When time counts:

Emergency medical dispatch

Exploring, understanding and addressing issues that impact upon timely and adequate allocation of prehospital medical assistance and resources to cardiac arrest patients

Camilla Hardeland

Dissertation for Philiosophia Doctor (PhD)
Institute of Clinical Medicine
Faculty of medicine
University of Oslo

2017
©Camilla Hardeland, 2017

Series of dissertations submitted to the
Faculty of Medicine, University of Oslo

ISBN 978-82-8377-070-4

All rights reserved. No part of this publication may be
reproduced or transmitted, in any form or by any means, without permission.

Cover: Hanne Baadsgaard Utigard.
Print production: Reprosentralen, University of Oslo.
# Table of Contents

Acknowledgement ................................................................................................................. 5
Abbreviations .......................................................................................................................... 7
List of papers ........................................................................................................................... 8
Preface .................................................................................................................................. 9
Introduction ............................................................................................................................. 10
  Out-of-hospital cardiac arrest and epidemiology ................................................................. 10
  The history of cardiac arrest ................................................................................................ 10
Chain of survival ....................................................................................................................... 11
Emergency medical communication centres ......................................................................... 13
  Organising EMCCs ............................................................................................................... 15
  Telephone-assisted CPR instructions ................................................................................... 17
Aims and objectives .................................................................................................................. 19
Methods ................................................................................................................................. 20
  Description of study sites .................................................................................................... 20
  Study design ....................................................................................................................... 22
Sampling strategy .................................................................................................................... 22
Data collection ........................................................................................................................ 23
  Paper I-III combined .......................................................................................................... 23
  Paper I .................................................................................................................................. 24
  Paper II ............................................................................................................................... 24
  Paper III ............................................................................................................................. 25
Analysis of interviews ............................................................................................................ 26
Statistical analysis ................................................................................................................... 28
Ethics and approvals .............................................................................................................. 29
Results .................................................................................................................................. 30
  Paper I ............................................................................................................................... 30
  Paper II ............................................................................................................................. 30
  Paper III ........................................................................................................................... 35
Discussion ............................................................................................................................... 36
  Discussion of results ......................................................................................................... 36
    Recognition of cardiac arrest and agonal breathing ......................................................... 36
    Measuring quality performance ..................................................................................... 40
    Time to first chest compression ..................................................................................... 41
  Discussion of methods ....................................................................................................... 42
    Quantitative methods .................................................................................................... 43
    Qualitative methods ...................................................................................................... 45
Limitations ............................................................................................................................... 45
Conclusions ............................................................................................................................ 47
Future perspectives

References

Appendices
  Appendix 1 Norwegian index for medical emergencies. Opening protocol
  Appendix 2 Norwegian index for medical emergencies. CPR instructions
  Appendix 3 Telephone CPR for adults – 1984
  Appendix 4 Data collection form non-participant observation

Reprint of papers I-III
Acknowledgement

First and foremost, I would like to express my infinite gratitude to my main supervisor Theresa M. Olasveengen. You have been there every step of the way, got me through small bumps in the road as well as insuperable difficulties, always with inspiration, great advice, coffee, and a sarcastic comment making me laugh of it all. As the brilliant mastermind behind this thesis, there would be no PhD without you. My sincere gratitude also goes to my co-supervisor Kjetil Sunde, who took it upon himself to be the motivator who encourage and build confidence whenever necessary, in addition to provide extensive professional input on manuscripts. My other co-supervisor, Helge Ramsdal, also deserves many thanks for invaluable help in qualitative research methods. My supervisor in my master thesis, Julianne Cheek, was of great inspiration to me and very much contributed to my interest in research. My participation in this study started out on her request, which I am very grateful for.

I have been very fortunate to be a part of the cardiovascular resuscitation research group at Oslo University Hospital. Initially, I was invited to this group by Petter Andreas Steen, to whom I owe many thanks. The remaining members of the group have been of invaluable inspiration to me, both as discussion partners, lunch partners and travel partners on miscellaneous conferences; Christiane Skåre, Arne Skullberg, Monica Thallinger, Hilde Karlsen, Per-Olav Berve, Henrik Stær-Jensen, Jan-Age Olsen, Lars Wik, and especially Jo Kramer-Johansen, who have shown a particular interest in the field of emergency medical dispatch.

Infrastructure was generously provided by Institute of Medical Experimental Research the first years of the study period. The last two years my work place has been at the Norwegian National Advisory Unit on Prehospital Emergency Medicine, where I have felt particularly welcomed by the generosity and warmth of Jan Erik Nilsen, Nora Seland, Ingvild Tjelmeland, Lars-Didrik Flingtorp and Siw-Lilly Osmundsen.

This research could not be performed without the collaboration and enthusiasm of all the participants in the study, and to all EMDs in Richmond EMCC, Oslo-Akershus EMCC, Vestfold-Telemark EMCC and Østfold EMCC, I am extremely grateful for your efforts and willingness to share your voice logs, thoughts and ideas with me. Especially thanks to the “door openers” and helpers at each place; Rob Lawrence, Danny Garrison, Linda Soilammi,
Rune Gehrken, Andreas Hansen, Sue Hebbert, Jon-Erik Steen Hansen, Fredrik Westmark, Trond Thoresen and Mailinn Odden.

This work was made possible through generous financial support from the University of Oslo, Institute of Clinical Medicine, and I wish to give a special thanks to Katrin Wirth-Petzold for going out of her way to help at all times. I have also been fortunate enough to be supported by grants from Laerdal Foundation for Acute Medicine. Laerdal Medical has also impacted on this work in other ways; Helge Myklebust and Tonje Birkenes has helped extensively in this thesis.

I have benefited tremendous from discussions and coffee drinking with fellow PhD students; my best friend and most ruthless critic Edel Jannecke Svendsen, Ann-Chatrin Leonardsen and Brita Fosser Olsen, thank you so much for support and encouragement whenever needed.

Finally, my closest family, parents and siblings deserve many thanks and appreciation for giving me the opportunity to complete this work by providing endless support and help in logistics, taking care of the kids, and solving everyday problems. Torunn, for proof reading this thesis in the middle of the night, Sten Erik, thank you for your patience, none of this would be achievable without you. And for my two wonderful children, Viktoria and Oskar, I am sorry for all the time I spent working on this, I will make it up to you in the near future.

Hvaler, January 2017

Camilla Hardeland
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AED</td>
<td>Automated External Defibrillator</td>
</tr>
<tr>
<td>AHA</td>
<td>American Heart Association</td>
</tr>
<tr>
<td>ALS</td>
<td>Advanced Life Support</td>
</tr>
<tr>
<td>BLS</td>
<td>Basic Life Support</td>
</tr>
<tr>
<td>CBD</td>
<td>Criteria Based Dispatch</td>
</tr>
<tr>
<td>CPR</td>
<td>Cardiopulmonary Resuscitation</td>
</tr>
<tr>
<td>EMCC</td>
<td>Emergency Medical Communication Centre</td>
</tr>
<tr>
<td>EMD</td>
<td>Emergency Medical Dispatcher</td>
</tr>
<tr>
<td>EMS</td>
<td>Emergency Medical Services</td>
</tr>
<tr>
<td>EMT</td>
<td>Emergency Medical Technician</td>
</tr>
<tr>
<td>ERC</td>
<td>European Resuscitation Council</td>
</tr>
<tr>
<td>MPD</td>
<td>Medical Priority Dispatch</td>
</tr>
<tr>
<td>OA-EMCC</td>
<td>Oslo-Akershus Emergency Medical Communication Centre</td>
</tr>
<tr>
<td>OHCA</td>
<td>Out-of-Hospital Cardiac Arrest</td>
</tr>
<tr>
<td>T-CPR</td>
<td>Telephone Assisted Cardiopulmonary Resuscitation</td>
</tr>
<tr>
<td>VF</td>
<td>Ventricular Fibrillation</td>
</tr>
<tr>
<td>VT-EMCC</td>
<td>Vestfold-Telemark Emergency Medical Communication Centre</td>
</tr>
<tr>
<td>WMA</td>
<td>World Medical Association</td>
</tr>
<tr>
<td>Ø-EMCC</td>
<td>Østfold Emergency Medical Communication Centre</td>
</tr>
</tbody>
</table>
List of papers

The thesis is based on the following papers, which are referred to in the text by their roman numerals:

Paper I:


Paper II:


Paper III

Preface

The cardiopulmonary resuscitation research team at Oslo University Hospital (OUH) is highly acknowledged for its contributions to emergency medicine, using both clinical and experimental methods, focusing on prehospital and in-hospital treatment of cardiac arrest. Historically, both within the research group and internationally, research was focused primarily on prehospital treatment in ambulances and in-hospital treatment.

In 2008 members of the research group discussed a knowledge gap in the chain of survival. Emergency medical dispatch is of vital importance for the outcome of cardiac arrest patients, but no research studies were performed in this field within the research group. Few international studies were conducted, but findings suggested low quality performance in emergency medical communication centres (EMCCs) in regard to cardiac arrest. Emergency medical dispatchers (EMDs) faced challenges in recognising cardiac arrest and initiating bystander CPR. At this time, Oslo – Akershus EMCC (OA-EMCC) reported high sick leave and turnover, without an obvious answer to which issues affected the work force. Nobody knew the quality performance of emergency medical dispatchers in Oslo EMCC in regard to cardiac arrest calls. As a consequence, the research group decided to conduct a research study in the field of emergency medical dispatch. However, questions were raised concerning the outcome of such a study. The aim was not just to measure quality performance, but intentions were made to further explore which challenges occurred and why, and how to use the competence of the emergency medical dispatchers to try to resolve some of the existing issues. However, all previous studies in the research group used quantitative methods and this was not an issue you could resolve by counting alone. There was a need for a new approach and members of the research group took contact with the Department of Nursing Science, Institute of Health and Society, University of Oslo and experts on qualitative methods.

At this point, I was in the process of completing my master thesis where qualitative methods were used. My supervisor, who had been contacted by the research group, invited me to participate in the introductory meetings. Two different disciplines met, and the collaboration between the two was the starting point for this thesis. Hopefully, we have succeeded in bringing the best of the two worlds together.
Introduction

Out-of-hospital cardiac arrest and epidemiology

Cardiac arrest is the abrupt loss of heart function. Etiologies are diverse, and current Utstein Resuscitation Registry Templates for out-of-hospital cardiac arrest (OHCA) define pathogenesis as either medical, traumatic cause, drug overdose, drowning, electrocution or asphyxial cause. Medical cause comprise cases in which the cause of the cardiac arrest is presumed to be cardiac, other medical cause (eg, anaphylaxis, asthma, GI bleed), and in which there is no obvious cause of the cardiac arrest (1). Medical etiology is predominant, reported by the Swedish cardiac arrest registry to include 92% of all OHCA cases from 1992-2014 (2). Historically, OHCA have been reported as cardiac and non-cardiac origin, with a majority of cases (55%-78%) having a presumed cardiac origin (2-6).

Incidence and survival rates vary widely across the globe. A review on global incidence and survival from 2010 reported Emergency Medical Services (EMS) attended 83.7 OHCA (all age groups) per 100 000 inhabitants and treated 34.7 OHCA per 100 000 inhabitants. Incidence of EMS treated OHCA was highest in North-America (54.6) somewhat lower in Australia (44.0) and Europe (35.0) whereas Asia (28.3) had the lowest incidence. Survival to hospital discharge varied from 2% to 11% across these regions (7). In Norway, there are approximately 3000 OHCA cases annually, with an incidence of 53 per 100 000 inhabitants per year per 2015. Survival rates of ambulance treated OHCA in 2015 was 15.6% (8).

