2002 and was defined by ICD-10 codes in the European

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[*] Danish Regions and The Laerdal Foundation for Acute Medicine. Available from [accessed 24.06.2014]: http://www.regionmidtjylland.dk/files/Sundhed/Pr%C3%A6hospital%20og%20Beredskab/Sundhedsberedskab%20-%20og%20pr%C3%A6hospital%20udvalg/Dansk%20Indeks%20version%201.2_010212.pdf

[†] Statistics Denmark. Available from[accessed 24.06.2014]: http://www.statistikbanken.dk/statbank5a/SelectVarVal/Define.asp?Maintable=FOLK1&PLanguage=1

Emergency Data Project.[(5)‡] Because 112 callers present with symptoms rather than diagnoses, we defined the five groups based on the chief initial complaint presented in the 112 call categorized according to the Danish Index. Information about the patient's civil registration number and the Danish Index code corresponding to the level of emergency, chief complaint, and specific subgroup symptom (list of included Index codes available from authors) was extracted from the dispatch software. The civil registration number is a unique 10-digit number assigned to all Danish citizens that enables unambiguous linkage among all public Danish registries. The Civil Registration System was established in 1968 and registers all persons living in Denmark. It has date of birth and sex information, as well as information that's updated daily regarding migration and changes in vital status (death).[(7)]

Covariates

The assessed demographic factors included patient age and sex. Demographic data were retrieved through the Civil Registration System described above. The hospitalization histories of the patients were obtained from the Danish National Registry of Patients (NRP). The NRP includes information about all admissions and visits to non-psychiatric hospitals, admissions dates, discharge dates, and discharge diagnoses classified according to the Danish version of the WHO's International Classification of Diseases, 10th edition (ICD-10) [(8)]. The history of hospitalization within the last ten years was described two ways: According to the Charlson Comorbidity Index[(9)] and according to a list of chronic conditions developed by Iezzoni et al.[(10)] The Charlson Comorbidity Index was originally constructed to predict the one-year mortality of admitted medical patients.[(11)] It consists of 19 different conditions that are each considered important for predicting patient outcome. Each condition is assigned a score from 1–6 according to its impact on mortality. We divided the index score into three

[‡] European Emergency Data Project report. Available from [accessed 24.06.2014]: http://www.eed-network.eu/assets/publications/eed_report_complete.pdf

categories: Charlson score 0, 1–2, and 3 and above. Iezzoni et al. compiled a list of 13 chronic condition categories that impact the risk of in-hospital death. The list by Iezzoni et al. was originally based on ICD-9 codes, but for the purpose of this study, two of the authors (Andersen and Johnsen) translated the list of chronic conditions into ICD-10 codes (available from authors).

Outcomes

The main outcome of the study was death the same day as the 112 call or the day after the 112 call, termed death day 1. The secondary endpoints included: death the same day as the 112 call (day 0); death 30 days after the 112 call (day 30); death the same day as the 112 call and/or admission to the intensive care unit (ICU); death the same day or the day after the 112 call and/or admission to the ICU; death 30 days after the 112 call and/or admission to the ICU. Vital status data (dead or alive) were retrieved from the Danish Civil Registration System. Information about admittance to an ICU was obtained via the Danish Intensive Care Database. The Danish Intensive Care Database is based on information from the National Registry of Patients and on ICU reporting to the database.[12, 13]

Statistics

The associations of age, sex, and hospitalization history with outcomes were studied using multivariable logistic regression. In order to ensure independence between observations, only the first call of each individual to 112 during the study period was included in the analyses. Two sets of covariates were used: one included age, sex, and hospitalization history and was categorized according to the Charlson Comorbidity Index; another, which also included age and sex, was categorized based on hospitalization history according to the Iezzoni chronic conditions list. The analyses were performed separately for all of the specified outcomes. In the regression analyses, each covariate was mutually adjusted for the other included covariates. Estimates are presented with 95% confidence intervals (95%CI).

The predictive ability of age, sex, and hospitalization history was assessed with discrimination and calibration analyses. Discrimination analyses were performed using area under the receiver operating curve (AUC). Discrimination describes the ability of a test to distinguish between those who got the outcome from those who did not. An AUC of 0.5 is equivalent to random prediction. Calibration analyses were performed using the Hosmer-Lemeshow test. The data were split into 10 groups, and the estimated values were compared with observed values in each group. A statistically significant *P*-value ($P<0.05$) for the Hosmer-Lemeshow test suggests that the model does not adequately fit the data. All logistic regression models outlined above were tested. In addition, age, sex, and hospitalization history were tested individually. Discrimination and calibration analyses were also performed after stratification of the FHQ into the five subgroups based on chief complaint.