The history of cardiac arrest

For much of recorded history, death has been viewed as irreversible. Attempts to reverse death were considered impossible, or even blasphemous, for both religious and scientific reasons. In the late 18th century, the idea that resuscitation was possible got foothold, especially focusing on the search for artificial ventilation. To understand why, we have to see deaths during the 18th century in their medical context. People generally died from accidents, infectious disease, drowning and smoke inhalation from fires, very rarely from cardiovascular disease. One of the first accounts of mouth-to-mouth resuscitation in the 18th century was in a fire victim, in whom a Scottish surgeon applied his mouth to the patients’ mouth, blew his breath as strong as he could, and experienced that the air came out of the patients’ nostrils. He blew again with one hand taking hold of the nostrils, and the patients’ chest fully rised. A heartbeat was subsequently discovered (9). One of the earliest descriptions of external chest
compressions are from the mid 19th century, when a professor of surgery at the University of Pest, Hungary, successfully resuscitated a patient by exerting bellows-like rhythmic pressure to the front of the chest (10). From the early beginning of anecdotal descriptions of resuscitation attempts, 200 years passed before resuscitation techniques were developed to a degree that made the reversibility of cardiac arrest a practicality in the mid 20th century (9). In 1958 Safar and Elam showed the usefulness of mouth-to-mouth artificial ventilation (11). Kouwenhoven, Jude and Knickerbocker developed a method of external chest compressions which became the applied therapy on sudden cardiac arrest patients at John Hopkins Hospital (Baltimore) from 1959 (12, 13). In 1961 Peter Safar published the landmark article “Ventilation and Circulation with Closed-Chest Cardiac Massage in Man”, introducing modern CPR (14). In parallel, external defibrillation was developed to induce electric countershock for patients in VF (15-17).

At present, CPR training conveys the same principles of chest compressions and artificial ventilations. Current international guidelines on resuscitation for CPR recommends that adults receive chest compressions between 5 and 6 cm deep at a rate of at least 100 to 120 per minute. CPR providers trained and able to perform ventilations should combine chest compressions and ventilations with a ratio of 30:2 respectively. The overall sequence for performance of CPR is described in ERC Guidelines for Resuscitation 2015 (18).

International guidelines for cardiopulmonary resuscitation recommend CPR training of both lay people and health care personnel in an effort to improve survival from OHCA (19, 20). Programs for educating lay people are widely implemented internationally, both for school children, adults and high-risk populations (21, 22). To ensure effective CPR training, simulation with debriefings is recommended, both for lay people and health care personnel (19, 20, 23).

**Chain of survival**

In 1991 the American Heart Association (AHA) published a scientific statement describing the “Chain of survival” (Figure 1) (24, 25). It outlines standard principles of system management and consists of a sequence of events that can improve survival of sudden cardiac arrest (25). Today, the concept of chain of survival is implemented in international guidelines for resuscitation and described as “the vital links needed for successful resuscitation” (18, 26). The chain of survival includes (1) early recognition of the emergency and call for help, (2) early CPR, (3) early defibrillation and (4) early advanced life support (ALS) and standardised post-resuscitation care. The chain of survival is like a relay where all links as well as the exchange between links must function optimally to maximise the chance for survival.
Figure 1 The chain of survival

*Early recognition* of an occurred OHCA is essential for prompt EMS activation and initiation of bystander CPR. Key observations in cardiac arrest are unresponsiveness and abnormal breathing (18). Recognition of cardiac arrest is challenging both for bystanders and EMDs, mainly due to the presence of agonal breathing (27-32). Studies on recognition of cardiac arrest by EMDs report wide variations; between 56 and 98% of OHCA are recognised by EMDs (27, 30, 32-37). Failure to recognise cardiac arrest during emergency calls is associated with decreased survival (30).

*Early bystander CPR* is highly associated with increased survival from cardiac arrest (18, 38-42). CPR can maintain the presence of VF and buy time until defibrillation can be performed. However, bystander CPR rates are low in many communities (18, 43). A one month analysis of OHCA outcomes in 27 countries in Europe showed bystander CPR rates varying from 6.3% to 78% (44). In Norway, bystander CPR rates are high, the national cardiac arrest registry reported 79% bystander CPR in 2015 (8). Several approaches have proved to be successful in improving bystander CPR rates. Community CPR training, mass CPR training events and targeting family members of patients with cardiovascular disease can all increase bystander CPR rates (41). It is reasonable to assume that the number of bystanders trained in CPR will impact on the first link in the chain of survival; early recognition and call for help.

Several studies have found that telephone assisted CPR instructions (T-CPR) offered by EMDs in emergency calls concerning OHCA can increase bystander CPR rates significantly (32, 36, 45). A large cohort study from King County (USA) with data from 1983 to 2000 indicated improved survival when T-CPR was performed compared with those who did not receive bystander CPR before EMS arrival (46).
Early defibrillation within 3–5 minutes of collapse can produce survival rates as high as 50–70% (18, 47). Each minute of delay before defibrillation reduces the probability of survival to discharge by 3-5% (48, 49). International guidelines for CPR from the European Resuscitation Council (ERC) and the American Heart Association (AHA) 2015 emphasise the importance of providing an AED on-scene before ambulance arrival, and recommend public access AED programmes are actively implemented in public places with high population density. Guidelines specifically recommend EMDs to direct bystanders to retrieve nearby AEDs when possible (18).

Early ALS and standardised post-resuscitation care. ALS includes advanced interventions after BLS has started, such as advanced airway management, vascular access and administration of medications. (50). AHA guidelines highlight that standardised post-resuscitation care must include identification and treatment of the precipitating cause of cardiac arrest combined with the assessment and mitigation of ischemia-reperfusion injury to multiple organ systems. Examples of standard post-resuscitation care is acute cardiovascular interventions, such as coronary angiography, maintaining haemodynamic stability, targeted temperature management, seizure management and respiratory care (51).

Optimal outcome for the cardiac arrest patient depends on high quality performance in all links in the chain of survival. Single factors are less important than how and how quickly all the treatments are put together, and the primary obstacle to effective treatment is time (9). Emergency medical dispatchers (EMDs) can be involved in the first three links in the chain of survival. They need to be equipped with appropriate guidelines, knowledge and experience to be able to quickly recognise OHCA, offer T-CPR and instructions to retrieve AEDs within a short period of time in order to provide best possible care for OHCA patients.

Emergency medical communication centres

The emergency medical communication centres and dispatchers are part of the emergency medical services (EMS). Their function is to answer emergency calls, identify callers’ needs and dispatch available and appropriate resources. The European Resuscitation Council (ERC) Guidelines 2015 highlights the critical importance of the interactions between the EMD, the bystander who provides CPR and the timely deployment of an automated external defibrillator (AED). They state that an effective, coordinated community response that draws these elements together is the key to improving survival from out-of-hospital cardiac arrest (18). In calls concerning cardiac arrest, the EMDs role is to quickly identify
cardiac arrest, determine exact location, rapidly dispatch appropriate resources, provide pre-arrival instructions for bystander CPR, and locate and dispatch automated external defibrillators (18, 52).

When CPR instructions are offered to bystanders per telephone by an EMD, it is referred to as T-CPR. ERC guidelines for resuscitation 2015 recommend that T-CPR should involve chest-compression-only CPR for adult victims of OHCA, unless a trained provider is already delivering CPR. If the victim is a child, T-CPR should involve both chest compressions and ventilations (18).

**The history of emergency medical communication centres**

In terms of organisation and research, emergency medical dispatch is a relatively new field. However, a need for transportation of critically ill or injured patients have been recognised since the Napoleonic wars (53), where some of the first records of prehospital treatment and triage systems were developed. In 1794 Baron Dominique Jean Larrey recognised that permitting wounded soldiers to remain on the battlefield for days without treatment increased both their morbidity and mortality. He therefor introduced a system where trained medical personnel initiated treatment and transported the wounded to a field hospital (54). Means of communication to organise transportations were of course limited, but the discovery of telephonic communication along wires by Alexander Graham Bell in 1875 opened up to new opportunities in prehospital emergency medicine. Telephone wires developed for a number of years and even in the earliest days of voice telecommunications, there was an awareness of the need for means to establish communications in case of emergency. Initially, all calls were handled by an operator, who would transfer the emergency call to the nearest ambulance station. The first mobile telephone was developed in the earliest years of the 20th century and was used to report a train robbery and actually contributed to the bandits' arrest at around 1907 (55). In 1937 the United Kingdom was the first country to implement a national emergency telephone number, using the number 999 (56). In the United States, the 3-digit emergency number 911 was introduced during the late 1950s, but not introduced nationwide until 1968. It was regulated by law as a national emergency number in 1999 (57). Today most countries have an emergency number, but throughout the continents there are no uniform emergency number. Both in South America, Africa and Asia there are a variety of different numbers in use. In Europe the common emergency number is 112, following Directive 2002/22/EC – Universal Service Directive (58), but in Norway the medical emergency number is 113.
The development of EMCCs in Norway was not regulated by law until 1989. The county of Hordaland was the first to develop a model for establishing an EMCC, after the so-called “Hordalandsmodellen” (59). The design and planning of the model started in 1981 and was a cooperation between health, police and fire services and Televerket (60), a state-operated telephone service in Norway. The first EMCC was established at Haukeland Hospital, Bergen, May 10\textsuperscript{th} 1984. Legislators decided to postpone national regulations to ensure establishment of EMCCs until decisions could be based on experiences from “Hordalandsmodellen” (61). Four years later, July 1\textsuperscript{st} 1989, changes were made to the Hospital Act “lov om sykehus m.v. (sykehusloven)” from 1969 (62) and “lov om helsetjenesten i kommunene (kommunehelsetjenesteloven)” from 1982 (63) holding the Norwegian government responsible for establishing a set of regulations for EMCCs and the county municipalities responsible for establishing EMCCs in selected hospitals. Today the laws regulating EMCCs in Norway are primarily “lov om spesialisthelsetjenester” from 1999 (64), lov om kommunale helse- og omsorgstjenester m.m. (helse- og omsorgstjenesteloven) (65) and “lov om helsepersonnel m.v.” (66) further regulated by “forskrift om krav til og organisering av kommunal legevaktssordning, ambulanstjeneste, medisinsk nødmeldetjeneste, mv. (akuttmedisinforskriften)” §§ 12-20 from 2015 (67). In 1998 there were 44 EMCCs throughout Norway. Today EMCCs are centralised and there are currently (2017) 16 EMCCs covering all parts of Norway.

**Organising EMCCs**

The primary goal of EMCCs was originally limited to coordination of ambulance dispatch. Today the EMCCs execute a high level of decision-making in terms of triage and provision of pre-arrival instructions to ensure lifesaving first aid before ambulance arrival, including T-CPR. The term “triage” is derived from the French word *trier*, to sort, and was originally used to describe the sorting of agricultural products. At present triage commonly refers to the distribution of medical resources to patients. Triage may be used in an extended sense to refer to any decision about allocation of medical resources, but in its primary sense it is conditioned by a scarcity of health care resources, assessments of a patients’ medical needs and use of an established system, usually based on an algorithm or a set of criteria, to determine a specific treatment or treatment priority for each patient (68). Triage is an essential part of the EMDs objective, aiming to send the right EMS resources to the right person at the right time in the right way, and to provide the right instructions for the care of the patient until help arrives (69). Different EMCCs possess different resources, but common EMS resources include
ambulances, helicopters, motorcycle units, physician staffed vehicles and first responders, such as fire fighters and police officers. In addition, ERC guidelines for CPR recommend implementations of public access AED programmes to allow EMDs to direct CPR providers to a nearby AED (18).