Ethics

This study was approved by the Danish Data Protection Agency (reference numbers 2011-41-6326 and 2013-41-1598). According to Danish law, Ethics Committee approval was not needed since the study was based on routinely collected data.

Results

In the 18-month study period, a total of 314,134 calls to the 112 number were registered. Of these, 82,256 calls fitted the FHQ definition, and 69,982 (85.1%) had a valid civil registration number registered, enabling follow-up through linkage with registers. Only the first call during the study period from an individual was included in the analyses. This yielded 59,943 unique FHQ individuals that were eligible for further analysis. Median patient age was 63 years (interquartile range, 44–77 years), and 45% were female. A total of 45.5% of the callers had hospitalization histories with diagnoses that were included in the Charlson Comorbidity Index, whereas 44.0% had hospitalization histories with diagnoses included in the Iezzoni chronic conditions categories. Patient demographics, hospitalization histories, and fatalities are shown in Table 1, stratified according to the five FHQ groups.

In a multivariable model with age, sex and hospitalization history (based on the Charlson comorbidity categories), the adjusted OR for the death of males versus females on day 1 after a 112 call was 1.37 [1.28–1.47]. Increasing age was associated with increased risk of death at day 1, e.g. the adjusted OR was 3.59 [2.88–4.47] on day 1 for patients aged 30–59 compared to those aged 0–29 years. Of the 19 diagnosis groups in the Charlson Comorbidity Index, 13 were associated with an increased risk of death on day 1, and 10 were statistically significant associations with ORs from 2.02–1.10. These 10 diagnosis groups were metastatic solid tumor, mild liver disease, hemiplegia, moderate to severe renal disease, peripheral vascular disease, congestive heart failure, any tumor, ulcer, dementia, and chronic pulmonary disease. Two of the diagnosis groups included in the Charlson Comorbidity Index, myocardial infarction and cerebrovascular disease, were associated with a lower risk of death on day 1.

Of the 13 Iezzoni Chronic Conditions diagnosis groups, 10 showed statistically significant associations with an increased risk of death on day 1 with (ORs 2.07–1.13). These 10 groups were: nutritional deficiencies, severe chronic liver disease, metastatic cancer, cancer with a poor prognosis, chronic renal failure, congestive heart failure, peripheral vascular disease, dementia, diabetes with end organ damage, and chronic pulmonary disease. Three diagnosis groups were associated with a lower risk of death on days 0 and 1. Two of them, functional impairment and coronary artery disease were statistically significant.

Tests of the associations of the covariates age, sex, and hospitalization history with the outcome death on day 30 and the outcome of combined death and admittance to the ICU showed the same trends mentioned above. An exception was dementia that showed decreased ORs of death day zero or ICU admittance of 0.89 [0.75-1.04] and 0.86 [0.74-1.00] when adjusting for hospitalization history, as done by Charlson and Iezzoni respectively. All results regarding associations between the outcomes and age, sex, and hospitalization history are displayed in Table 2 (Charlson) and Table 3 (Iezzoni).

The ability of age, sex, and hospitalization history to predict patient outcome was tested using discrimination and calibration analyses. Concerning the main outcome, i.e. death on day 1, the full model, which included age, sex, and hospitalization history, showed AUC values of 0.70 (Charlson) and 0.69 (Iezzoni) with p-values from the Hosmer-Lemeshow test of 0.00. A statistically significant Hosmer-Lemeshow test (*P*-value <0.05) indicates little correspondence between patients who are predicted by the model to have the specified outcome and patients who are observed to have the specified outcome. This result is considered poor calibration. In contrast, a high Hosmer-Lemeshow test p-value indicates a big overlap between the observed and predicted outcomes, which is considered good calibration. When studying the contributions of the individual covariates to the prediction model, sex showed AUC values of 0.53 (Hosmer-Lemeshow test p-value 0.00). Age showed an AUC value of 0.65 (Hosmer-Lemeshow test *P*-value 0.00). Hospitalization history alone according to the Charlson Index showed an AUC value of 0.61 (Hosmer-Lemeshow test *P*-value 0.72), whereas hospitalization history alone according to the Iezzoni Chronic Conditions showed an AUC value of 0.61

(Hosmer-Lemeshow test *P*-value 0.00). The results of the discrimination and calibration analyses for the entire FHQ group are shown in Table 4.

After stratification of FHQ patients into the five main groups, the discrimination and calibration analyses were repeated on all outcomes (Table 5). Regarding the main outcome, death day 1, the stratified analyses yielded AUC values between 0.67 and 0.74 with p-values from the Hosmer-Lemeshow tests ranging between 0.00 and 0.99. An AUC value of 0.74 was obtained for trauma patients when hospitalization history was categorized using the Iezzoni Chronic Conditions. The calibration test in this group showed a p-value of 0.99. Chest pain patients showed a similar AUC value, 0.73, and a Hosmer-Lemeshow test p-value of 0.00 when using either the Charlson Comorbidity Index or Iezzoni Chronic Conditions to classify the hospitalization history.