Primarily, there are two different emergency medical dispatch systems widely in use throughout the world; Medical Priority Dispatch (MPD) and Criteria Based Dispatch (CBD).

*Medical Priority Dispatch*

MPD was developed by Jeff Clawson in the United States in the late 1970s. MPD has a set of standardised protocols to triage patients via the telephone and thus improve the emergency response system. It includes three essential components: interrogation questions, known as key questions, telephone help, known as pre-arrival instructions, and response determinants for the level of response and the use of warning lights and siren (53). MPD does not require the EMD to be medical personnel, but trained in the software based decision-making program.

*Criteria Based Dispatch*

In 1990, King County introduced a new EMD system; Criteria Based Dispatch (CBD) (70). CBD is a triage program that is based on patient signs and symptoms. It has structured opening questions and provides direction and assist in decision-making without structuring the course of action to the point that it becomes restrictive or limits the EMDs' ability to quickly gather critical information and take action. In CBD, guidelines are used to define appropriate levels of care in order to assist EMDs in determining course of action (71). CBD relies on individual EMDs ability to correctly recognise the severity of the condition and allocate appropriate resources. The dispatch system in use in Norway is CBD and the current dispatch decision support tool is the Norwegian Index for Medical Emergencies (NIM, Appendix 1 and 2) (72) This tool was derived from the original CBD guidelines in King County, and further developed by a board of Norwegian physicians in 1994. It consists of standardised questions categorising complaints into specific protocols with different degrees of urgency in an effort to standardise emergency dispatch service.
**Telephone-assisted CPR instructions**

Emergency medical communication centres were established with the primary goal of dispatching ambulances to the right place, and also reducing unnecessary ambulance transports (53). EMDs, whether in medical, fire, or police dispatch centres, tended to have little or no specific medical training. The EMDs job was more that of a telephone operator’s than a paramedic’s, firefighter’s, or police officer’s (73). In 1975, an EMD in Phoenix, Arizona, gave unplanned and unscripted pre-arrival CPR instructions to the mother of a non-breathing baby. The baby survived, and the Phoenix fire chief instructed all EMDs in Phoenix to routinely give such pre-arrival instructions, known as “medical self-help”. No formal script or protocol was used (53). This was the very beginning of T-CPR.

During the early 1980s a research team in King County/Seattle developed, tested and implemented a template for T-CPR (74-76). The effect of implementation showed that overall bystander CPR increased from 45% to 56 %. Dispatcher-assisted CPR increased from 9% to 23% (45). The first systematic template for T-CPR resembles many of the present protocols, which are widely in use in different dispatch systems (appendix 3).

Bystander CPR algorithms are described in detail in international guidelines (26, 77), and several studies have investigated the effect of T-CPR (32, 36, 78). However, no recommendations are given on how to instruct callers to do CPR, although most T-CPR protocols follow the recommended two sequel questions to determine if a patient is in cardiac arrest; is the patient responsive and breathing normally (18).

For optimal provision of T-CPR, a number of factors in the chain of survival have to be successfully handled, both by EMD and bystander. The sequence of events that make up the dispatching process include identification of patient needs and address, decision of priority, definition and dispatch of response and assistance by telephone if indicated (79). In this process, there are many opportunities for delay and potential barriers to overcome. Some are in the hands of the EMDs, but some barriers cannot be overcome only by EMD interventions. Fukushima et al explored the distributions of barriers to T-CPR identifying the following barriers: (1) the caller leaving phone, (2) the caller not being with patient, (3) CPR instructions being refused, (4) caller in emotional distress, (5) difficult access to the patient, (6) a language barrier, (7) an inability to place victims on a hard, flat surface, (8) a physical inability to perform CPR, and (9) the caller hanging up the phone before CPR instruction (80). Concordant barriers were found by Ho et al (34). These studies explored barriers to performance of T-CPR when a need for T-CPR was recognised. Most barriers are due to circumstances at scene and out of the hands of the EMD. Language barriers can be addressed.
in multiple approaches, such as third party telephonic interpretation, use of on-scene bystanders, reliance on multilingual coworkers in the dispatch centre, and alteration of speech patterns (81). However, the single most important barrier for initiation of T-CPR is lack of recognition of cardiac arrest.

Berdowski et al found that the most important reason for not recognising cardiac arrest was insufficient questioning. As an example, in half of cases not recognised by EMDs, they did not ask about breathing. In 20% they did ask if the patient was breathing but misinterpreted answers confirming breathing as a sign of circulation when specific type of breathing never was described (30). These findings are supported by Dami et al who found that half of all missed OHCA cases were due to poor breathing assessment (27). Introduction of, and adherence to, scripted protocols for delivering T-CPR are indicated as effective measures to improve recognition of cardiac arrest (32, 82-84). Different protocols are in use in different EMCCs without any consensus on which protocols are most effective. However, ERC guidelines recommend that protocols include specific questions designed to recognise cardiac arrest, specifically questions about responsiveness and abnormal breathing (18).

In approximately 40-60% (29, 85-87) of the cardiac arrest cases, the unconscious patient continues to have some form of breathing after the arrest occurs, sometimes up to several minutes. This abnormal breathing represents a brain stem response to ischemia and is usually referred to as "agonal breathing" (88). Agonal breathing is associated with increased survival (85, 87), but presence of agonal breathing along with the unexpected nature of the OHCA itself, often makes it difficult for bystanders and EMDs to recognise OHCA. This can potentially leave the patient with suboptimal or no treatment at all until arrival of ambulance personnel.

Recommendations on how to provide T-CPR are limited. Health care personnel and EMDs are highly educated in performing CPR, but not necessarily in how to provide high quality T-CPR. Standard EMD education in Norway recommended by KoKom, (National Centre on Emergency Communication in Health) include five modules in which all should be followed by testing of the individual dispatchers. The five modules consist of; laws and regulations, responsibilities and tasks, caller communication, information and communication technology (ICT) and ethics (89). At present, no national education for EMDs exist, but there is broad cooperation between EMCCs in developing curriculums for new employees, based on the five modules described.
Aims and objectives

The overall aim in this thesis was to provide a comprehensive description and analysis of factors impacting EMDs when handling cardiac arrest calls in order to develop strategies to improve uptake and translation of current evidence based guidelines into best practice. By identifying factors/issues affecting both the use and usefulness of current cardiac arrest treatment protocols, we aimed to contribute to understandings on how knowledge can be successfully translated into practice in emergency medicine to ensure optimal treatment for patients suffering cardiac arrest. Specific objectives of the thesis were;

Paper I:

The aim of this study was to compare two commonly used medical dispatch tools in handling cardiac arrest calls; Medical Priority Dispatch (MPD) used in Richmond, USA and Criteria Based Dispatch (CBD) used in Oslo and Akershus, Norway. Primary outcome was defined as time to chest compressions performed from dispatch-assisted CPR instructions, secondary outcomes were recognition of cardiac arrest, provision of telephone instructions, response intervals and protocol adherence.

Paper II:

The aim of this study was to explore, understand and address issues impacting upon timely and adequate allocation of prehospital medical assistance and resources to OHCA patients. This includes provision of timely and optimal ambulance dispatch and telephone CPR, adherence to evidence based protocols (Norsk Indeks for Medisinsk Nød hjelp) and how the specific cardiac arrest protocol is in three different Norwegian EMCCs.

Paper III:

In this study we sought to evaluate the effectiveness of performance based education, training and feedback on cardiac arrest call handling in our EMCC. In-depth analysis of quality of care during the baseline period utilising observations, interviews and cardiac arrest call process measures were used to develop a tailored education and training bundle including key issues identified by both EMDs and research team (37). These key issues were included in traditional lectures, web-based e-learning and simulation training. Primary outcome was recognition of cardiac arrest, and secondary outcomes were time to telephone assisted chest compressions and bystander CPR.
Methods

Various study designs were selected in order to explore and describe how cardiac arrest calls are handled, and how to address possible barriers to ensure optimal treatment of cardiac arrest patients. The initial step was to compare two different dispatch systems (paper I). This yielded further questions about the Norwegian dispatch system, and the next study went on to more thoroughly explore how cardiac arrest calls are handled in our criteria based dispatch systems (paper II). These results formed the basis for an education and training intervention that was implemented and evaluated at Oslo-Akershus EMCC (OA-EMCC) (paper III).

Description of study sites

In all three papers we have described results from four study sites; one in The United States; Richmond EMCC (R-EMCC), and three in Norway; OA-EMCC, Vestfold-Telemark EMCC (VT-EMCC) and Østfold EMCC (Ø-EMCC). The four study sites have different organisations and protocols, and the following is a description of the four study sites:

Richmond EMCC

R-EMCC serves a population of 202 000 (over one million during working day). They dispose a total of 32 ambulances, and in 2011 they conducted 56,000 responses and 42,000 transports. All 16 staff members in the EMC centre are trained and qualified as EMDs, but not necessarily health care personnel of origin. R-EMCC operates an MPD based system with a cardiac arrest protocol prescribing compression only CPR in arrests of presumed cardiac origin. Staff members respond to an average of 11 cardiac arrest calls per year.

Oslo-Akershus EMCC

OA-EMCC is part of OUH. OA-EMCC covers the regions of Oslo, Akershus and Rømskog consisting of both rural and urban areas and a population of 1,2 million people. In 2013 OA-EMCC received approximately 315 000 calls of which approximately 124 000 were emergency calls. The region has 45 regular ambulances at its disposal in addition to one single paramedic manned ambulance, one motorcycle unit, and one physician staffed rapid response vehicle. In addition, OA-EMCC is responsible for two physician staffed helicopters. OA-EMCC employs 25 emergency medical technicians (EMTs)/paramedics coordinating ambulance responses and 29 registered nurses answering emergency calls.
Before the study period in paper III, standard dispatch education at OA-EMCC included three weeks of theoretical education focusing on technical skills, medical knowledge and laws and regulations, followed by approximately two months practical one-on-one training in call handling. Less than one hour was allocated training on recognition of cardiac arrest and CPR instructions. EMDs had annual training in performing CPR themselves, but minimal training on how to instruct bystanders to initiate and perform CPR.

*Vestfold-Telemark EMCC*

VT-EMCC serves a population of approximately 400,000, and deploys 31 ambulances at 15 stations. It is staffed by registered nurses with additional training in emergency medical dispatch answering emergency calls, and EMTs/paramedics coordinating ambulance responses. The VT-EMCC has on-site training in telephone triage and dispatch, and keeps the staff professionally updated with regular courses and training days. In 2013 they responded to 32,776 emergency calls and handled a total of 63,025 calls, resulting in 47,486 ambulance assignments. VT-EMCC uses a locally designed protocol with reduced opening lines and specific key words for OHCA suspicion. Instructions in CPR for adults recommend compression-only CPR for all OHCAs except those with hypoxia or trauma.

*Østfold EMCC*

Ø-EMCC is operated by Østfold Hospital Trust and covers a population of 287,000 people. It deploys 23 ambulances, and delivers emergency and non-emergency services to the city and nearby community. Ø-EMCC is staffed by registered nurses with additional EMCC training answering emergency calls, and EMTs/paramedics coordinating ambulance responses. The nurses rotate between work in the dispatch centre and as clinical nurses in the emergency room. Ø-EMCC employs 21 EMDs each responding to an average of eight OHCA calls annually. Ø-EMCC handles almost 110,000 calls per year, respond to approximately 42,000 calls of which approximately 28,000 are emergency calls.

*Cardiac arrest protocols*

In Richmond-EMCC the cardiac arrest protocol prescribed compression only CPR in arrests of presumed cardiac origin. In all Norwegian study sites, the cardiac arrest protocol during the study period prescribed standard CPR with compression and ventilation (30:2) if presumed respiratory or traumatic cause of the arrest. If presumed cardiac cause (adults) OA-EMCC and Ø-EMCC followed the current dispatch tool in use in Norway (72) and prescribed chest compression only CPR the first ten minutes of the call then moving on to standard
CPR (30:2). VT-EMCC used a locally designed protocol with reduced opening lines and specific key words for OHCA suspicion. Chest compression only CPR were recommended in all adult OHCA cases with no instructions to move on to standard CPR after ten minutes.

**Study design**

Paper I was a retrospective, observational study, performed in two different study sites comparing two different dispatch systems, MPD and CBD.

Paper II was a descriptive and exploratory study with a mixed method design. Mixed methods may be defined as “research in which the investigator collects and analyses data, integrates the findings and draws inferences using both qualitative and quantitative approaches or methods in a single study” (90). The rationale for using a mixed methods design in this study was that quantitative data as collected in all three papers describe quality of care, but do not provide understandings about why quantitative data show similar challenges and barriers yet differences in results. Hence, we aimed to use qualitative data to explore results from quantitative data in paper I and II.

Paper III was a prospective experimental study with a pretest-posttest design implementing targeted interventions in OA-EMCC. Pretest-posttest design involves data collection before and after introducing an intervention (91).

**Sampling strategy**

Consecutive cardiac arrest cases were identified from respective cardiac arrest registries of ambulance confirmed arrests in all three papers. In Paper II, study sites were specifically selected based on purposive sampling method. This entails selecting information rich cases for in-depth study. Information rich cases are those “from which one can learn a great deal about issues of central importance to the purpose of the study” (92). Maximum variation purposive sampling aims to capture and describe the central themes that cut across a great deal of variation, and any common patterns emerging from great variation are of particular interest. Value is placed on capturing the core experiences and central, shared dimensions of a setting or phenomenon (92).
Maximum variation in our three study sites in paper II was captured by:

- **Location:** metropolitan vs. non-metropolitan/remote. OA-EMCC is the only metropolitan EMCC in the study. VT-EMCC and Ø-EMCC are both located in smaller cities in Norway. All sites cover remote areas, but there are large variations in population density. VT-EMCC covers a large geographical area of more than twice the size of OA-EMCC, but only one third of the population.

- **Size:** OA-EMCC is the largest EMCC in Norway, serving 1.2 million inhabitants vs Ø-EMCC being one of the smallest serving 282 000 inhabitants. VT-EMCC is somewhere in between serving 372 000 inhabitants.

- **Organisation of EMCCs:** In OA-EMCC and VT-EMCC EMDs work only with dispatch, vs in Ø-EMCC EMDs rotate half the time through ambulance or emergency room shifts.

Interview participants in paper II were selected from specific criteria; cardiac arrest calls representing all three categories of recognised arrests (arrest recognised, not recognised and delayed recognition) were identified and corresponding EMDs were asked to participate in an interview.

**Data collection**

*Paper I-III combined*

Digitalised voice recordings of cardiac arrest cases were audited. Clarification of consciousness and normal breathing was used to evaluate protocol compliance. Recognition of cardiac arrest and incidence of pre-arrival instructions with appropriate time intervals were recorded. Additional information was obtained from respective computer based programmes containing automated time records and EMDs’ codes, as well as ambulance records. The following cases were excluded:

- patients not in cardiac arrest at time of call
- caller not present at the scene
- cases without need for CPR instructions (health care facility, medical personnel at scene, or on-going CPR at scene)
- cases where calls were interrupted before recognition of cardiac arrest was possible
- cases with missing or corrupted audio files
Cardiac arrest was classified as recognised by the EMD when one of the following criteria were met:

- CPR instructions offered
- documented as cardiac arrest in dispatch chart
- cardiac arrest was unmistakably described by person with patient, but CPR instructions were not offered due to circumstances at scene

Absence of normal breathing was classified as clarified if the EMD recognised OHCA or asked specifically if the patient was breathing normally. In paper I we identified a number of patients receiving suboptimal treatment due to delayed recognition of cardiac arrest. Hence, we included the third group “delayed recognition” when reporting recognition of cardiac arrest in paper II and III. “Delayed recognition” was defined as failure to initially clarify consciousness or abnormal breathing before moving on to further questioning regarding other symptoms or patient history.

**Paper I**

All consecutive OHCA calls were retrospectively collected during a one year period. Originally OHCA cases were selected from the same time period, but due to the identification of differences in data collection method, final data collection was made between May 1st 2010-April 30th 2011 in the MPD site, and January 1st – December 31st 2007 in the CBD site.

**Paper II**

*Collection of quantitative data*

All consecutive adult OHCA calls during a one-year period in three different study sites were prospectively registered and audited, from Jan 28th 2013 to Jan 31st 2014, from Jan 1st 2013 to Dec 31st 2013, and from April 1st 2013 to Mar 30th 2014.

*Collection of qualitative data*

**Non-participant observations**

We performed on-stage non-participant observations at the three EMCCs. Non-participant observations were performed by the researcher entering the EMCCs to observe events, activities, and interactions with the aim of gaining an understanding of the EMCC centre in its natural context. As a non-participant, the observer did not participate directly in the activities
being observed (93) although reflective conversations in-between took place to clarify aspects of what was observed (92). Observations focused on physical surroundings, interactions with and between EMDs, workload and intensity and use of protocols. A data collection form based on validated principles from the observational methodology literature was developed for this study (Appendix 4) (94).

**In-depth interviews**

In-depth interviews are useful to achieve a holistic understanding of the participants’ point of view; it can also be used to explore interesting areas for further investigation (92). In-depth interviews addressed challenges and barriers, but also promoting factors, in daily work to identify factors affecting the delivery of what was considered “optimal” treatment. Numbers of interviews were not decided beforehand. In keeping with principles of qualitative method, data collection would continue until saturation (92). Saturation is reached when new data yield redundant information (95). The interviews focused particularly on three themes: (1) the selected cardiac arrest case and cardiac arrest calls in general, (2) the use of relevant protocol, and (3) contextual conditions, such as work environment (social and physical), work load, organisational factors and leadership.

**Paper III**

Data collection was performed in OA-EMCC, pre-intervention from Jan 28th 2013 – Jan 31st 2014 and post-intervention from May 14th – Dec 31st 2014. OHCA cases were identified from the Oslo University Hospital cardiac arrest registry.

The intervention consisted of four different approaches;

1) *One-day training program* divided in two segments. The first half of the day consisted of lectures concerning

- preliminary results from the cardiac arrest study performed in OA-EMCC
- information about agonal breathing and challenges that might occur
- practical advice on T-CPR
- future plans for improving T-CPR in OA-EMCC

2) *Simulation training* including five different scenarios where all participants simulated both the role of the EMD and the caller. The scenarios were progressively difficult with themes developed based on challenges identified pre-intervention (agonal breathing, paediatric arrest,
health care provider as caller, difficult/distressed caller). An extended protocol focusing on continuous coaching was introduced. All scenarios were followed by debriefing with two or more moderators in each group.

3) Structured EMD feedback where EMDs were informed about their own performance in all cardiac arrest cases they answered to during the study period, both in the pre- and post-intervention. Details about recognition of cardiac arrest, protocol compliance and relevant time intervals were provided to all EMDs.

4) Electronic telephone-assisted CPR training program, the “Telecommunicator CPR Training Course”, developed by an interdisciplinary team in Seattle, consisting of emergency physicians, paramedics, EMTs, CPR instructors, education experts and EMDs (96). The training program consisted of the following modules: (1) Introduction with general information about cardiac arrest, (2) General information about CPR and the heart, (3) Recognition of cardiac arrest, (4) Advice on how to coach effective CPR, (5) Special circumstances EMDs can experience, such as CPR for children or the use of AEDs, and (6) summary and practice of all previous information put together. Each module had real-life audio files to exemplify issues raised in the text and were followed by self-assessment questions that all had to be answered correctly to proceed in the program.

All parts of the training program were made mandatory for all EMDs (both ambulance coordinators and call takers) and the one-day training program was repeated six times to ensure all EMDs would complete the program. EMDs were given 3 hours of a workday to complete the electronic telephone-assisted CPR training program.

Analysis of interviews
All interviews were digitally recorded and transcribed verbatim. Data analysis of interviews in paper II ensured consistency and rigor in the analytical process by being iterative and involved several readings of the data and discussions between the first author (CH) and co-authors (TMO, HR, KS). All data were analysed manually, but to be able to organise the massive amount of data HyperRESEARCH 3.7.3. Computer Software, Researchware, Inc., 2015 was used.
Data analysis were based on Malterud’s method “Systematic text condensation”, a strategy for quality analysis consisting of 4 steps:

1. Total impression – from chaos to themes,

2. Identifying and sorting meaning units – from themes to codes

3. Condensation – from code to meaning

4. Synthesising – from condensation to descriptions and concepts (97)

*Step 1. Total impression – from chaos to themes.*

We started out with a read-through of all the material to establish an overview of the data. In total, the 19 interviews consisted of 761 transcribed pages. We focused on the main issue concerning recognition of cardiac arrest but were also able to identify several themes of interest coinciding with the original theme. Altogether, 18 different themes were identified from the data of which 14 were associated with recognition of cardiac arrest. This yielded 132 pages.

*Step 2. Identifying and sorting meaning units – from themes to codes*

We systematically read through the text line by line to identify meaning units. Three researchers were involved in this work to ensure rigour in the analysis. In keeping with the strategy of systematic text condensation, only parts of the whole text were considered meaning units, and 365 meaning units were identified. All meaning units were given one or several codes. Originally, 26 different codes were assigned to the meaning units. After scrutinising and discussing the different codes, they were merged into five overall themes, following the chronological order of a cardiac arrest call;

1) Platform of knowledge,

2) Assessment of the situation

3) Assessment of breathing

4) Indicators of cardiac arrest other than breathing

5) Decision on starting telephone assisted CPR instruction.

All meaning units were assigned to the different groups.
Step 3 Condensation – from code to meaning

This step of analysis implies systematic abstraction of meaning units within each of the code groups. We created new condensed text based on meaning units within the code group. This gave a systematic overview of the data. During this process, code groups were adjusted, according to the evolving understanding, and new suggestions for themes/subgroups were made. This was also done as a team work with three researchers (CH, TMO, KS) discussing the groups. Final groups were the following:

1) Protocol use and platform of knowledge
   Subgroups:  a) Use and non-use of protocols
   b) Education and training

2) Situational assessment
   Subgroups:  a) Caller – EMD collaboration (relationship/cooperation)
   b) Circumstances at scene

3) Interrogation strategy/assessment of breathing
   Subgroups:  a) Assessment of breathing
   b) Indicators of cardiac arrest other than breathing

Step 4 Synthesising – from condensation to descriptions and concepts

During this step, data were reconceptualised, to put the pieces together again. Three researchers (CH, TMO, KS) discussed how to synthesise the contents of the condensates and descriptions and concepts were discussed. For the purpose of exploring factors impacting upon recognition/non-recognition of cardiac arrest within the limitations of a research article, potential barriers or problem areas were targeted when presenting the data.