Discussion

This study showed that approximately half of FHQ 112 callers have at least one important diagnosis from a previous hospitalization. This study also showed that increasing age, male sex, and several hospitalization history diagnosis groups are associated with increased risk of short-term adverse outcomes for 112 callers presenting with FHQ symptoms. Information about age, sex, and hospitalization history showed the potential to predict adverse outcomes, particularly for chest pain and trauma patients.

Data were collected prospectively in a real life setting, which is a major strength of the study. The study covered a large geographical area and included 3 different EMCCs, which contributed to the generalizability of the study. The large volume of patients contributed to high statistical precision in the data analyses. We used the Charlson Comorbidity Index and the Iezzoni chronic conditions to define relevant hospitalization history. They are, especially Charlson, well-established methods based on valid diagnoses from the patient's hospitalization history. [9, 10, 14] The Charlson Comorbidity Index was originally constructed to predict 1-year mortality among admitted medical patients. In that respect, the use of these indices could also be regarded as a study limitation, since neither the Charlson or Iezzoni indices were intended to predict outcomes in a prehospital setting. However, since there are no prehospital comorbidity indices, these indices represent a starting point for investigating the use of hospitalization history to predict risk in the prehospital setting.

One limitation of this study is that the civil registration numbers were missing for about 15% of the 112 callers identified as FHQ cases. If this was not random, it may have introduced selection bias into the study. The authors have no reason to believe that there is such a bias in the dataset.

The majority of the included diagnosis groups were associated with an increased risk of short-term adverse outcomes. In particular, cancers, liver and renal disease and congestive heart failure showed strong associations with larger OR values. Hemiplegia and nutritional deficiencies showed strong associations with increased ORs for adverse outcomes, as did chronic pulmonary disease, although the latter had a lower OR. Former myocardial infarction and cerebrovascular disease yielded statistically significant decreased ORs for adverse outcomes. Part of the explanation may be that patients who had myocardial infarctions or cerebrovascular disease tended to be “healthy” survivors of the original event, whereas non-survivors were not a part of this study. Another possible explanation is that they receive lifelong secondary medical prophylaxis, including antithrombotic, antihypertensive, and lipid-lowering therapies, which reduces the risk of death and recurrent cardiovascular events. Studies suggest that these survivors of the initial acute phase of their myocardial infarction live longer than, or at least as long as, the background population.[15] Furthermore, our study compares these patients to other 112 callers rather than to the background population, which may also partly explain the reduced ORs in these groups.

Around 45% of the patients in this study had diagnoses from prior hospitalizations that could be interpreted as important comorbidities. The comorbid conditions were not equally prevalent. Chronic pulmonary disease (n=9,325), cerebrovascular disease (n=8,119), and tumors (n=5,826) were the most prevalent conditions using the Charlson Comorbidity Index, whereas leukemia (n=189) and AIDS (n=67) showed low prevalence. Concerning Iezzoni Chronic Conditions, coronary artery disease (n=11,996), chronic pulmonary disease (n=9,289), and diabetes (n=6,043) were prevalent, and nutritional deficiencies (n=294) and AIDS (78) showed low prevalence.

Risk prediction tools like the Euroscore, Apache II score, and SAPS II score offer AUC values from 0.79 to 0.88.[16-18] These prediction tools are used in settings that are very different than the one in this study; notably, substantially more patient-time and information is available in those settings. A 112 call is an urgent call for help, and little information is available for making a rapid assessment. We examined the potential value of making information on age, sex, and hospitalization history available to the EMCC staff when they perform telephone-based triage. We focused on these factors since they can quickly be made available to the staff of some health care systems via electronic records if the staff can determine the identity of the patient.

In terms of predicting outcome in the chest pain and severe trauma subgroups, the results indicated that age, sex, and hospitalization history can provide valuable information. This information could be used to predict outcome and ultimately to identify 112 callers at high risk of adverse outcomes, and it may have enough predictive power to justify implementation of the use of information about age, sex, and hospitalization history into daily practice at EMCCs. Through the civil registration number and the well-organized registries of Denmark there are good conditions regarding an implementation of this tool as an automated part of the assessment process. In a future setup at the EMCC it would be possible for EMCCs, through the unique civil registration numbers, to retrieve demographic and hospitalization history data for 112 callers. If this were automated no time would be wasted in the telephone interview asking about a list of diagnoses. It should be noted that the Charlson and Iezzoni approaches to categorizing diagnoses may not be the best way to use hospitalization history information in emergency medical dispatching. Accordingly, development of a specific emergency medical dispatch comorbidity index may be warranted.