Statistical analysis

Statistical calculations in all three papers were performed using a spreadsheet program (Microsoft Excel 2007 and 2011 for Mac, Microsoft Corp, Redmond, WA, USA) or a statistical software package (SPSS 19.0 and 23.0 SPSS Inc., Chicago, IL, USA). Values were given as numbers with percentages or medians with 95% confidence intervals. Categorical outcome data were analysed using 2-sided Fishers exact test in paper I and Pearson chi-squared test in paper II and III. Comparisons of continuous data were done with independent samples non-parametric Mann-Whitney U-tests in paper I and III and a non-parametric independent-Samples Kruskal-Wallis Test in paper II. P-Values ≤ 0.05 were considered significant.
Ethics and approvals

The Declaration of Helsinki is a statement of ethical principles for medical research involving human subjects, including research on identifiable human material and data. It was published by The World Medical Association (WMA) in 1964 and has been amended seven times since, most recently in October 2013. All studies (paper I-III) were conducted in accordance with the Declaration of Helsinki, specifically incorporating principles of informed consent, right to withdraw, privacy and confidentiality (98). All patient data were de-identified during data collection by assigning a number to each case and deleting information about date, place and name. When data collection was complete, assigned numbers were deleted and data were anonymised. EMDs participating in interviews were informed about the study’s aims and methods, anticipated benefits and potential risks of the study, and gave written consent in each case. They were informed of the right to refuse to participate in the study or to withdraw consent to participate at any time without reprisal. This was done in accordance with the Declaration of Helsinki, which describe that the research protocol must be submitted for consideration, comment, guidance and approval to the concerned research ethics committee before the study begins (98).

In Norway, the Regional Committees for Medical and Health Research Ethics (REC) are responsible for approving medical and health related research projects. The committees are appointed by the Ministry of Education and Research for a four-year term and are founded on the Norwegian law on research ethics and medical research, the Health Research Act (99). The aim of the Health Research Act is to promote good quality, ethically acceptable medical and health research. REC carries out an assessment as to whether research is undertaken in an acceptable manner. This entails the consideration of benefit versus risk and whether data protection is assured (100). The original research protocol for paper I included auditing voice recordings from both trauma and cardiac arrest and was approved by REC Nov 20th 2006. (Reference no. 682-062861.2006.1056). Exemption from confidentiality were given from the Ministry of Social Affairs 29.01.2007 (Reference no. 06/4845). Research protocol for Paper II and II was considered by REC not to be a medical or health related research project, and did not need REC approval, except for exemption from confidentiality (Reference no. 2012/1611/A). However, approval from local data protection officials was obtained (Reference no. 2012/9029) Approved exemption from confidentiality to selected individuals involved in data collection, assured access to patient data without the need to obtain informed consent from patients or callers identified in voice recordings.
Results

All three papers measured and evaluated performance standards for cardiac arrest calls at various EMCCs using similar key metrics. See table 1 for an overview of performance found in all papers combined. While there were differences in adherence to identification algorithms, recognition of arrest and efficiency in providing CPR instructions between the sites, failure to recognise cardiac arrest due to misinterpretation of agonal breathing was a common challenge for all EMCCs.

**Paper I:**
Few differences were observed when comparing MPD and CBD. Both MPD and CBD systems were highly efficient in clarification of respiratory arrest and consciousness. Initial clarification of normal breathing was only done in 28% vs. 36% respectively (p=0.17) of calls in the MPD vs. CBD systems. Recognition of cardiac arrest was also similar; 82% vs. 77%, respectively (p=0.42). The most frequent reason for not recognising cardiac arrest was misinterpretation of agonal breathing in both systems. Pre-arrival CPR instructions were offered in 81% vs. 74% in the MPD vs. CBD systems, respectively (p=0.22). In both systems, the most frequent reason for not offering CPR instructions was failure to recognise cardiac arrest. Both systems dispatched ambulances efficiently, although the MPD system was 18 seconds faster compared to the CBD system (15 seconds vs. 33 seconds, respectively, p<0.001). Telephone assisted CPR instructions lead to chest compressions more frequently (65% vs. 31%, p<0.001) and rapidly (3.7 vs. 4.3 minutes, p=0.001) in the CBD system compared to the MPD system. Ventilations were also delivered more frequently in the CBD system (31% vs. 3% respectively, p= 0.001).

**Paper II:**
The overall protocol adherence was high for all sites, with consciousness and respiratory arrest being clarified for almost all calls at all the sites. However, there were significant site differences in most key metrics with one site (VT-EMCC) consequently performing better than the other two. Universally the most frequent reason for delayed or failed recognition of cardiac arrest was misinterpretation of agonal breathing. There were no significant differences in time to chest compression instructions or performance of actual chest compressions.
Table 1. Efficacy of recognition of cardiac arrest and pre-arrival CPR instructions

<table>
<thead>
<tr>
<th></th>
<th>Paper I</th>
<th>Paper II</th>
<th>Paper III</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MPD</td>
<td>CBD</td>
<td>p-value</td>
</tr>
<tr>
<td>Number of cases</td>
<td>N= 100</td>
<td>N=140</td>
<td></td>
</tr>
<tr>
<td>Adherence to identification</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>algorithm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>clarification of consciousness</td>
<td>100 (100)</td>
<td>136 (97)</td>
<td>0.14</td>
</tr>
<tr>
<td>- clarification of breathing</td>
<td>100 (100)</td>
<td>137 (98)</td>
<td>0.27</td>
</tr>
<tr>
<td>clarification of normal breathing</td>
<td>28 (28)</td>
<td>51 (36)</td>
<td>0.17</td>
</tr>
<tr>
<td>Recognition of cardiac arrest</td>
<td>82 (82)</td>
<td>108 (77)</td>
<td>0.42</td>
</tr>
<tr>
<td>immediate recognition</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>delayed recognition</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cardiac arrest not recognised</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reasons for lack of recognition</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>misinterpretation of agonal breathing</td>
<td>13 (13)</td>
<td>26 (19)</td>
<td></td>
</tr>
<tr>
<td>poor adherence to algorithm</td>
<td>0 (0)</td>
<td>4 (3)</td>
<td></td>
</tr>
<tr>
<td>no obvious/other</td>
<td>2 (2)</td>
<td>1 (1)</td>
<td></td>
</tr>
<tr>
<td>CPR instructions started</td>
<td>81 (81)</td>
<td>103 (74)</td>
<td>0.22</td>
</tr>
<tr>
<td>chest compressions performed</td>
<td>31 (31)</td>
<td>90 (65)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>mouth-to-mouth performed</td>
<td>3 (3)</td>
<td>43 (31)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>CPR stopped due to agonal breathing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OA-EMCC</td>
<td>300 (90)</td>
<td>137 (96)</td>
<td>74 (72)</td>
</tr>
<tr>
<td>VT-EMCC</td>
<td>326 (98)</td>
<td>143 (100)</td>
<td>96 (93)</td>
</tr>
<tr>
<td>Ø-EMCC</td>
<td>331 (99)</td>
<td>143 (100)</td>
<td>99 (96)</td>
</tr>
<tr>
<td>P1</td>
<td>298 (90)</td>
<td>219 (95)</td>
<td></td>
</tr>
<tr>
<td>P2</td>
<td>296 (89)</td>
<td>218 (95)</td>
<td></td>
</tr>
</tbody>
</table>
| Values given as numbers (percentages).
Non-participant observations were performed in all three EMCCs. In each EMCC observations were made over a period of two times four hours, in daytime- and evening shifts. Observations gave an overview and insights in the EMCCs, both concerning organisation and the call taking process. Results are summarised in the following:

Physical surroundings:

There were large variations in size in the three EMCCs. Ø-EMCC had a small room with four desks close together, VT-EMCC had a larger, more open room with extensive open space and seven desks throughout the room. OA-EMCC was extensively larger, yet limited open space, they had twelve desks and numerous cabinets for the staff. Ø-EMCC and VT-EMCC had four computer screens at each desk, in OA-EMCC there was an additional fifth screen not in use at the time of observations. Computer programs coincided in all three EMCCs.

Call taking process:

In Ø-EMCC and VT-EMCC ambulance coordinators often answered emergency calls when needed and both call takers and ambulance coordinators monitored most calls simultaneously. In OA-EMCC, ambulance coordinators were not observed answering emergency calls or monitoring calls after obtaining a correct address. Telephone number and location of the address was the first thing asked by EMDs, before moving on to collecting information about patient symptoms. Communication between call taker and ambulance coordinator was largely based on the electronic documentation system, but verbal and non-verbal communication was often used to get attention, such as snapping fingers, standing up, pointing or speaking out loud. Several processes occurred simultaneously; caller interrogation, electronic documentation, communication between EMDs, potential communication with other health care resources and monitoring of ambulance location.

Working environment

At daytime Ø-EMCC was staffed by three EMDs (one emergency call taker, one ambulance coordinator for emergency calls and one ambulance coordinator within health services), VT-EMCC was staffed by five EMDs, (two emergency call takers, two ambulance coordinators for emergency calls and one ambulance coordinator within health services) and OA-EMCC was staffed by ten EMDs (four emergency call takers, three ambulance coordinators for emergency calls, one ambulance coordinator within health services and one EMD in charge, responsible for larger incidents). All three EMCCs were frequently visited by EMS staff,
management, IT-services, apprentices and students. A lot of communication and discussion between EMDs occurred, conversations were of both professional and private character.

*Use of Norwegian index for medical emergencies (NIM)*

Different approaches on how to use NIM were observed. Some EMDs used both the opening protocol and symptom descriptions meticulously and used their index finger to ensure that all lines were spoken correctly and all correct questions were asked. Others would not open NIM at all through most of the conversations; one EMD did not open NIM throughout the entire shift. Many observations were made of NIM being used after an extended interrogation and in many cases NIM were used solely to define level of urgency.

**Interviews**

Nineteen EMDs were interviewed, ten from OA-EMCC, the largest dispatch centre, five from VT-EMCC, and four from Ø-EMCC. Fourteen women and five men with median age 44 (range 29-62) were selected based on a recent cardiac arrest call, and interviewed about the challenges they had faced and how they tried to solve these challenges during the specific call. The following three main themes emerged with subsequent groups:

1) Protocol use and platform of knowledge  
   a) Use and non-use of protocols  
   b) Education and training  
2) Situational assessment  
   a) Caller – EMD collaboration (relationship/cooperation)  
   b) Circumstances at scene  
3) Interrogation strategy/assessment of breathing  
   a) What is normal breathing?  
   b) Indicators of cardiac arrest other than breathing

*Protocol use and platform of knowledge*

Most of the time EMDs would follow protocol, but some found it necessary to deviate and rather base their decisions on their own experience, competence and intuition. Both experienced and inexperienced EMDs considered that following a protocol would be more useful if you were inexperienced, indicating a belief that competence and intuition improved with experience and could to some extent replace the need for a strict protocol. For example,
several EMDs indicated that the best tool to assess normal breathing was broad experience. It was frequently described that experience and competence of the individual EMD was the main basis for decision making in general, and that you bring your own background and attitudes into the work as a EMD.