Conclusion

Age, sex and a wide variety of diagnosis groups from previous hospitalizations were associated with increased risk of short term adverse outcomes among FHQ 112 callers. As part of a prediction tool for predicting outcome among FHQ 112 patients, age sex and hospitalization history has limited impact on performance, but concerning the subgroups chest pain and severe trauma it appears promising.

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Table 1. First Hour Quintet (FHQ) 112 callers: Demographic information, hospitalization histories, and case fatalities.

FHQ group	Cardiac arrest	Chest pain	Stroke	Breathing difficulties	Severe trauma	**FHQ (all)**
All	6.136	19,747	11,687	9.376	12.997	59,943
Age, median (IGR)	67 (51–80)	64 (49–76)	72 (59–82)	69 (53–80)	37 (21–56)	63 (44–77)
Age 0–29, n (%)	659 (10.74)	1,188 (6.02)	461 (3.94)	1,156 (12.33)	5,284 (40.66)	8,748 (14.59)
Age 30–59, n (%)	1,554 (25.33)	6,970 (35.30)	2,532 (21.67)	1,881 (20.06)	5,008 (38.53)	17,945(29.94)
Age 60–89, n (%)	3,498 (57.01)	10,762(54.50)	7,758 (66.38)	5,808 (61.95)	2,546 (19.59)	30,372 (50.67)
Age 90–107, n (%)	425 (6.93)	827 (4.19)	936 (8.01)	531 (5.66)	159 (1.22)	2,878 (4.80)
Female (%)	2,609 (42.52)	8,767 (44.40)	5,728 (49.01)	4,863 (51.87)	5259 (40.46)	27,226 (45.42)
Hospitalization hist. Charlson[(12)] (%)	3,250 (52.97)	10,140(51.35)	6,718 (57.48)	6,664 (71.08)	2,314 (17.80)	29,086 (45.52)
Charlson score 0 (%)	2,886 (47.03)	9,607 (48.65)	4,969 (42.52)	2,712 (28.92)	10,683(82.20)	30,857 (51.48)
Charlson score 1–2 (%)	1,975 (32.19)	6,558 (33.21)	4,420 (37.82)	3,963 (42.27)	1,823 (14.03)	18,739 (31.26)
Charlson score >2 (%)	1,275 (20.78)	3,582 (18.14)	2,298 (19.66)	2,701 (28.81)	491 (3,77)	10,347 (17.26)
Hospitalization hist. Iezzoni[(13)] (%)	2,834 (46.19)	9,980 (50.54)	5,348 (45.76)	6,348 (67.70)	1,883 (14.49)	26,393 (44.03)
ICU admission, n (%)	349 (5.69)	250 (1.27)	375 (3.21)	456 (4.86)	367 (2.82)	1,797 (3.00)
Case fatalities day 0 (%)	2,544 (41.46)	173 (0.88)	236 (2.02)	316 (2.7)	111 (0.85)	3,380 (5.64)
Case fatalities day 1 (%)	2,662 (43.38)	235 (1.19)	372 (3.18)	478 (5.10)	133 (1.02)	3,880 (6.47)
Case fatalities day 30 (%)	3,003 (48.94)	622 (3.15)	1,056 (9.04)	1,332 (14.21)	243 (1.87)	6,256 (10.44)

Table 2. Hospitalization history categorized according to the Charlson Comorbidity Index.[9] Odds ratios (ORs) of death and ICU admittance, mutually adjusted.

	Death on day 1 OR [CI] (n)	Death on day 0 OR [CI] (n)	Death on day 30 OR [CI] (n)	Death on day 0/ICU OR [CI] (n)	Death on day 1/ICU OR [CI] (n)	Death on day 30/ICU OR [CI] (n)
Charlson comorbidity index category (n)						
Metastatic solid tumor (806)	2.02 [1.65–2.49] (137)	1.90 [1.52–2.37] (113)	2.47 [2.09–2.92] (261)	1.53 [1.25–1.86] (141)	1.65 [1.37–2.00] (163)	2.18 [1.86–2.57] (278)
Hemiplegia (282)	1.84 [1.22–2.77] (27)	1.62 [1.03 –2.55] (21)	2.18 [1.57–3.02] (49)	2.00 [1.44–2.76] (46)	2.14 [1.56–2.92] (51)	2.19 [1.64–2.93] (65)
Mild liver disease (1,250)	1.68 [1.36–2.07] (136)	1.70 [1.36–2.12] (120)	1.77 [1.49–2.12] (212)	1.47 [1.23–1.76] (193)	1.47 [1.24–1.76] (202)	1.59 [1.35–1.87] (262)
Moderate to severe renal disease (2,209)	1.30 [1.13–1.50] (262)	1.31 [1.13–1.52] (226)	1.38 [1.24–1.55] (466)	1.30 [1.15–1.48] (356)	1.31 [1.16–1.47] (383)	1.41 [1.27–1.57] (559)
Peripheral vascular disease (4,418)	1.31 [1.18–1.46] (492)	1.28 [1.14–1.44] (417)	1.33 [1.22–1.45] (846)	1.26 [1.15–1.38] (666)	1.28 [1.17–1.40] (722)	1.28 [1.18–1.39] (996)
Moderate to severe liver disease (378)	1.30 [0.92–1.83] (50)	1.20 [0.83–1.74] (42)	1.38 [1.03–1.85] (80)	1.39 [1.03–1.86] (72)	1.36 [1.02–1.82] (75)	1.45 [1.11–1.90] (100)
Dementia (1,661)	1.29 [1.10–1.52] (184)	1.10 [0.92–1.32] (136)	1.61 [1.43–1.82] (383)	0.89 [0.75–1.04] (177)	1.01 [0.87–1.17] (216)	1.41 [1.25–1.59] (406)
Congestive heart failure (5,638)	1.25 [1.13–1.38] (604)	1.27 [1.13–1.41] (519)	1.33 [1.23–1.44] (1,096)	1.20 [1.10–1.31] (808)	1.20 [1.10–1.31] (874)	1.28 [1.18–1.38] (1,276)
Any tumor (5,826)	1.24 [1.12–1.37] (655)	1.21 [1.09–1.35] (552)	1.51 [1.40–1.63] (1,244)	1.05 [0.96–1.15] (781)	1.09 [1.00–1.19] (871)	1.36 [1.27–1.47] (1,392)
Ulcer (2,443)	1.16 [1.01–1.34] (246)	1.14 [0.98–1.32] (207)	1.11 [0.99–1.25] (408)	1.10 [0.97–1.25] (328)	1.13 [1.00–1.27] (359)	1.08 [0.97–1.20] (484)
Chronic pulmonary disease (9,325)	1.10 [1.01–1.20] (810)	1.05 [0.96–1.15] (678)	1.35 [1.26–1.44] (1,511)	1.25 [1.17–1.34](1,251)	1.27 [1.18–1.36](1,347)	1.38 [1.30–1.46] (1,882)