Several of the EMDs expressed concerns regarding education and training. Some of them had never had any feedback on their work, and felt there was little or no focus on cardiac arrest calls. EMDs who had these concerns wanted more education and training, both traditional theoretical education and practical training such as simulation training and listening to/reviewing real cardiac arrest cases.

Situational assessment

Key factors in the process of recognising cardiac arrest were visualisation of the scene and circumstances in each particular situation, and a positive collaboration between caller and EMD. Barriers to good communication and collaboration could be language problems, or the caller was not willing or able to receive instructions in a particular situation. The caller could convey emotional response through tone of voice, use of certain words and non-verbal cues indicating that the patient was in a critical condition, and this would trigger the EMD to suspect cardiac arrest even before information about breathing and consciousness was established. On the other hand, the emotional state of the caller could also be a barrier to recognition of cardiac arrest if the caller was calm and did not express signs of an ongoing emergency.

Interrogation strategy/assessment of breathing

EMDs in general found it difficult to assess normal breathing. Each of them had their own definition of “normal breathing” and individual interrogation strategies. Several examples of relevant questions were suggested, displaying the wide variety of interrogation strategies. Several EMDs argued that other questions apart from breathing are relevant to recognition of cardiac arrest. Face/lip/skin colour was often highlighted as the main “red flag” for recognition of cardiac arrest. Normal skin colour was considered a sign that the patient was not in cardiac arrest and if it was difficult to assess whether or not the breathing was normal, skin colour could be the determining factor for recognition of cardiac arrest. Snoring respiration in combination with normal skin colour was the most common symptom to lead
the EMD to abstain from CPR instructions in spite of abnormal breathing. Snoring respiration was often considered a distinct sign of a cerebral incident, not cardiac arrest.

_Paper III_

EMDs improved their performance in all key quality metrics after the intervention was performed. Immediate recognition of cardiac arrest improved from 69% to 89% (p<0.001), and delayed recognition was reduced from 21% to 6% (p<0.001). Cases that were recognised as OHCA at any time during the call (included cases with delayed recognition) improved from 89% to 95% (p=0.024). However, agonal breathing continued to challenge EMDs, but misinterpretation of abnormal breathing decreased from 25% to 10% (p<0.001) of calls. Chest compressions performed by bystanders increased from 71% to 83% (p=0.002) and median time to first chest compression was reduced from 3.3 to 2.8 minutes (p=0.015).
Discussion

This thesis adds perspectives on issues that impact upon timely and adequate allocation of prehospital medical assistance and resources to cardiac arrest patients. We demonstrated that EMCCs of various organisation, size and location all share similar barriers to recognition of cardiac arrest and timely provision of chest compressions. By exploring these barriers, both by traditional quantitative performance metrics, as well as by observations and in-depth interviews, effective strategies to improve quality of care could be developed. But this exploratory descriptive study did not only uncover areas for EMD improvement, our findings also made us question the accuracy and usefulness of our current protocol and definition of cardiac arrest. There is an urgent need to further clarify when and which type of “abnormal breathing” indicates a person may be in cardiac arrest, and implement this into our EMD education and training.

The following discussion is divided in two parts; Discussion of results and Discussion of methods. The discussion of results will focus mainly on recognition of cardiac arrest and measurement of key quality metrics, whereas the discussion of methods will provide reflections of the strengths and weaknesses of our chosen methodologies.

Discussion of results

Recognition of cardiac arrest and agonal breathing

The three papers describe four different EMCCs, differing in culture, organisational structure, protocols, and size as well as EMD background and competence. In spite of all these differences, challenges concerning recognition of cardiac arrest and misinterpretations of agonal breathing are found in all four EMCCs at some level, similar to previous findings from different parts of the world (27, 29-31, 101, 102). Fukushima et al found that patients who expose some form of breathing are less likely to receive T-CPR than patients being described as “not breathing” (27.8% vs. 84.2%, p<0.001) (29). Consequently, a large number of cardiac arrest patients throughout the world receive suboptimal treatment due to misinterpretation of agonal breathing. Paper II aimed to further explore this issue of recognition of cardiac arrest by using qualitative methods to provide an understanding of why this challenge continues to persist despite increasing knowledge and awareness of this problem.
Findings from interviews led us to question the very definition of cardiac arrest. International guidelines define cardiac arrest as an unconscious patient with abnormal breathing (26, 77). This definition is widely accepted, and in an effort to increase bystander CPR, the importance of “rapid activation of the EMS and prompt initiation of bystander CPR” is advocated whenever patients meet these criteria (26, 77). Hesitation to start T-CPR due to uncertainties on cardiac arrest, could potentially rob the patient the opportunity to receive life-saving bystander CPR. CPR will not inflict serious injuries if initiated on patients not in cardiac arrest (83, 103). Still, the current definition of cardiac arrest is problematic for two reasons:

1) The definition is inaccurate, and EMDs frequently handle calls where patients may be unconscious, not breathing normally, but still obviously not in cardiac arrest.

2) Even when accepting the definition of cardiac arrest as unconscious and “not breathing normally”, abnormal breathing is not further defined, leaving it up to EMDs to assess what is normal breathing and what is not, and which type of abnormal breathing is consistent with cardiac arrest, and which is not.

Inaccurate definition of cardiac arrest

A great number of patients can be unconscious and not breathe normally without having a cardiac arrest. Patients with cerebral incidents, seizures, diabetes or drug overdoses can all potentially display similar symptoms and these patient groups outnumber cardiac arrest patients by far. A cohort study of EMD-assisted bystander CPR, showed that nearly half of the patients for whom EMDs offered CPR instructions were not in cardiac arrest (103). Berdowski et al argued that if protocol compliance was strict and CPR instructions were initiated in all cases where breathing was described as abnormal or absent, 100% of cardiac arrests would be recognised, but the false-positive rate (cardiac arrest was suspected, but not present) would be 76% (30). They argued that this approach would be beneficial for cardiac arrest patients, but have both financial and organisational implications. When a protocol defines cardiac arrest as a patient being “unconscious and not breathing normally”, assessment of whether or not a patient is in cardiac arrest is left to the individual EMD and this should be acknowledged and deserves more attention. Interviews in paper II revealed that EMDs use a variety of skills and clinical experience when making decisions, not just the protocol. As an example:
“To assess the patient I use a hotchpotch of knowledge, experience, protocol, colleagues and intuition” (Paper II).

Although it makes sense to simplify this definition to lay people, we have to acknowledge that protocols are not used in a vacuum. EMDs’ experience, competence and knowledge exceed that of a lay person and will necessarily be part of decision-making. When experienced EMDs have strong suspicions that the case might not be a cardiac arrest, they tend to ask additional questions. The definition of cardiac arrest is perceived as too simple, and being limited to only two questions to clarify consciousness and breathing is not always enough to achieve a clear comprehension of the situation. In these cases EMDs potentially deviate from their protocol, and interpret answers to additional questions individually. In some cases they decide not to offer T-CPR although the patient is unconscious with abnormal breathing. In interviews EMDs justified this action with a desire to provide the patient with best possible care. Performing CPR on a patient not in cardiac arrest was perceived as a serious error with potential harm to the individual as well as unnecessary use of limited resources.

Cardiac arrest protocols in Norway include dispatch of two ambulances and instructions to keep the caller on the phone until ambulance arrival. When decision-making is based on EMDs own competence, some patients will receive more optimal treatment by avoiding unnecessary CPR in patients not in OHCA. Nurmi et al found that protocol compliance was significantly higher in false negative cases (cardiac arrest present, but not suspected by EMD) and false positive (cardiac arrest suspected, but not present) calls compared with correctly identified cardiac arrests (104). However, when EMDs do not trust the accuracy of the definition of cardiac arrest and base their decisions on experience rather than protocol, the factor of human errors must be taken into account. For instance, the cardiac arrest patient with diabetes will potentially be treated with sugar instead of CPR or the suspected stroke patient will mistakenly be put in recovery position awaiting ambulance arrival when actually suffering from cardiac arrest. Additional questions can be time-consuming and might not lead to an accurate diagnosis, depending on how the EMD interprets the answers from callers.

Inaccurate definition of “not breathing normally”

The second problem with the definition of cardiac arrest is that “abnormal breathing” is not further defined, and assessment of breathing is left to the individual EMDs. In the Consensus
of science and treatment recommendations for CPR presented in the 2015 International Consensus on Cardiopulmonary Resuscitation (77), key words used by callers associated with cardiac arrest is pointed out as an important knowledge gap. A few studies have explored how abnormal breathing in cardiac arrest patients is described, and a wide variety of descriptions of abnormal breathing are used. I have summarised these descriptions in table 2 and included unpublished data from our study (paper II).

Table 2 Descriptions of abnormal breathing

<table>
<thead>
<tr>
<th>Study by author</th>
<th>Descriptions of abnormal breathing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fukushima et al (29)</td>
<td>having difficulties in breathing</td>
</tr>
<tr>
<td></td>
<td>weak breathing</td>
</tr>
<tr>
<td></td>
<td>snoring</td>
</tr>
<tr>
<td></td>
<td>others</td>
</tr>
<tr>
<td>Bång et al (86)</td>
<td>difficulties breathing</td>
</tr>
<tr>
<td></td>
<td>poorly breathing</td>
</tr>
<tr>
<td></td>
<td>gasping breathing</td>
</tr>
<tr>
<td></td>
<td>wheezing breathing</td>
</tr>
<tr>
<td></td>
<td>impaired breathing</td>
</tr>
<tr>
<td></td>
<td>occasional breathing</td>
</tr>
<tr>
<td>Clark et al (87)</td>
<td>barely breathing</td>
</tr>
<tr>
<td></td>
<td>heavy or labored breathing</td>
</tr>
<tr>
<td></td>
<td>problems breathing</td>
</tr>
<tr>
<td></td>
<td>noisy breathing</td>
</tr>
<tr>
<td></td>
<td>gasping</td>
</tr>
<tr>
<td></td>
<td>snorting</td>
</tr>
<tr>
<td></td>
<td>gurgling</td>
</tr>
<tr>
<td></td>
<td>moaning</td>
</tr>
<tr>
<td></td>
<td>groaning</td>
</tr>
<tr>
<td>Berdowski et al (30)</td>
<td>occasional breathing</td>
</tr>
<tr>
<td></td>
<td>barely/hardly breathing</td>
</tr>
<tr>
<td></td>
<td>heavy breathing</td>
</tr>
<tr>
<td></td>
<td>labored or noisy breathing</td>
</tr>
<tr>
<td></td>
<td>sighing</td>
</tr>
<tr>
<td></td>
<td>strange breathing</td>
</tr>
<tr>
<td>Hardeland - Unpublished data from paper II</td>
<td>ineffective breathing</td>
</tr>
<tr>
<td></td>
<td>barely breathing</td>
</tr>
<tr>
<td></td>
<td>snoring</td>
</tr>
<tr>
<td></td>
<td>gurgling</td>
</tr>
<tr>
<td></td>
<td>strange breathing</td>
</tr>
<tr>
<td></td>
<td>deep breaths</td>
</tr>
<tr>
<td></td>
<td>shallow breathing</td>
</tr>
<tr>
<td></td>
<td>pauses between breaths</td>
</tr>
</tbody>
</table>

When agonal breathing is perceived in so many different ways, it is difficult to find a more accurate definition than “abnormal breathing”. All examples of breathing patterns shown in
table 2 can be classified as abnormal breathing. However, there is room for interpretation in most of them with regards to when breathing patterns transform from normal to abnormal, for instance respiration frequency and depth. These breathing patterns can also be symptoms of another diagnosis. Interviews with EMDs revealed that some of them perceived snoring as a typical sign of a cerebral incident and shallow or weak breathing is common in drug overdoses.