Diabetes I+II (5,263)	1.10 [0.97–1.25] (502)	1,13 [0,99–1,30] (442)	1.10 [0.99–1.23] (847)	1.19 [1.07–1.32] (735)	1.17 [1.05–1.30] (776)	1.16 [1.05–1.27] (1,050)
Diabetes with end organ damage (3,035)	1.05 [0.90–1.24] (306)	1.06 [0.89–1.27] (269)	1.04 [0.91–1.19] (516)	1.01 [0.88–1.16] (435)	0.99 [0.87–1.14] (457)	1.00 [0.88–1.13] (623)
Connective tissue disease (2,054)	0.95 [0.80–1.12] (156)	0.98 [0.82–1.17] (137)	0.90 [0.79–1.04] (262)	0.90 [0.77–1.04] (210)	0.89 [0.77–1.02] (225)	0.91 [0.80–1.03] (322)
Lymphoma (381)	0.91 [0.63–1.31] (33)	0.86 [0.58–1.29] (27)	1.11 [0.85–1.46] (68)	0.98 [0.72–1.33] (49)	1.02 [0.76–1.37] (55)	1.18 [0.92–1.52] (86)
Cerebrovascular disease (8,119)	0.75 [0.68–0.83] (594)	0.71 [0.64–0.79] (484)	0.96 [0.89–1.03] (1,205)	0.77 [0.71–0.84] (834)	0.78 [0.73–0.85] (913)	0.93 [0.87–1.00] (1,432)
Leukemia (184)	0.72 [0.40–1.31] (12)	0.63 [0.32–1.24] (9)	1.34 [0.91–1.97] (35)	0.98 [0.62–1.54] (22)	1.03 [0.67–1.59] (25)	1.46 [1.03–2.07] (45)
AIDS (67)	0.72 [0.22–2.30] (3)	0.52 [0.13–2.15] (2)	1.00 [0.42–2.36] (6)	1.02 [0.46–2.25] (7)	0.98 [0.44–2.16] (7)	1.21 [0.61–2.40] (10)
Myocardial infarction (4,823)	0.66 [0.58–0.75] (327)	0.64 [0.56–0.74] (276)	0.68 [0.62–0.75] (582)	0.66 [0.59–0.73] (462)	0.66 [0.60–0.73] (498)	0.67 [0.61–0.73] (704)
Sex						
Male (32,717)	1.37 [1.28–1.47] (2,338)	1.41 [1.31–1.52] (2,069)	1.26 [1.19–1.33](3,585)	1.44 [1.36–1.52](3,600)	1.42 [1.35–1.51](3.801)	1.33 [1.26–1.39] (4,747)
Female (27,226)	1.00 [ref] (1,542)	1.00 [ref] (1,311)	1.00 [ref] (2,671)	1.00 [ref] (2,210)	1.00 [ref] (2,386)	1.00 [ref] (3,328)
Age groups, years						
0–29 (8,748)	1.00 [ref] (92)	1.00 [ref] (84)	1.00 [ref] (101)	1.00 [ref] (283)	1.00 [ref] (289)	1.00 [ref] (294)
30–59 (17,945)	3.59 [2.88–4.47] (698)	3.67 [2.91–4.61] (648)	4.08 [3.31–5.02] (898)	2.27 [1.99–2.59](1,324)	2.27 [1.99–2.59](1,354)	2.37 [2.08–2.69] (1,475)
60–89 (30,372)	8.40 [6.79–10.39] (2,733)	8.11 [6.49–10.12] (2,363)	11.49 [9.39–14.05](4,480)	4.13 [3.64–4.69](3,878)	4.29 [3.78–4.86](4,150)	5.20 [4.60–5.88] (5,511)
90+ (2,878)	13.21 [10.41–16.76] (357)	11.72 [9.11–15.08] (285)	26.89 [21.66–33.38] (777)	4.10 [3.46–4.86] (325)	4.87 [4.14–5.73] (394)	9.95 [8.59–11.52] (795)