**Measuring quality performance**

Standard data points to be recorded on cardiac arrest cases are described in the Utstein Resuscitation Registry Template (1). Researchers and clinical service directors who wish to get a better description of dispatch operation and quality are directed to the consensus paper on dispatch assistance of cardiac arrest (79). Castrén et al describe the dispatch process and recommend a template for recording of data. Core data not included in the original Utstein Resuscitation Registry Template involve whether or not EMD suspect and identify cardiac arrest, pre-arrival instructions provided and ongoing bystander CPR. Additional suggested supplementary data involve cases mistakenly defined by the dispatcher as OHCA, number of calls per year per dispatcher, which priority is assigned and type of EMS response, if basic life support (BLS) is dispatched at a different time than ALS, protocol adherence and barriers to T-CPR. Time points are limited to time to bystander CPR initiation (79). In this thesis we provided all core and supplementary data except whether or not BLS is dispatched at a different time than ALS. To provide insight in the time line during the call, we included time points on all parts of bystander CPR; time to initial instructions (e.g. “put the patient down on the floor”), time to first chest compression and time to first ventilation. Inspired by other studies, we made an effort to include the data point “time to recognition of need for T-CPR”, but found it difficult to accurately pinpoint the exact time (36, 105). Dameff et al defined this data point as whenever the EMD mentioned the following: “cardiopulmonary resuscitation”, “CPR”, “chest compressions”, “compressions”, “continuous chest compressions”, “hands-only CPR”, “Cardiocerebral resuscitation” or “CCR”, “rescue breaths”, “rescue breathing”, “ventilations”, or “rescue ventilations” (105). Bobrow et al defined “time to recognition of need for T-CPR” as whenever the EMD used any of several key terms in the context of providing T-CPR (eg; “CPR”, “chest compressions”, and “compressions”) (36). We identified numerous cases where cardiac arrest was obviously recognised, but the EMDs did not necessarily use these specific words. A typical example would be that the patient was found unconscious with no breathing and the caller was not able to put the patient on the floor (or
other obstacles would hinder the caller to start CPR). Several minutes could go by without the key terms ever being mentioned, even though it was obvious that the EMD had recognised the need for T-CPR. In an attempt to develop an alternative to this relatively unreliable data point, we introduced the concept of “delayed recognition”. When collecting data for paper I, we identified several cases were arrest was not initially recognized until all agonal breathing had ceased. Callers were typically instructed to put these patients in the recovery position and monitor their breathing. Typically, these patients would stop breathing after a few minutes followed by initiation of T-CPR by the EMD. When following the recommended template for reporting cardiac arrest (106), these cases will be reported as recognised by EMD and bystander CPR performed, consequently regarded as high quality performance. In an abstract from 2014 we showed that median time to first chest compression was 3.2 minutes in OA-EMCC, but when divided in groups of “initially recognised” and “delayed recognition” median time to first compression was 2.6 minutes vs. 5.1 minutes, respectively (106). “Delayed recognition” was defined as failure to initially clarify consciousness or abnormal breathing before moving on to further questioning regarding other symptoms or patient history. Cases of delayed recognition have great potential for improvements in quality of care. However, what is not measured is difficult to improve, and it seems pertinent that delayed recognition should be included as a standard key metric for reporting quality of care for cardiac arrest in the EMCC.

**Time to first chest compression**

For CPR to be as effective as possible, it is vital to start chest compressions immediately after the arrest has occurred. Survival is shown to decrease by 3-5% for each minute delay (48, 49). Time to first compression can be difficult to measure, and the most recent update on the Utstein Resuscitation Registry Template comments that this data point is considered unlikely to be recorded accurately (1). Still, Castrén et al recommend reporting of time to bystander CPR initiation (79). In all the three papers in this thesis, this data point has been reported, ranging from median 2.8 minutes in the post-intervention period in paper III to 4.3 minutes in the MPD site (R-EMCC) in paper I. Other studies have reported similar time intervals, ranging from 2.9 minutes to 4.8 minutes (27, 31, 33, 34, 36, 105, 107). Best-practice benchmarks for time to first compression are not well established. Lewis et al suggested two minutes from start of call to delivery of the first telephone assisted chest compressions performed as an achievable target (33). The AHA scientific statement suggest that each dispatch organisation should establish local benchmarks because resources and systems vary
widely, but underline that high performing dispatch centres have demonstrated that this interval can be reduced to one minute (88). Bobrow et al has also argued that starting CPR within one minute after call is answered is an achievable target (108). These are ambitious goals, and probably not achievable in all cases, as EMDs face several barriers outside their control, where initiation of CPR cannot possibly start this early, or at all, due to different circumstances at scene. However, EMDs should be informed about these benchmarking metrics and what is considered the gold standards, and potentially achievable (88). The intervention in paper III included education on what is regarded to be the “gold standards”, as well as current quality metrics within their own EMD, together with simulation training practicing efficient interrogation and CPR instructions. While reaching the “gold standard” one minute to chest compression so far has been elusive in our EMD, significant improvements were seen following the intervention. The aim to reduce this interval further and reach the goal of two minutes seems within range. Noteworthy, these “gold standards” might also need to better reflect organisational differences. While some EMDs are primary call takers reached by callers directly, many systems have one emergency number for ambulance, police and fire departments. These systems often transfer calls to the EMD after the initial operator had identified the caller’s name, telephone number, location and chief complaint. This initial interrogation interval is rarely included in EMDs quality metrics, allowing for shorter intervals compared to systems that perform initial interrogation within the EMD.

**Discussion of methods**

Although the requirements are different in qualitative and quantitative research, the terms validity and reliability are applicable to both methods and appropriate for a mixed-method design. Validity is the degree to which an instrument measures what it is intended to measure. Internal validity refers to the degree to which it can be inferred that the experimental treatment is responsible for observed effects, and not uncontrolled, confounding factors. External validity refers to the degree to which study results can be generalised to settings or samples other than the one studied. Reliability is the degree of consistency or dependability with which an instrument measures the attribute it is designed to measure (95). Quantitative methods in paper I-III coincide and will be presented combined. Qualitative methods in paper II will be presented separately.
**Quantitative methods**

One threat to validity in quantitative research is selection bias. Selection bias can be defined as a systematic error originating from the procedures used to select subjects and from factors influencing on study participation (109). In paper I-III, all cardiac arrest cases registered by the ambulance department and local cardiac arrest registries within a certain time period were included, minimising the risk of selection bias. However, it is likely there is some degree of missing data in the cardiac arrest registry. Inclusions in the cardiac arrest registry highly depend on EMS crews’ protocol adherence regarding Utstein registration. A Swedish study on validity of the national cardiac arrest registry, concluded that 25% of cardiac arrest cases were not reported prospectively by the EMS crew. The missing 25% had different characteristics than the patient group prospectively included, being older, having less frequently received bystander CPR and paradoxically, yet had a higher survival rate. The authors state that it is difficult to explain the differences found between the two groups, but that there are reasons to assume that other registries have similar shortcomings and may be influenced by selection bias (110). Whether or not the local cardiac arrest registries in our studies have the same or perhaps other deficiencies remains unknown. It is conceivable that cardiac arrest patients with agonal breathing not believed to be in arrest by caller and EMD, could be perceived as arresting just as the ambulance arrives, thereby being classified as ambulance witnessed arrests. Similarly, the EMD might perceive a person to be “too dead” or “too old” for T-CPR, influencing the ambulance to come to the same conclusion upon their arrival. These cases would be excluded for further analysis, and could yield a systematically higher recognition and T-CPR percentage for our EMCC, underreporting issues that should be addressed in quality assurance. Auditing calls reported to be ambulance witnessed or “dead on arrival” would provide some insight, but without specific interrogation of ambulance crew it is impossible to conclude.

Another concern regarding internal validity can be related to the design of the studies described in paper I-III. In observational studies like paper I-II, as well as before-after studies, like paper III, conclusions of causality cannot be made. Skewness between groups and known or unknown confounders might affect the results. Randomised, controlled trials are considered the golden standard. The improvements observed in paper III following the intervention could partly be due to an increasing “Hawthorne effect”, defined as a research participant's altered behaviour in response to being observed (111). Providers might become increasingly aware they were being observed after initiation of education, feedback and simulation training. However, as they were given extensive oral and written information on
the project before and during the pre-intervention period as well, we expect this effect to be
limited. Unrelated temporal changes in the EMCC could also have occurred, but to our
knowledge, no major changes in protocols, organisation, personnel or workload occurred
during the study period.

Data collection of quantitative data was performed mainly by the use of auditing
digitalised voice recordings. The programs used were Scenario Replay and Nice 02 Inform.
Although the audio quality was high, there were some non-auditable cases due to
circumstances at scene (noise, panic-stricken caller etc), and in some cases there were room
for interpretations for when things occurred at scene, especially regarding time to first
compression. Two other research assistants were involved in data collection, and audited
voice recordings. Approximately 5% of calls were audited by both CH and one research
assistant to ensure consistent registrations, and there was overall very high agreement in
scoring. If classification of calls or any of the process measures were ambiguous or unclear,
the call was reviewed and discussed by at least two researchers (CH and TMO). If needed,
 supplemental information from ambulance records, hospital records and/or cardiac arrest
registry was consulted.

External validity, or generalisability of findings from our study sites to other EMCCs,
may be questioned. For the descriptive, observational data, similar challenges across various
EMCCs in Norway and in Richmond were observed. Many of these challenges have also been
corroborated by others (27, 28, 80). However, the interventional study was done at a single
center, and the improvements in quality of care seen after our education, feedback and
simulation training strategy may not be applicable to other EMCCs. The differences in
organisation of EMCCs can call for different strategies and interventions to overcome
challenges specific to one system. In our study, challenges were identified not only by
measuring key quality parameters, but also from in-depth interviews and observations in the
EMCC. The interventions could therefore be tailored to improve these specific challenges in
cooperation with the EMCC. Although the specific method or content of education and
simulation training might need to be tailored to each EMCC, we believe the overall strategy
might be useful for other EMCCs.
**Qualitative methods**

The chosen inclusion criteria for inviting participants to interviews were a validity-concern because it had unintended consequences for the interview climate. To ensure information rich cases (92) for interviews, we chose participants based on three categories (cardiac arrest recognised, not recognised and delayed recognition). We acknowledged in advance that we might reveal mistakes made by EMDs, and made efforts to ensure that we only wanted to explore how they experienced and evaluated the cardiac arrest calls and that what was shared during interviews would have no consequences for the individual EMD. Retrospectively we question whether this was an appropriate selection criteria. EMDs who accepted to participate in the interview on account of a not recognised or delayed recognised case were concerned with how to justify or excuse their actions. EMDs who were included on account of a recognised case were more likely to elaborate on their experiences and also gave examples of mistakes made during cardiac arrest calls. However, interviews from non- or delayed recognised cases provided important information on for instance why cardiac arrest was difficult to recognise.