Table 3. Hospitalization history categorized according to Iezzoni et al.[10](ref) Odds ratios (ORs) of death and ICU admittance, mutually adjusted.

Chronic condition (n)	Death on day 1 OR [CI] (n)	Death on day 0 OR [CI] (n)	Death on day 30 OR [CI] (n)	Death on day 0/ICU OR [CI] (n)	Death on day 1/ICU OR [CI] (n)	Death on day 30/ICU OR [CI] (n)
Nutritional deficiencies (294)	2.07 [1.47–2.92] (42)	2.00 [1.38–2.88] (35)	2.51 [1.89–3.34] (78)	1.83 [1.34–2.50] (51)	1.95 [1.45–2.46] (58)	2.39 [1.83–3.12] (90)
Severe chronic liver disease (554)	2.02 [1.57–2.59] (77)	1.99 [1.53–2.57] (68)	2.14 [1.73–2.66] (119)	1.66 [1.33–2.08] (98)	1.66 [1.33–2.07] (103)	1.86 [1.52–2.27] (138)
Metastatic cancer (872)	1.95 [1.61–2.37] (153)	1.88 [1.53–2.31] (128)	2.31 [1.97–2.71] (280)	1.48 [1.23–1.78] (159)	1.57 [1.31–1.87] (181)	2.01 [1.72–2.34] (298)
Cancer with a poor prognosis (1,491)	1.77 [1.52–2.07] (235)	1.63 [1.38–1.93] (192)	2.65 [2.34–3.00] (475)	1.32 [1.14–1.53] (251)	1.46 [1.27–1.68] (291)	2.28 [2.02–2.57] (511)
Chronic renal failure (1,492)	1.56 [1.33–1.83] (201)	1.55 [1.31–1.84] (173)	1.55 [1.35–1.77] (336)	1.47 [1.27–1.69] (262)	1.48 [1.29–1.70] (283)	1.54 [1.36–1.75] (399)
Congestive heart failure (6,035)	1.42 [1.28–1.57] (632)	1.43 [1.28–1.60] (544)	1.57 [1.45–1.71] (1,150)	1.36 [1.25–1.49] (852)	1.73 [1.25–1.49] (920)	1.50 [1.39–1.62] (1,347)
Peripheral vascular disease (3,102)	1.40 [1.24–1.59] (356)	1.34 [1.18–1.53] (298)	1.43 [1.29–1.58] (602)	1.32 [1.19–1.47] (479)	1.37 [1.23–1.51] (524)	1.38 [1.26–1.52] (714)
Dementia (1,902)	1.28 [1.10–1.49] (207)	1.09 [0.92–1.30] (155)	1.59 [1.41–1.78] (429)	0.86 [0.74–1.00] (201)	0.99 [0.86–1.13] (244)	1.37 [1.23–1.53] (455)
Diabetes with end organ damage (6,043)	1.24 [1.13–1.37] (588)	1.27 [1.15–1.41] (517)	1.22 [1.13–1.33] (976)	1.28 [1.18–1.39] (850)	1.26 [1.16–1.37] (899)	1.25 [1.16–1.35] (1,210)
Chronic pulmonary disease (9,289)	1.13 [1.04–1.23] (805)	1.08 [0.99–1.19] (675)	1.34 [1.25–1.43] (1,478)	1.26 [1.17–1.35](1,223)	1.27 [1.19–1.36](1,318)	1.36 [1.28–1.44] (1,834)
Functional impairment (4,215)	0.80 [0.70–0.90] (314)	0.80 [0.70–0.91] (267)	1.08 [0.98–1.18] (676)	0.89 [0.80–0.98] (466)	0.87 [0.79–0.96] (499)	1.06 [0.98–1.16] (807)
AIDS (78)	0.80 [0.29–2.24] (4)	0.67 [0.21–2.16] (3)	0.95 [0.42–2.15] (7)	1.03 [0.49–2.15] (8)	0.97 [0.46–2.03] (8)	1.11 [0.57–2.16] (11)
Coronary artery disease (11,996)	0.55 [0.50–0.60] (783)	0.55 [0.50–0.61] (671)	0.55 [0.51–0.59] (1,373)	0.56 [0.52–0.61](1,124)	0.56 [0.52–0.60](1,208)	0.55 [0.51–0.59] (1,687)
Sex						
Male (32,717)	1.40 [1.30–1.50] (2,338)	1.43 [1.33–1.54] (2,069)	1.30 [1.22–1.37] (3,585)	1.46 [1.38–1.55](3,600)	1.45 [1.37–1.53](3,801)	1.36 [1.29–1.43] (4,747)
Female (27,226)	1.00 [ref] (1,542)	1.00 [ref] (1,311)	1.00 [ref] (2,671)	1.00 [ref] (2,210)	1.00 [ref] (2,386)	1.00 [ref] (3,328)
Age group, years						
0–29 (8,748)	1.00 [ref] (92)	1.00 [ref] (84)	1.00 [ref] (101)	1.00 [ref] (283)	1.00 [ref] (289)	1.00 [ref] (294)
30–59 (17,945)	3.69[2.96–4.60] (698)	3.76 [2.99–4.73] (648)	4.23 [3.44–5.21] (898)	2.33 [2.04–2.66](1,324)	2.33 [2.05–2.66](1,354)	2.45 [2.16–2.79] (1,475)
60–89 (30,372)	8.82 [7.14–10.90] (2,733)	8.43 [6.75–10.52] (2,363)	12.58 [10.30–15.38](4,480)	4.29 [3.78–3.87](3,878)	4.48 [3.96–5.08](4,150)	5.63 [4.98–6.37] (5,511)
90+ (2,878)	14.09 [11.12–17.86](357)	12.30 [9.57–15.81] (285)	30.46 [24.55–37.79] (777)	4.24 [3.58–5.04] (325)	5.10 [4.34–5.99] (394)	11.02 [9.53–12.75] (795)

Table 4. Discrimination and calibration analyses of the entire study population of First Hour Quintet (FHQ) 112 callers show the predictive ability of all covariates.

Covariate	Death day 1	Death on day 0	Death on day 30	Death on day 0 or ICU	Death on day 1 or ICU	Death on day 30 or ICU
Sex, AUC/HL	0.53/0.00	0.54/0.00	0.52/0.00	0.54/0.00	0.54/00	0.52/0.00
Age, AUC/HL	0.65/0.00	0.64/0.00	0.68/0.00	0.61/0.00	0.61/0.00	0.65/0.00
Charlson, AUC/HL	0.61/0.72	0.61/0.90	0.66/0.00	0.59/0.70	0.59/0.51	0.64/0.00
Iezzoni, AUC/HL	0.61/0.00	0.61/0.01	0.65/0.00	0.59/0.00	0.60/0.00	0.63/0.00
Age, sex, and Charlson, AUC/HL	0.70/0.00	0.69/0.00	0.74/0.00	0.65/0.00	0.66/0.00	0.70/0.00
Age, sex, and Iezzoni, AUC/HL	0.69/0.00	0.68/0.00	0.73/0.00	0.65/0.00	0.65/0.00	0.69/0.00

AUC=Area under the receiver operating curve. HL=Hosmer-Lemeshow P-value.

Table 5. Discrimination and calibration analyses stratified according to First Hour Quintet (FHQ) group. Patients' hospitalization histories were categorized according to Charlson Comorbidity Index or Iezzoni Chronic Conditions as indicated.

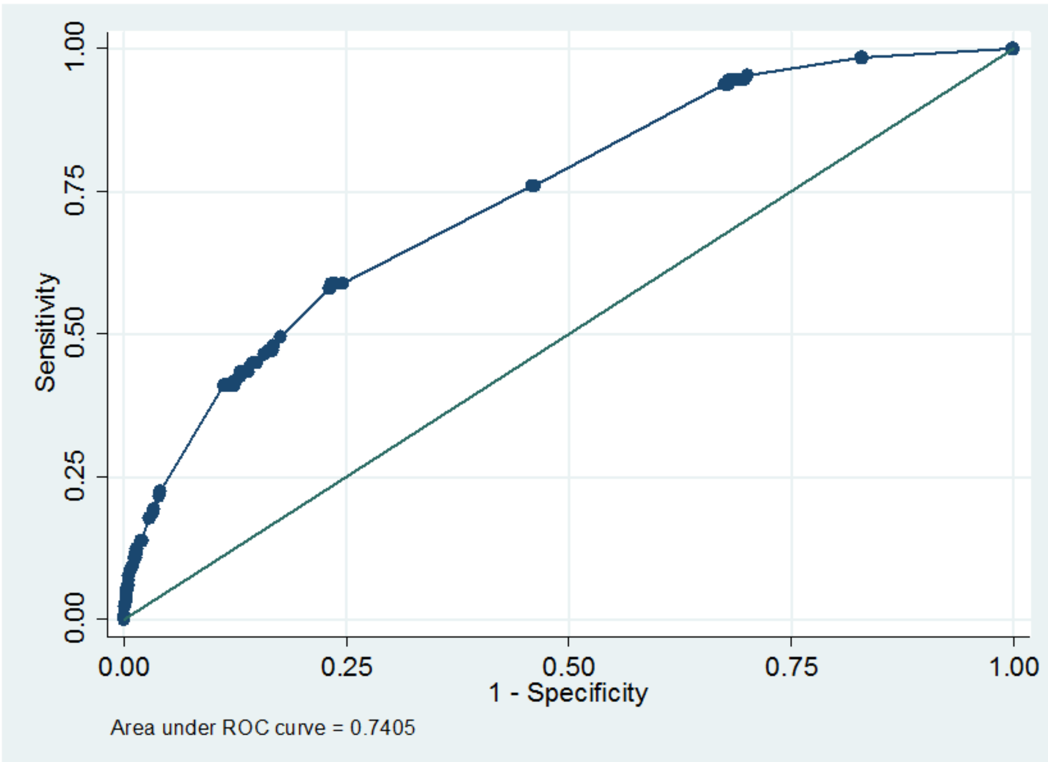
Charlson

Outcome	FHQ AUC/HL	Cardiac arrest AUC/HL	Chest Pain AUC/HL	Stroke AUC/HL	Breathing Difficulties AUC/HL	Severe Trauma AUC/HL
Death on day 1	0.69/0.00	0.69/0.00	0.73/0.00	0.67/0.23	0.71/0.00	0.73/0.00
Death on day 0	0.68/0.00	0.69/0.00	0.71/0.00	0.70/0.09	0.69/0.00	0.73/0.95
Death on day 30	0.73/0.00	0.71/0.00	0.76/0.00	0.72/0.00	0.73/0.00	0.81/0.00
Death on day 0 or ICU	0.65/0.00	0.69/0.00	0.67/0.00	0.62/0.03	0.63/0.00	0.65/0.26
Death on day 1 or ICU	0.65/0.00	0.70/0.00	0.68/0.00	0.61/0.07	0.69/0.00	0.65/0.16
Death on day 30 or ICU	0.69/0.00	0.71/0.00	0.72/0.00	0.66/0.20	0.69/0.00	0.68/0.08

Iezzoni

Outcome						
Death on day 1	0.70/0.00	0.69/0.00	0.73/0.00	0.67/0.00	0.71/0.00	0.74/0.99
Death on day 0	0.69/0.00	0.68/0.00	0.71/0.00	0.70/0.00	0.69/0.00	0.72/1.00
Death on day 30	0.74/0.00	0.71/0.00	0.77/0.00	0.71/0.00	0.74/0.00	0.80/0.75
Death on day 0 or ICU	0.65/0.00	0.69/0.00	0.67/0.00	0.62/0.03	0.63/0.00	0.65/0.72
Death on day 1 or ICU	0.66/0.00	0.69/0.00	0.69/0.00	0.61/0.00	0.64/0.00	0.65/0.58
Death on day 30 or ICU	0.70/0.00	0.70/0.00	0.73/0.00	0.66/0.00	0.70/0.00	0.67/0.80

Figure 1. Receiver operating curve (ROC) illustrating discrimination in the trauma group for the outcome death on day 1 using age, sex, and hospitalization history categorized according to Iezzoni et al.



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