Another potential concern regarding selection of participants to interviews, was that we do not know why three of the invited EMDs declined to participate. As participation was voluntary without any obligation to provide any explanation as to why they did not want to participate, we were unable to collect any data from these individuals. These interviews could potentially provide new insight. These three individuals were from three different EMCCs, so there was no indication that their reasons were site specific. However, it is unlikely that the lack of information from these individuals would reduce the value of the remaining interviews.

**Limitations**

Several additional limitations need to be addressed. Some limitations are consequences of the chosen methods or organisational structure in different settings. These limitations were expected and discussed before the studies were performed. Findings from paper II and III are based on criteria based dispatch and the use of NIM as a decision support tool. Findings from both quantitative and qualitative data may not reflect issues and potentials at other national or international dispatch centres, nor will findings from interviews necessarily be representative for the entire EMD population or apply to the individual informant. However, in keeping with the principles of qualitative method of maximum variation, cases believed to be information
rich were purposely selected to give a broader understanding of challenges EMDs face. In paper I, there were differences in a number of organisational, educational and cultural factors, such as level of experience and proficiency in the EMDs, and resources available. In paper III we do not know if the improvements we observed are sustainable over a longer time frame as we only followed up for 7.5 months after the interventions.

Some unexpected limitations needed to be addressed during the study period. In paper I we discovered differences in inclusion criteria after data collection had been initiated. Consequently, data collection had to be repeated in one study site and there was a difference in data collection period between the two sites. In paper II and III, data from dispatcher-suspected cardiac arrests that were not confirmed by ambulance crews were also intended to be collected. These data needed to be manually registered by the EMDs. However, due to low EMD compliance only a limited number of OHCA cases were registered. We attempted to identify all suspected arrests from the electronic records, but unfortunately our system used approximately 40 different non-specific codes for acknowledged cardiac arrests, and it was not possible to determine which of these were arrests without auditing a significant percentage of all EMCC calls.
Conclusions

The main conclusions of this thesis are that all the included EMCCs faced similar challenges with agonal breathing as the main barrier to recognition of cardiac arrest. A mixed-methods approach is effective to further explore the challenges regarding OHCA calls in an EMCC, and revealed both use and non-use of protocols, inaccuracy of definition of cardiac arrest and differences in interrogation strategies, in particular concerning assessment of breathing. Monitoring key quality indicators helped identify the challenges to the system, and enabled development of effective strategies to improve quality of care.

Paper I

Few differences were observed when comparing the efficacy and efficiency of the two commonly used dispatch tools, Medical Priority Dispatch (MPD) and Criteria Based Dispatch (CBD). Pre-arrival CPR instructions were offered faster and more frequently in the CBD system, but in both systems initiation of chest compressions were delayed with three – four minutes.

Paper II

The performance standards varied between the three study sites despite similar organisation, professional backgrounds and dispatch tool/protocols. Individual differences among EMDs’ strategies can potentially directly impact on performance, mainly due to the wide definition of cardiac arrest and lack of uniform tools for assessment of breathing.

Paper III

Targeted simulation, education and feedback significantly increased recognition of OHCA, delivery of T-CPR and reduced time to first chest compression. Continuous measurement of key quality metrics can facilitate development of targeted education and training, as well as evaluation of efficacy and efficiency of quality interventions.
Future perspectives

My top priority would be developing a more accurate and operationalized definition of cardiac arrest and abnormal breathing to ensure more efficient recognition of cardiac arrest. It could be argued that the current “two question method” is either too simple or too complicated. As the previous question of: “Is the person breathing” morphed into “Is the person breathing normally?” two questions were to some extent forced into one. Most cardiac arrest patients do not have agonal breathing, and could perhaps be more easily identified by simply asking if the person is breathing. The question of “breathing normally” may confuse some callers, and throw the interrogation off track. A case could be made of a three question strategy, following up with questions describing the breathing in any unconscious person reported to have any kind of breathing. The specific assessment of breathing need to be further explored and tested, and each local protocol need to be adjusted accordingly, but a suggestion for a three-question method would be the following:

1) Is the patient conscious?

2) Is the patient breathing?

If yes;

3) Describe how the patient is breathing.

More research is also needed to either confirm or refute the many other clinical signs commonly used to indicate the presence or absence of arrest in emergency medical dispatch. The challenge of potential differential diagnosis will still be an issue even if breathing assessment improves and is an important area for future research.

Differences in language, cultures and social settings, complicate potential common protocols or interrogation strategies, and it seems inevitable that each country or region need to develop their own set of protocols based on local dialects and social structure. However, principles of interrogation strategy and clinical decision making are likely to be similar, and a better understanding of the underlying mechanisms and methods would be useful across systems.
International collaboration across different systems using both qualitative and quantitative methods would be an appropriate approach to further explore the area of how EMDs handle cardiac arrest. The principle of maximum variation in regards to dispatch systems, dispatcher background and competence, cultural differences and system resources would provide further exploration of this issue and yield information not obtainable in this study. The use of mixed-methods in an international setting with a wide variety of EMCCs would be the preferred course of action in regards to future perspectives.

Lastly, new technologies will most likely change clinical practice in the EMCCs in the near future. Better access to video communication, mobile applications that can alarm nearby trained rescuers with access to defibrillators, and perhaps also development home medical monitors and equipment that may alarm or provide patient data to the EMCC all have the potential to radically change the way EMD handle critical calls. These new technologies need to be scientifically evaluated as they emerge, ensuring that they actually improve quality of care before widespread implementation.


61. Sosialdepartementet. Ot.prp. nr. 54 (1983-84) Transporttjenesten i helsevesenet


64. Helse- og omsorgsdepartementet Lov 2. juli 1999 nr. 61 om spesialisthelsetjenester m.m. (spesialisthelsetjenesteloven).

65. Helse- og omsorgsdepartementet. Lov 24. juni 2011 nr. 30 om kommunale helse- og omsorgstjenester m.m. (helse- og omsorgstjenesteloven).

66. Helse- og omsorgsdepartementet. Lov 2. juli 1999 nr. 64 om helsepersonell m.v. (helsepersonel.loven).


74. Eisenberg MS, Bergner L, Hallstrom A. Cardiac resuscitation in the community. Importance of rapid provision and implications for program planning. JAMA. 1979;241.


100. Regional Committees for Medical and Health Research Ethics (Retrieved 2016-12-12) Available from: https://helseforskning.etikkom.no/ikbViewer/page/forside?_ikbLanguageCode=us
Appendices

Appendix 1 Norwegian index for medical emergencies. Opening protocol.

Appendix 2 Norwegian index for medical emergencies. CPR instructions.

Appendix 3 Telephone CPR for adults – 1984

Appendix 4 Data collection form non-participant observation
Appendix 1 Norwegian index for medical emergencies. Opening protocol.
Appendix 2 Norwegian index for medical emergencies. CPR instructions.

01 Bevisstls voksen (fra pubertet)

Bevisstls, og puster IKKE normalt

- Ambulansen er på vei.

A.01.01 Stans av antatt kardial årsak

Brystkompresjoner i 10 min.

- Hør på meg!
- Legg pasienten på ryggen på gulvet.
- Legg deg på knæ ved siden av brystet.
- Legg én hånd midt på brystet og den andre oppå.
- Trykk hardt og dypt - 30 ganger - i rask takt 1, 2, 3, 4, 5, 6. Tell høy!
- Kom så tilbake til meg.

- Har pasienten begynt å puste normalt nå?
  Hvis pasienten har begynt å puste normalt, fortsett fra høyre side "Puster normalt".

- Hold på slik til du ser tegn til liv, eller til ambulansen kommer.
- Hvis du ikke orker mer, må du si fra til meg.
- Ikke legg på før jeg sier fra.

- Er det en hjertestarter i nærheten?
  Hvis ja: Få noen andre til å hente den. Si ifra når den er på plass.
  Hvis nej: Fortsett med brystkompresjoner.

Hvis / når hjertestarteren er på plass:

- Slå på hjertestarteren og gjør det den sier.
- Hvis noen andre kan kople til hjertestarteren, må du selv gjøre brystkompresjoner helt til hjertestarteren sier at du må vekk fra pasienten.

Etter ca. 10 min. med bare brystkompresjoner:
  Fortsett instruksjon fra "Standard HLR".

A.01.02 Stans av antatt hypoksisk eller traumatisk årsak

Standard HLR


- Hvis fremmedlegeme
  Hvis pasienten har begynt å puste normalt, fortsett fra høyre side "Puster normalt".

- Nå må du blåse munn-til-munn.
- Bøy hodet godt bakover med en hånd på pannen.
- Klem sammen neseborene med fingrene på den samme hånden.
- Løft opp haka med den andre hånden.
- Hold nå hodet slik.
- Legg leppene dine omkring pasientens munn og blås til du ser at brystkassen hever seg.
- Blås en gang til.

- Nå må du trykke 30 ganger på brystet.
- Trykk hardt og dypt i rask takt: 1, 2, 3, 4, 5, 6...
- Fortsett med å blåse 2 ganger og trykke 30 ganger.
- Hold på slik til du ser tegn til liv, eller til ambulansen kommer.
- Hvis du ikke orker mer, må du si fra til meg.
- Ikke legg på før jeg sier fra.
Appendix 3 Telephone CPR for adults – 1984

**TELEPHONE CPR INSTRUCTIONS — FOR ADULTS**

- What is the PROBLEM?
- What is the ADDRESS?
- What is the TELEPHONE NUMBER?
- What is your NAME?

**Answer:**
- IS THE PATIENT CONSCIOUS? (able to talk) YES
- (continue usual interrogation)
- IS THE PATIENT BREATHING NORMALLY? YES
- (continue usual interrogation)
- STAY ON THE LINE! Dispatch will HELP ON THE WAY!
- IS THE PATIENT OVER 40 YEARS OLD? NO
- DO YOU WANT TO DO CPR? I’LL HELP YOU. NO
- DO YOU WANT TO DO CPR? I’LL HELP YOU. NO
- (continue usual interrogation)
- IS THE PATIENT MOVING OR BREATHING NORMALLY? YES
- (continue usual interrogation)

**TURN HEAD TO SIDE.**

**INFORMATION FOR VOMITING:**

- TELEPHONE CPR INSTRUCTIONS
  - William E. Davis, M.D.
  - Henry S. Even, M.D., Ph.D.
  - Alfred F. Allin, Ph.D.
  - Judith R. Pierce, M.A.

**Annals of Emergency Medicine**

13th September 1984 (Part 1)
## Appendix 4 Data collection form non-participant observation

<table>
<thead>
<tr>
<th>Tema</th>
<th>Observasjoner</th>
<th>Refleksjoner</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fysisk miljø</strong></td>
<td>Beskrivelse - hvordan er rommet utformet? Arbeidsplass, lys, skjermer osv</td>
<td></td>
</tr>
<tr>
<td><strong>Arbeidsoperasjoner</strong></td>
<td>Beskrive prosessen når samtalen kommer inn. (hvor mye rutine er det i det de gjør, skjønnsmessige vurderinger?)</td>
<td></td>
</tr>
<tr>
<td><strong>Indeks</strong></td>
<td>Hvordan bruker man indeks når man tar en nødsamtale? Tidsaspekt – når brukes den? Brukes den alltid eller ved spesielle tilfeller? Er det stor variasjon blant aktørene på i hvor stor grad man bruker indeks?</td>
<td></td>
</tr>
</tbody>
</table>
Reprint of papers I-III

Paper I:

Paper II:

Paper III: