UiT The Arctic University of Norway

Faculty of Health Sciences

Studies on the Chain of Survival in Out-of-Hospital Cardiac Arrest

Inger Lund-Kordahl

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Table of Contents

List of Tables

List of Figures

1 Preface

It takes a village to raise a child. It took at least two villages to do this PhD project. The journey started in Oslo when Professor Petter Andreas Steen and Professor Kjetil Sunde included me in their dynamic and successful research group at Oslo University Hospital Ullevål, giving me the opportunity to start my PhD education in prehospital emergency medicine. I will stay forever grateful. I got to share office with the extremely talented, structured and caring Theresa Olasveengen. Her hands-on and caring supervision made me believe that this was something I could actually go through with. I will never forget the investments Theresa made in my PhD education, and I am still carrying all the knowledge and support she provided with me.

In 2013 I moved far north to Tromsø to continue my clinical training and I brought my PhD project with me, hoping to finish it in Tromsø. I knew they had a strong research environment for emergency medicine at the University Hospital of Northern Norway and I hoped someone wanted to help me with main supervision for the last part of the degree. I was very lucky when I mentioned my research to my ambitious chief Marianne Nordhov, in which immediately linked me up with Professor Knut Fredriksen who wanted to be main supervisor for my PhD. Theresa and Kjetil from Oslo University Hospital Ullevål moved into roles as co-supervisors and I am extremely thankful for the willingness to do that and the flexibility they showed me in the process. I was given a lot of trust and responsibility in Tromsø, but with that also independency and the possibility to build my own project for the last part of my PhD. I am very glad and proud that I got this chance. I am even thankful for all the pitfalls, resistance and mistakes in which I gained a lot of strength, experience and knowledge from. Knut Fredriksen have been an extremely supportive and trusting supervisor, even in the darkest and heaviest parts of my PhD journey. I am very thankful for everything Knut has done for me.

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Thank you to Per Ivar Kaaresen for always keeping his office door open for me, for all the good advices and good laughs, discussions about statistics and all of the understanding and support during the years as my clinical chief.

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A deep and humble thank you to my family. My mother and father, Hilde and Knut, sister Kari, brother-in-law Vegard, uncle and aunts, cousins and extended family. Thank you for your love, trust, patience and never-ending support in all aspects of life, work and research.

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Per ardua ad astra

2 Abstract

Background:

Sudden death due to out-of-hospital cardiac arrest (OHCA) remains a major health issue with estimated 250-300.000 cases in Europe/year. Survival depends on a well-functioning Chain of Survival. The Chain of Survival concept of early access, early cardiopulmonary resuscitation (CPR), early defibrillation and good post-resuscitation care is the documented and recommended guide for improving outcome after OHCA. I aimed to assess if targeted attempts to strengthen the weak links of our local chain; quality of advanced life support (ALS) and post-resuscitation care, would improve outcome in paper I. Physician-manned ambulances (PMAs) is believed to facilitate optimal management of OHCA but had not been sufficiently documented and paper II investigates if there is increased survival among patients treated by a PMA in our local emergency medicine system (EMS). As further improvement in survival rates after OHCA remains a challenge, I aimed to investigate the early links in the Chain of Survival, bystander CPR and CPR training in paper III. One of the most important strategies is to identify the arrest immediately and initiate CPR. Quality of bystander CPR skills may influence OHCA outcomes. Consequently, CPR training for the public is of utmost importance. Bystanders trained in CPR are three times as likely to perform CPR than those untrained.

Methods:

Locally adapted Utstein style forms, dispatcher recordings, and ambulance-/hospital records were collected and reviewed. Outcome categories were non- survival/survival to hospital discharge with cerebral performance categories (CPC) for both paper I and II. Values for parametric data are given as means with standard deviations. Comparisons of continuous data were analysed by one-way analysis of variance (ANOVA) for parametric data in paper II. Categorical data were analysed using linear by linear associations for trends over time periods in paper I. p-Values ≤ 0.05 were considered significant. To recruit study participants for the bystander CPR part of the study (paper III), 237 soldiers from the Norwegian armed forces were invited to participate. 125 had basic training (group I), 84 reported advanced training

(group II), and 28 advanced training plus additional courses (group III). The participants' real-life CPR experience and self-reported CPR skills was recorded, and then assessed on selected CPR quality indicators on a manikin. The data were analysed with multivariate logistic regression. Differences between groups were analysed with ANOVA/Multivariate analysis of variance (MANOVA)

Results:

ALS was attempted in 454, 449, and 417 patients with OHCA in the first, second and last time period, respectively in paper I. Overall survival increased from 7% (first period) to 13% (last period). 977 patients were included in analyses in paper II, 232 (24%) and 741 (76%) were treated by PMA and non-PMA, respectively. The PMA group received better CPR quality but short- and long-term survival were not different for patients treated by the PMA vs. non-PMA, with 34% vs. 33% ($p = 0.74$) achieving return of spontaneous circulation (ROSC), and 13% vs. 11% ($p = 0.28$) being discharged from hospital, respectively. In paper III, group II (advanced life support training) and group III (advanced life support training and additional courses) had shorter start-up time, better compression depth and hand positioning, higher fraction of effective rescue ventilations, shorter hands-off time, and thus a higher chest compression fraction than group I (basic life support training). Chest compression rate did not differ between groups. The participants in group I assessed their own skills and preparedness significantly lower than groups II and III both before and after the test.

Conclusion:

Survival after OHCA was increased after improving weak links of our local Chain of Survival. Survival after out-of-hospital cardiac arrest was not different for patients treated by the PMA and non-PMA in our EMS system. Training of non-professional bystanders is necessary and even basic training can provide high quality compressions. High quality airway management and ventilations seem to require more extensive training. Self- assessments of CPR ability correlated well to actual test performance and may have a role in probing CPR skills in students.

3 Abbreviations

ACLS = Advanced Cardiac Life Support

AHA = American Heart Association

ANOVA= Analysis of Variance

ALS = Advanced Life Support (the same as ACLS; ACLS in US, ALS in Europe)

CI = Confidence Interval

CPC = Cerebral Performance Category

CPR = Cardiopulmonary resuscitation

ECG = Electrocardiography

ED = Emergency Department

EMS = Emergency Medical Services

ERC = European Resuscitation Council

IEMR = Institute for Experimental Medical Research

IHCA= In-Hospital Cardiac Arrest

ILCOR= International Liaison Committee on Resuscitation

OHCA=Out-of-hospital cardiac arrest

OPC = Overall Performance Category

OUH = Oslo University Hospital

OUHU= Oslo University Hospital Ullevål

OR= Odds Ratio

MANOVA= Multivariate Analysis of Variance

PCI = Percutaneous Coronary Intervention

PEA = Pulseless Electrical Activity

ROSC = Return of Spontaneous Circulation

VF = Ventricular Fibrillation

VT = Pulseless Ventricular Tachycardia

4 List of papers

I. **Improving outcome after out-of-hospital cardiac arrest by strengthening weak links of the local Chain of Survival; quality of advanced life support and post-resuscitation care.**

Lund-Kordahl I, Olasveengen TM, Lorem T, Samdal M, Wik L, Sunde K.

Resuscitation. 2010 Apr;81(4):422-6. doi: 10.1016/j.resuscitation.2009.12.020. Epub 2010 Feb 1

II. **Out-of-hospital advanced life support with or without a physician: effects on quality of CPR and outcome.**

Olasveengen TM, Lund-Kordahl I, Steen PA, Sunde K.

Resuscitation. 2009 Nov;80(11):1248-52. doi: 10.1016/j.resuscitation.2009.07.018. Epub 2009 Aug 26.

III. **Relationship between level of CPR training, self-reported skills, and actual manikin test performance—an observational study**

Lund-Kordahl I, Mathiassen M, Melau J, Olasveengen TM, Sunde K, Fredriksen K

Int J Emerg Med. 2019;12(1):2. doi: 10.1186/s12245-018-0220-9. Epub 2019 Jan 10.

5 Introduction

5.1 Cardiac Arrest

Cardiac arrest is a cessation of cardiac mechanical activity making the pump function in the heart unable to deliver blood and oxygen to vital organs; a highly time-critical medical emergency. (1) Patients who are unresponsive and not breathing normally should be presumed to be in cardiac arrest.

Cardiac arrest events are often categorized into out-of-hospital cardiac arrest (OHCA) and in-hospital-cardiac-arrest (IHCA). The key distinctions between IHCA and OHCA are; more medical comorbidities, more witnessed arrests and more professional first responders in IHCA. Resuscitation guidelines do not differ much between IHCA and OHCA but due to the mentioned differences, they need to be considered as different populations. (2)

Cardiac disease is the most frequent aetiology in OHCA in the western world. Acute ischemia due to coronary artery disease is most common (70%-85%). (3-5) Cardiac aetiologies also include arrhythmias, heart failure, valve disease and congenital heart disease. (6, 7) Non-cardiac aetiologies include strangulation, intracerebral events, trauma, drowning, intoxication, asphyxia, electrocution and primary respiratory arrests. (6, 8)

OHCA is a major cause of death globally, but due to large regional variations to uniform reporting of incidence and outcome measures, the exact burden to public health globally is unknown. The estimated worldwide, overall incidence of OHCA is correlated with age, and between 60 and 100 patients per 100 000 inhabitants suffers from OHCA every year.(9-11) In 2005 the incidence of OHCA in Europe was reported 38 per 100 000. (4) The European Registry of Cardiac arrest (EuReCa) was established as a project in 2008, and studies from this project implies higher incidence (36-86 per 100 000) and estimates that more than 350.000 Europeans suffers from OHCA yearly. (12) Current results from the EuReCa TWO study, confirmed large variations in OHCA incidents across Europe 21-91/100,000 with a mean incident of 56/100.000. (13) The Norwegian cardiac arrest registry reported that 3405 patients suffered from OHCA in 2020, an incidence of 70/100.000. (14)

The ECG patterns during cardiac arrest events are either shockable (ventricular fibrillation VF and pulseless ventricular tachycardia VT) or non-shockable rhythms (asystole and pulseless electrical activity-PEA). In ventricular fibrillation (VF), or pulseless ventricular tachycardia (VT), parts of the ventricular myocardium depolarize erratically in an uncoordinated manner, and these rapid electrical impulses are causing myocardial fibrillation without production of blood flow to vital organs. (15, 16) Shockable rhythms are mainly associated with cardiac causes, 3-12% of cases of myocardial infarction (MI) develop VF during the acute phase. (17, 18) The incidence of VF/VT has gradually decreased over the last decades, probably due to better treatment of coronary heart disease. (19-21)

Non-shockable rhythms include all other ECG patterns, most commonly referred to as pulseless electric activity (PEA) or asystole (no detectable ECG rhythm, a flat line). Non-shockable rhythms are frequently related to underlying non-cardiac aetiology, and the prognosis for survival with neurological favourable outcome is poorer than for shockable rhythms. Particularly is this the case if an underlying reversible cause is not found and treated. Common aetiology for an initial non-shockable rhythm is hypoxia, but non-shockable rhythms may also occur in end-stage VF if untreated or when the treatment is unsuccessful. (22)

Improved survival after implementation of quality improvement strategies are shown in a several regions over the last 15 years. (23, 24) Early defibrillation, increased rates of bystander cardiopulmonary resuscitation (CPR) and structured and high-quality post-resuscitation care are important contributions to this increase in survival. (25-28)

This PhD thesis is based on three studies exploring potential and known factors impacting survival after OHCA.

5.2 History of cardiopulmonary resuscitation and advanced cardiac life support

Examining the history of resuscitation is useful to understand the evolution up until modern practice. Development has been driven forward by rejection of inexpedient techniques, adaptions to useful and successful interventions and even cyclic process of abandonment and subsequent rediscovery. (29)

Cardiopulmonary resuscitation (CPR) was first described by the Hungarian surgeon Janos Balassa in 1858 who performed external chest compressions. (30) The first successful resuscitation was performed by the German surgeon Friedrich Maas in 1892, more than a century ago. Maas also described the importance of minimal hands-off time and concluded that it was important to make as few pauses in compressions as possible. This is still a valid quality parameter of CPR. (31)

We do have contributions to the history of resuscitation from Tromsø as well, as the surgeon Kristian Igelsrud performed the first documented successful open-heart compression in history. The event did not get much attention, and Igelsrud did little to make sure it did. Igelsrud's operation is one of the most important contributions by a Norwegian to the development of anaesthesiology and resuscitation. (32)

The practice of medicine made a slow progress toward use of effective cardiopulmonary resuscitative methods. External chest compressions was not mentioned in the literature for a long time until it was described in 1960 by Kouwenhoven, Jude and Knickerbocker. (33) Mouth-to-mouth ventilation was first described in resuscitation in 1744. (30) Use of expired air for resuscitation was discredited later in the 18^{th} century when Lavoisier revealed the role of oxygen in respiration. (34) Maybe the world was not ready to be convinced as the physiological basis of cardiac arrest was not yet understood.

Expired air was considered not being adequate until Safar, Gordon and Elam showed that expired air indeed contained enough oxygen for expedient mouth-to-mouth ventilation. (35-38) In the 1960s Safar, Jude, Kouwenhoven and Hackett published treatment of cardiac arrest patients with the combination of chest compressions and artificial mouth-to-mouth ventilation that we recognize as basic CPR.(36) Kouwenhoven provided the first clinical evidence of efficacy of external manual chest compressions in 1960. (33) Safar published the first "chain of survival" and described several treatment steps for patients with cardiac arrest, starting with chest compressions and ventilations and proceeding to intensive care treatment, including therapeutic hypothermia in 1967. (39)

The basic principles of chest compressions and artificial ventilation has remained essentially unchanged since the 1960s. Modern CPR was developed by the joined efforts of Elam and Safar (37) and Kouwenhoven, Jude and Knickerbocker who rediscovered the effectiveness of external chest compressions.(33) With the development and use of defibrillators, modern CPR was complete.(36) The limitation of use of defibrillators until the 1960's was mainly because of the need of heavy transformers to produce alternate current and the influence of this on portability. When switched from alternate to direct current in the defibrillators around 1960, it was possible to power the defibrillators by batteries and the defibrillators became portable. (40) The Irish cardiologist Pantridge described successful out-of-hospital defibrillation in 1967. (41) The same year, the Irish Heart Foundation sponsored training of the first non-medical ambulance personnel to use a defibrillator for pre-hospital cardiac arrest. (42)

Today, automatic defibrillators are small, portable and available in public areas, and we know that early defibrillation by lay rescuers or first responders improves survival after OHCA. (43, 44)

Pre-hospital advanced life support (ALS) started with the use of a coronary care ambulance initiated by Pantridge in Belfast. (41) As most sudden cardiac patients died before they even reached the hospital, he thought that advanced physician-led treatment should be brought out to the patient. In his landmark publication he described six survivors among the ten patients who were resuscitated from OHCA. (41) The Belfast program with a physician-manned coronary unit ambulance was a revolution in prehospital emergency care. Pantridge visited the United States, and intensive care ambulances like the Belfast unit was established in several cities.

An anaesthesiologist-manned ambulance was also providing advanced care in Oslo, Norway from 1967. Established by the Norwegian anaesthesiologists Lund and Skulberg. (45) In Oslo, the anaesthesiologists working in the physician-manned ambulance, were over the years moved into a main role as instructors, consultants and mentors, while anaesthesiologists working in the helicopter emergency service established in Norway in 1978 has a more active physician role, analogue to the services in France and Germany.

As a cardiologist Pantridge focused on patients initially reporting chest pain and other coronary symptoms such as difficulties breathing and nausea. Lund and Skulberg in Oslo were anaesthesiologists and had a broader emergency care focus. Together with colleagues from Seattle they extended the physician- manned vehicle tasks to respond wide range of emergencies, even accidents and surgical emergencies. (45, 46) The first article showing increased survival in OHCA when bystander CPR was taught to and provided by bystanders was published by Lund and Skulberg in 1976 (47).

The tradition of incorporating physicians in emergency medicine systems were maintained in European EMS systems (in France and Germany in particular) during the 1970s, while an extended education of paramedics started in UK and US (48, 49)

Clinical guidelines are defined by the Institute of Medicine as "systematically developed statements to assist practitioner and patient decisions about appropriate health care for specific clinical circumstances". (50)

An international Symposium on Emergency Resuscitation held in Stavanger in August 1961 made the first official recommendations for resuscitation. (51) This led to the standard treatment recommendations from Cardiopulmonary Resuscitation Committee on CPR from the American Heart Association in 1966. (52) Based on today's knowledge on bystander CPR, it is an interesting curiosity to read the first guidelines encouraging practice with manikins but disapproving of teaching resuscitation to laypersons out of concern for complications. (53)

International awareness was further enhanced the following year when an International Symposium on Emergency Resuscitation was held in Oslo. (54, 55)

To address the challenge of variations in resuscitation technique, particularly internationally, AHA invited in 1985 resuscitation leaders from many countries to initiate an international collaboration (56) and at the 1992 AHA conference more than 40% of the participants were from outside the US. (57-60)

The ERC had its first international conference in 1992. At the end of the conference, the International Liaison Committee on Resuscitation (ILCOR) was founded and held its first meeting. ILCOR coordinate members of guideline-producing organizations worldwide and has become the authoritative voice on the consensus on science behind national and international guidelines on resuscitation. (61)

The 2010 International Consensus Conference involved 313 experts from 30 countries, culminating in the 2010 ILCOR recommendations and subsequent 2010 AHA and ERC guidelines (62-64)

2010 Guidelines emphasized that chest compression should be initiated as soon as there is the slightest suspicion of cardiac arrest and should be continuous and uninterrupted in order to avoid cerebral low flow (28) A ratio of 30:2 was recommended in European Resuscitation Council (ERC) Guidelines 2010 for the single CPR provider attempting resuscitation of an adult.

In 2010 the introduction of a new additional phase of standardized post-resuscitation care in guidelines was included for the first time. (65)

The most recent Consensus Conference when this dissertation was written was held in 2015. The most important evidence-based recommendations from the 2015 guidelines for BLS and ALS was focus on the EMS dispatcher's critical role in identifying cardiac arrest, planning and coordination of public AED programs, emphasis on adequate rate and depth in compressions and minimizing pauses in CPR.

New AHA guidelines are published late 2020. (66) European guidelines from ERC are scheduled to be published March 2021.

Despite huge efforts to synchronize guidelines worldwide, slightly different guidelines are published in different parts of the world (e.g. from the ERC and AHA). For pedagogical and practical reasons, mainly due to arguments based on timing of drugs, the Norwegian Resuscitation Council (NRC) introduced a modified ALS algorithm with three minute cycles of CPR instead of two minutes. (67) The effect of this discrepancy in guidelines has not been tested, but Norwegian studies with improved quality of ALS and survival seems to indicate no negative impact on outcome.(27, 68, 69)

5.3 Chain of survival

The German anaesthesiologist Fritz Ahnefeld introduced the first outline of the universal concept of the ´Chain of Survival´ in a German publication in 1967 ("die Rettungskette"). (70) The modern concept of the "chain of survival" was presented by the American Heart Association in 1991, and implemented in the 1992 AHA guidelines. (71) (Fig 1)

The *chain of survival* states that survival from cardiac arrest depends on a sequence of time-critical interventions. The concept emphasizes that all these interventions interact, and all links should be optimized to maximize the chance of survival. The original four links of the chain comprise:

(1) *The first early access link* starts when a medical emergency is recognized and the activation of the emergency medical services (EMS) is initiated. The access time starts when a person is witnessed collapsing or calls the emergency number with symptoms of a medical emergency. Recognition of early warning signs, such as chest pain and shortness of breath, that encourage patients to activate the emergency response system is a key component of this link. The first link in the chain of survival comprises time-critical events such as the decision to make the emergency call; the interrogation and recognition of a cardiac arrest by the dispatcher; the actual dispatch of a responding EMS and the response time before the ambulance reaches the patient. Rapid emergency medical dispatch is a critical component of the early access link. Several studies have addressed the training of the dispatcher in recognizing cardiac arrest, in order to reduce time loss in the dispatch to cardiac arrests. (72, 73)

(2) *The second link* is early CPR. Victims of cardiac arrest need immediate CPR to provide a low but critical blood flow to the heart and brain, and bystander CPR improves survival. (74) It also increases the likelihood that the heart will stay in VF if that rhythm was present from the beginning after collapse. (75) Chest compressions are especially important if a shock cannot be delivered within the first few minutes after collapse. (76, 77)

The rate of bystander CPR in OHCA has generally been reported as low but it varies widely. Though it has increased over the years; results from the European Registry of Cardiac arrest implies that bystander CPR rate varies 3-fold from 20% to 60% between participating countries (4, 78, 79). A prospective ten-year study from Denmark showed that an increase in survival following OHCA was significantly associated with a concomitant increase in bystander CPR (80). Dispatcher-assisted CPR (telephone-CPR) instructions have increased bystander CPR rates, and improved patient outcomes following OHCA. (81-83) Dispatchers should provide telephone-CPR instructions in all cases of suspected cardiac arrest unless a trained provider is already delivering CPR. Where instructions are required for an untrained CPR provider for an adult victim, dispatchers should provide chest compression-only CPR instructions. (77, 84)

(3) The third link is early defibrillation to restore a perfusing rhythm. Defibrillation is by far the most effective treatment among the components recommended in the ERC and AHA guidelines. About 10-20% of defibrillation attempts will ultimately lead to a perfusing heart rhythm, but success rates rely heavily on the duration of cardiac arrest. (85-88) Chest compressions have been demonstrated to counteract some of the negative effects on shock success with time, and clinical investigations prompted changes in ERC and AHA guidelines. (89-91) Patients presenting with VF or pulseless VT are generally reported to have higher rates of survival to discharge, and in a systematic review as high as 14.8%- 23.0%. (92) Defibrillation within five minutes of a cardiac arrest event can increase survival rates as high as 50–70%. (93, 94) This may be achieved by public access Automated External Defibrillators (AEDs). AEDs are safe and efficient even when used by lay people with minimal training. (95, 96) A Dutch cohort showed doubling of neurologically favourable survival after OHCA when an onsite AED was used. (94) In most urban areas median response time for EMS is median 8-11 min. (19, 97, 98) During the response time survival of the cardiac arrest victim completely depends on the effort of bystanders. One-minute delay to defibrillation reduces the survival rate to discharge by 10–12%, but if bystander CPR is provided, it is less decline in survival rates and averages 3–4% per minute delay to defibrillation. (99-101)

(4) The last link in chain of survival is ALS and post resuscitation care. ALS includes advanced interventions during resuscitation and includes use of intravenous drugs, advanced airway devices and more advanced defibrillators. BLS will continue during and overlap with ALS interventions. Airway strategies include basic techniques such as bag-valve mask and oropharyngeal/nasopharyngeal airway and advanced options such as endotracheal intubation or various supraglottic airway devices. (102)

Both the ERC and AHA Guidelines recommend that the airway management reflect the level of rescuer competence and emphasize skill training to avoid increased hands-off time, interrupted chest compressions and misplaced tubes and devices. These recommendations have remained the same during the latest guidelines revisions (62, 103-105) A recent systematic review performed by ILCOR Task Force still considers that the preferred airway option will likely be provider-dependent and also depend on the specific patient circumstance, but emphasizes the use of supraglottic airways in circumstances of providers with limited training or experience with endotracheal intubation.(106)

Drugs used during ALS are mainly vasopressors and antiarrhythmics. The preferred vasopressor is adrenaline intravenously. For refractory VF/VT, after two unsuccessful shocks and still presence of VF, amiodarone is recommended. Atropine was recommended for asystole or PEA as first presenting rhythm but is taken out of the current guidelines due to very weak evidence of effect, and an aim to simplify the algorithm for non-shockable rhythms. Adrenaline and amiodarone are still included in guidelines, though there has been debated and shifting clinical and scientific evidence to support the use of any of the drugs during cardiac arrest. (105) ERC Guidelines for Resuscitation 2018 update is focused on the role of antiarrhythmic drugs during ALS for cardiac arrest with shock refractory ventricular fibrillation/pulseless ventricular tachycardia. This guideline update is focused on antiarrhythmic drugs and emphasizes beneficial effects on ROSC for amiodarone, and that these drugs are most effective when given early after the onset of cardiac arrest. (107) A recent meta-analysis has shown that the effects of adrenaline on ROSC are stronger for patients with initially non-shockable rhythm. (108) The optimal timing for adrenaline in patients with shockable rhythms is unknown. 2020 ILCOR guidelines suggests administering adrenaline if initial defibrillation attempts is unsuccessful, but the best timing or number of shocks after which adrenaline should be administered remains unclear.(109)

Mechanical compression devices to assist circulation during cardiac arrest have been implemented in EMS around the world. These devices have been thought to have potential benefits such as releasing rescuers to perform other interventions during ALS, and the possibility to continue high-quality compressions during transport. (110) Several large randomized trials of mechanical devices during OHCA have been published (111-113), and meta-analysis has shown that the routine use of mechanical devices does not improve survival in OHCA. (114, 115) Current ERC and AHA guidelines suggest considering use of these mechanical devices in situations where manual compressions might be difficult such as CPR during transport to hospital in patients who fulfils inclusion criteria for percutaneous coronary intervention (PCI), extracorporeal membrane oxygenation (ECMO) or other treatment options to improve prognosis. (105, 116)

Successful return of spontaneous circulation (ROSC) is the first step towards the goal of complete recovery from cardiac arrest. The complex pathophysiological processes following whole body ischemia due to cardiac arrest and the subsequent reperfusion response have been termed the *post-cardiac arrest syndrome*. (117) The post-resuscitation phase starts at the location where ROSC is achieved but, once stabilized, the patient is transferred to the most appropriate receiving hospital for continued diagnosis, monitoring and treatment. Implementation of standardized post resuscitation in-hospital treatment has shown increased survival and is included in the recent post-arrest care ERC guidelines. (118, 119)

Figure 1 - Chain of survival. (Reproduced with permission Laerdal Medical)

5.4 Basic life support and cardiopulmonary resuscitation

CPR training for the public is of utmost importance. External chest compressions and supported ventilation, either by mouth-to-mouth or bag-valve-mask are the core components of CPR. External chest compressions provide blood flow to the heart and brain, and two main theories are used to explain how; the cardiac pump theory and the thoracic pump theory. External compressions to the chest impact on the intrathoracic pressure thereby moving blood flow in and out of the thoracic cavity, and this is known as the thoracic pump theory. On the other hand, the cardiac pump theory is based on the direct pump mechanism induced by the direct force to the chest wall, pushing the heart between the sternum and the vertebrae, moving blood in and out of the heart. (120) The flow effect is probably a combination of both.

The basic principle of all external chest compression is provision of a force on a given rate onto the chest wall to generate blood flow. During decompression, the chest should recoil completely to facilitate filling of the heart. This is emphasized in the 2015 basic life support guidelines. (105)

The initial goal of CPR is to generate a substitute circulation and flow of blood and oxygen to the heart, brain and vital organs while the heart is unable to provide such by itself. Chest compressions are the first and simplest external circulatory support, followed by defibrillation as early as possible for shockable rhythms. CPR may cause a reperfusion to the heart and thereby a perfusing heart rhythm, but the main goal is to win time and delay ischemic injuries in vital organs while other treatments are planned and conducted.

An animal study from 1986 estimates that high-quality, standardized CPR may provide 30% of normal circulation to the heart and 60% of normal circulation to the brain. (120)

The gold standard in manual chest compressions during resuscitation is compressions with a frequency between 100 and 120 compressions/min and a compression depth of 5 cm. (121) Several studies show that even professional rescuers are not able to perform high quality chest compressions over a longer period of time without deteriorated quality. An earlier multi-centre study on adherence to CPR guidelines among paramedics revealed too shallow compressions, and were provided only 50% of the time, resulting in a low mean compression rate. (122) In a

2005 in-hospital study, chest compressions did not meet the recommended frequency in 30% of the cases and not the required depth in 40%. (123) Fatigue has been shown to start approximately after 1 min of CPR with a continuous drop in quality afterwards in another study. (121) During the first three minutes, compression depth and frequency has been shown to decrease significantly. (124) A manikin-RCT showed that a rest period was needed after two minutes of chest compressions to maintain good CPR quality. (125) A Norwegian study has shown that some providers of compressions are able to give high quality compressions for ten minutes without rest, but others cannot even give proper compressions from the start of CPR. It is important to pay attention to the provider of compressions and switch if the compressions become too shallow or the provider seem tired, no matter how long time they have been given compressions. (126)

In the subgroup of witnessed cardiac arrest with ventricular fibrillation treated by professionals, initial immediate compression-only CPR, meaning continuous compressions while high flow oxygen provided through a conventional mask have shown to triple survival.(127) Compression-only CPR may be particularly beneficial in the early phases of CPR, but ventilations are still recommended as part of CPR in adult life support. (128) CPR providers should aim for an inflation duration of about 1 s, with enough volume to make the victim's chest rise, but avoid rapid or forceful breaths. The maximum interruption in chest compression to give two breaths should not exceed 10 seconds. (129)

Bystanders’ role in resuscitation in OHCA patients is crucial. A recent study from UK showed that the one single most important factor to make increase people's willingness to act in the event of a cardiac arrest is training and education in CPR. There is a considerable opportunity to increase the proportion of the general population trained in CPR. (130)

5.5 Public BLS training in Norway

A high proportion of the Norwegian population report being exposed to situations requiring first aid actions, and the large majority is willing to act.(131)
As part of its latest guidelines, the European Resuscitation Council (ERC) recommends providing BLS training to every member of a community (132) BLS is recommended as part of the school curriculum, (133) and compulsory resuscitation training was introduced in Norwegian schools in 1961. (134)

First aid training is part of the national school curriculum in Norway in grades 7 and 10. (131) Since 2003 first aid training has also been compulsory for obtaining a driver's license. Employees in schools and kindergartens, and fishermen are required by law to be able to perform first aid. All other occupational groups are unregulated by Norwegian law, and only subject to their various occupational standards, if any. First aid guidelines are provided by the Norwegian First Aid Council, a cooperative body comprising non-government organizations and government agencies with focus on first aid training, and the Norwegian Resuscitation Council.

An important arena for public BLS training is the mandatory BLS training for all conscripted soldiers in the Norwegian Armed Forces. 8000 young men and women are selected for initial compulsory military training each year.

5.6 Evaluation of BLS quality

CPR quality affects OHCA outcome. Both adequate compression depth and rate as well as a high compression fraction (the proportion of the CPR time spent on chest compressions) have been shown to correlate with return of spontaneous circulation.(26, 135, 136) Monitoring, evaluation and feedback on rescuers' performance improves chest compression quality. (137)

As feedback is an essential part of BLS training, several devices are available to assess CPR performance during training (138, 139)

For example, directive or audio feedback devices during training are recommended within the current 2015 ERC guidelines to improve the ability to perform CPR. (132) As such high-fidelity devices may not be available in low-income environments or financially weak surroundings, a simpler method of assessment is needed to provide feedback on CPR performance in these settings. In 1999, Graham et al. tested a scoring system based on simple observation as an inexpensive but effective method to assess CPR performance. The results suggested that an observation-based scoring system is an objective method to reflect the ability to perform BLS. (140)

A recent study used a simple ten-point checklist to assess BLS performance to evaluate if a checklist is a sufficient rating tool and an alternative instrument compared to Skill Reporting software for CPR quality measurement using BLS training manikins.(*1Undressed torso, 2 Adequate minimum no-flow time (no longer than 2 s for two rescue breaths), 3 Correct hand position 4,Correct compression depth, 5 Correct compression rate, 6 Complete release between compressions, 7 Arms kept straight, 8 Vertical direction of compressions, 9 No delay to start CPR, 10 Compression-ventilation ratio of 30*:2)(141)

A simple observational checklist can be used to assess BLS quality and identify sufficient and insufficient performances. In order to provide more detailed feedback concerning CPR, skill feedback devices may be useful in addition to the checklist. The checklist is a valuable assessment tool if high-tech feedback devices are not available or useful; for example, due to high numbers of participants in training groups or limited training time.

Data from public AEDs collected to investigate the quality of CPR during real-life bystander CPR showed valuable results. The main findings were overall high-quality CPR provided from bystanders, without deterioration over time but compression depth had poorer quality compared to other parameters. (142, 143) Findings of high quality CPR recorded by public AEDs were also supported in a large Canadian study using data from the Resuscitation Outcome Consortium (144)

5.7 Evaluation of ALS quality

Possibilities to monitor and evaluate ALS quality and CPR has evolved strongly over the latest decades. The first attempts to monitor quality of ALS were limited to direct observation on-site or investigating audio recordings. (85, 145, 146) Magnetic induction and accelerometers were developed to measure the chest displacement and rate during CPR and guide the rescuer to high quality chest compressions and became an important and helpful tool during CPR training. (147) A detailed assessment of chest compression quality was assessed using accelerometers mounted to the sternum during CPR. (122, 123)

With the development of methods to measure transthoracic impedance (TTI) through standard defibrillation pads, a new era of collecting data from resuscitation started. Transthoracic impedance varies for each compression and ventilation from the chest wall's baseline impedance, and is capable of measuring chest compressions, and movement of air (ventilations) and fluids (blood) through the chest. It is possible to calculate compression fraction and compression rate from TTI, but some studies have shown that it cannot reliably estimate compression depth. (148, 149) Advanced systems incorporating chest force measurements/force sensors and accelerometer signals can calculate compression depth. (150, 151) The first comprehensive trial of ALS evaluation was Sunde et al, reconstructing events and timelines from variations in the ECG recordings in addition to TTI. (85)

A recent study investigated the reliability and accuracy of the TTI signal for measuring CPR quality metrics, finding reliably results for all defined metrics except instantaneous ventilation rate, where the study revealed unacceptable large errors due to artefacts in the TI signal. (152)

Measurement tools of ALS quality metrics has been built-in functions in many different defibrillators today, and the use of monitoring tools is of great importance, and widely used in resuscitation research and quality improvement.

Efforts are made to standardize reports defining CPR quality metrics that should be reported. (153), to make a joint understanding on good quality CPR, and to monitor quality improvement programs.

Without reliable methods for collecting quality metrics and parameters in a uniform fashion, the effectiveness across EMS and measurements of intervention cannot be compared. (154)

5.8 Post resuscitation care

The whole-body ischemia-reperfusion response during cardiac arrest and subsequent restoration of systemic circulation results in a series of pathophysiological processes that have been termed the post-cardiac arrest syndrome.(155)

The post-cardiac arrest syndrome comprises post-cardiac arrest brain injury, post-cardiac arrest myocardial dysfunction, the systemic ischemia-reperfusion response with systemic inflammatory reaction, and the persistent precipitating disease. (156)

Post resuscitation care after OHCA requires a comprehensive and complex effort from multidisciplinary teams and involves intensive care support with input from various other medical specialties. A standardized in-hospital post arrest protocol was implemented in Oslo in 2002. The protocol was founded on Norwegian data on in-hospital factors associated with improved outcome after out-of-hospital cardiac arrest, (157) and findings of better neurologic outcome after treatment with mild therapeutic hypothermia after ROSC, (158) in addition to benefits of immediate coronary angiography in suitable OHCA patients to improve survival. (7)

Recommendations on implementation of comprehensive, structured post-resuscitation protocols was first included in the ERC 2010 guidelines. (118, 159) The most important change in post-resuscitation care in the 2015 guidelines after first incorporated in 2010, include a greater emphasis on the need for urgent coronary catheterization with subsequent percutaneous coronary intervention (PCI) following OHCA of cardiac cause. Primary percutaneous coronary intervention is the preferred method for restoring coronary perfusion when cardiac arrest has been caused by an ST-elevation myocardial infarction. Many cardiac arrest survivors with non-ST-elevation myocardial infarction may also benefit from urgent revascularization as studies have shown that initial ECG findings are not reliable in detecting patients with an indication for PCI after experiencing a cardiac arrest. (160) (161) (162) From the just recently published 2020 AHA guidelines the most conspicuous changes from earlier post-arrest guidelines are focus on simplifying guidelines for neuroprognostication and specific guidance on use of serum biomarkers, neuroimaging and electrophysiological test. It is also added an additional link to the chain of survival-“Recovery from OHCA”, concerning multimodal rehabilitation, mental health and multidisciplinary discharge plans after cardiac arrest. (66) The latest ERC guidelines (2021) is not published at the time of writing.

Therapeutic hypothermia, or now called targeted temperature management (TTM) is generally accepted as part of a treatment strategy for comatose survivors of cardiac arrest. It was recommended that patients should be cooled to 32 °C to 34 °C for 12 to 24 hours in 2010 ERC guidelines. (65) But with new evidence, all TTM procedures (e.g. 36 °C-TTM and 33 °C-TTM) seem to be similarly beneficial for comatose patients obtaining ROSC. (158, 163-166) A large randomized TTM trial revealed no main outcome differences between the two evaluated levels of TTM: 33 °C versus 36 °C.(164) There is still no international consensus on the precise target temperature but maintaining a constant temperature between 32 °C and 36 °C during TTM is recommended in 2015 ERC guidelines. (119, 167)

ILCOR is awaiting published results from the TTM2 study before updating 2020 guidelines on therapeutic hypothermia. (168, 169)

TTM may render traditional methods of prognostication more challenging or even unreliable. Prognostication is now undertaken using a multimodal strategy and there is emphasis on allowing enough time for neurological recovery and to enable sedatives to be cleared before neurological testing and prognostication. (170, 171)

Recommendations include the systematic organization of follow-up care, which should include screening for potential cognitive and emotional impairments and provision of information. Evidence is emerging that concentrating post-resuscitation care in centres of excellence with multidisciplinary teams could be an innovative strategy to improve cardiac arrest survival, like other time-sensitive conditions. (172)

5.9 Outcome measures

Primary endpoints in resuscitation research have traditionally been survival to discharge, 30-day survival and/or one-year survival after discharge. There has been a lack of consistency in definition and the time points at which outcome was assessed and researchers and clinicians experienced inconsistency on outcome reporting, limiting the possibility of pooling results for meta-analysis.(173)

Even though some patients survive to hospital discharge, all OHCA patient undergo cerebral hypoxia to some degree and neurological outcome is important to consider when evaluating the overall outcome after OHCA. There has been an interest in cardiopulmonary-cerebral resuscitation among critical care investigators since late 1970s.(174)

The Glasgow Outcome Scale (GOS) was first published in 1975. It was a highly cited study on outcome measure in studies of brain injury and became worldwide a standardized assessment of outcome after severe brain damage (175). Peter Safar modified the GOS to fit neurological outcome measures after anoxic brain injury following cardiac arrest. (176) The modification of GOS, the Cerebral Performance Category scale (CPC) was included in the Utstein guidelines as an outcome measure describing brain function for resuscitation research and clinical purposes. Even though it has been criticized to correlate weakly to actual quality of life measures, (177) CPC scoring has become the most widely used approach to evaluate neurological outcome after successful resuscitation up until recently. (176, 178, 179)

The CPC has five categories, ranging from normal brain function (CPC 1) to death (CPC 5). (Table 1) The Overall Performance Category (OPC), on the other hand, reflects overall clinical status taking both clinical and cerebral function into consideration. These outcome categories are reliable and easy to obtain and often require only a telephone call to family members.

Survival to discharge with CPC 1-2 has been considered as favourable outcome and CPC 3-5 as bad outcome.
Neurological status does not directly reflect overall functional outcome after cardiac arrest. (171). The CPC score has been criticized for being too focused on mental function and less

informative about body functions, activity, and participation, which may explain the reported lack of agreement between CPC and more direct quality of life measures. (165) (177)

The COSCA initiative (Core Outcome Set for Cardiac Arrest), a partnership between patients, their partners, clinicians, research scientists, and the ILCOR, sought recently to develop a consensus core outcome set for cardiac arrest. They refined recommendations for when these outcomes should be measured and further characterized relevant measurement tools. Consensus emerged that a core outcome set for reporting on effectiveness studies of cardiac arrest (COSCA) in adults should include survival, neurological function, and health-related quality of life. This should be reported as survival status and modified Rankin score (mRS). It is a six-point disability scale with possible scores ranging from 0 to 5. A separate category of six is usually added for patients who expire. Standardized interviews to obtain a mRS score are recommended at discharge and/or at three months (90 days) after hospital discharge. The mRS is currently the recommended evaluation on quality of life and neurological outcome in OHCA survivors. (173, 180)

5.10 Outcome of Brain Injury: The Glasgow-Pittsburgh Cerebral Performance and Overall Performance Categories

Cerebral Performance Categories	Overall Performance Categories
1. Good cerebral performance. Conscious. Alert, able to work and lead a normal life. May have minor psychological or neurological deficits (mild dysphasia, non-incapacitating hemiparesis, or minor cranial nerve abnormalities).	1. Good overall performance. Healthy, alert, capable of normal life. Good cerebral performance (CPC 1) plus no or only mild functional disability, from non-cerebral organ system abnormalities.
2. Moderate cerebral disability. Conscious. Sufficient cerebral function for part-time work in sheltered environment or independent activities of daily life (dressing, traveling by public transportation, and preparing food). May have hemiplegia, seizures, ataxia, dysarthria, dysphasia or permanent memory or mental changes.	2. Moderate overall disability. Conscious. Moderate cerebral disability alone (CPC 2) or moderate disability from non-cerebral system dysfunction alone or both. Performs independent activities of daily life (dressing, traveling, and food preparation). May be able to work part-time in sheltered environment but disabled for competitive work.
3. Severe cerebral disability. Conscious. Dependent on others for daily support because of impaired brain function (in an institution or at home with exceptional family effort). At least limited cognition. Includes a wide range of cerebral abnormalities from ambulatory with severe memory disturbance or dementia precluding independent existence to paralytic and able to communicate only with eyes, as in the locked-in syndrome.	3. Several overall disability. Conscious. Severe cerebral disability alone (CPC 3) or severe disability from non-cerebral organ system dysfunction alone or both. Dependent on others for daily support.
4. Coma, vegetative state. Not conscious. Unaware of surroundings, no cognition. No verbal or psychological interactions with environment.	4. Same as CPC 4.
5. Death. Certified brain dead or dead by traditional criteria.	5. Same as CPC 5.

Table 1 - Outcome of Brain Injury: The Glasgow-Pittsburgh Cerebral Performance and Overall Performance Categories (171)

5.11 Benchmarking OHCA treatment quality

An international multidisciplinary meeting on resuscitation was held at the Utstein Abbey near Stavanger, Norway, in June 1990, the term “Utstein style” originated from this meeting and is synonymous with consensus reporting guidelines for resuscitation. (179)

The original Utstein definitions were revised in 2004 with the aim of reducing complexity and updating data elements based on advances in resuscitation science (181) The Utstein 2004 revision included all EMS-treated cardiac arrests irrespective of first monitored rhythm and whether or not the arrests were witnessed. The International Liaison Committee on Resuscitation (ILCOR) proposed a group form to review and, if necessary, update the Utstein templates for cardiac arrest.(182)

A cardiac arrest registry measures all aspects of the resuscitation care and can act as a benchmark for the entire EMS system. As stated by the “Global Resuscitation Alliance” measurement and improvement in a cyclic manner is crucial in the efforts to improve survival from OHCA. There has been a globally increasing trend towards resuscitation registries and clinical trial groups, with major national and regional registries established around the world (78, 183-185). These registries are being used increasingly to compare the epidemiology and outcome of cardiac arrest, explore the relation between key treatments and outcome, identify and prioritize gaps in resuscitation science knowledge, and drive quality improvement.
A recent study across twelve large registries showed valuably results of the outcome variation, where more than half of the variations of survival to discharge were explained by Utstein variables. (186)

The Norwegian registry of cardiac arrest (Hjertestansregisteret) was founded in 2002 and obtained status as a nationwide medical quality register in 2013. The data register is hosted by Oslo University Hospital and the aim is to monitor quality of health service provided to cardiac arrest patients. (14)

Since 2010 efforts have been directed to specify definitions of cardiac arrest treatment, survival and neurological outcome and establish registries all over Europe. In October 2014 27 European countries gathered in the prospective, multicentre one-month study Eu-Re-Ca

One ,based on registry data from seven nationwide registries and 20 countries.(12) The aim of this study was to determine the incidence and outcome for OHCA throughout Europe. The follow up study, EuReCa Two collected data between October and December 2017, and evaluated the epidemiology and outcome in OHCA, with particular focus on bystander CPR, because the term “bystander CPR” was interpreted differently across countries during the EuReCa One. (12)

The Resuscitation Outcomes Consortium (ROC) established a registry of OHCA in the United States and Canada, which covers 264 EMS agencies and a population of 23 million people. (187) CPR quality metrics are collected as a non-mandatory item in the registry dataset. However, the collection of a large amount of data has enabled the group to produce a series of observational studies which examine the association between CPR quality metrics and patient outcomes. (79, 188)

6 Aims of the thesis

Paper I and *II* are register-based studies, while *paper III* is a prospective manikin study.

Paper I aimed to evaluate if distinct areas of improvement in the local treatment chain; focus on quality in CPR and ALS in Oslo EMS and implementation of a structured post-resuscitation treatment protocol improved outcome in OHCA in Oslo.

Paper II investigated if having a physician present during resuscitation of OHCA was associated with better quality in ALS and more favourable outcome than OHCA treated without a physician present.

Paper III was a controlled simulation-based assessment aiming to investigate CPR performance in non-health professionals with different levels of life support training and to evaluate the correlation between perceived and actual skills in CPR.

The following research questions were defined:

Paper I: Does targeted interventions to improve CPR and ALS quality and implementations of in-hospital post-resuscitation care protocols improve survival and neurological outcome for OHCA patients?

Paper II: Does quality of CPR, ALS and outcome in OHCA patients differ between patients treated with or without involvement from the physician-manned ambulance within the EMS system?

Paper III: Does level of BLS training impact on CPR performance in non-health professional bystanders, and is perceived and actual CPR performance corresponding?

7 Material and methods

7.1 Overview Materials and Methods

	Paper I	Paper II	Paper III
Paper title	Improving outcome after out-of-hospital cardiac arrest by strengthening weak links of the local Chain of Survival; quality of advanced life support and post-resuscitation care.	Out-of-hospital advanced life support with or without a physician: effects on quality of CPR and outcome.	Relationship between level of CPR training, self-reported skills, and actual manikin test performance. An observational study.
Study design	Observational registry study	Observational registry study	Observational simulation-based study
Power calculations	No	No	Yes
Study period	1996-1998, 2001-2003,2004-2005	2003-2008	2013-2015
N (patients/study objects)	1320	1128	247
Population	OHCA patients, older than 18 yrs with non-traumatic cardiac arrest in three defined time periods in Oslo.	OHCA patients, older than 18 yrs with non-traumatic cardiac arrest between 2003 and 2008 in Oslo.	Conscripted and professional soldiers from the military camp Setermoen, with three different levels of life support training.
Data material	Utstein cardiac arrest forms, computer-based time records, ambulance run sheets, hospital records for admitted patients	Utstein cardiac arrest forms, computer-based time records, ECG with impedance records, ambulance run sheets, hospital records for admitted patients	Questionnaires and direct observation and evaluation of CPR performance in study objects during a cardiac arrest scenario
Statistical analysis	One-way ANOVA, linear by linear association for trends over time periods	Chi-square test with continuity correction. Student's t-test or Mann-Whitney U-test for continuous data as appropriate. Stratification analysis using Maentel-Haenzel method	One-way multivariate ANOVA. Tukey test for post hoc comparisons. Multiple logistic regression.
Primary outcome	Survival to discharge with CPC scores	CPR quality, survival to discharge	CPR quality

Table 2 - Overview Materials and Methods

7.2 Paper I

Improving outcome after out-of-hospital cardiac arrest by strengthening weak links of the local Chain of Survival; quality of advanced life support and post-resuscitation care.

Paper I is a relatively large, single centre registry study. Patients older than 18 years suffering from non-traumatic OHCA of all causes in Oslo and included in the local cardiac arrest registry in the three defined study periods were included. The city of Oslo covers 454km^2 and has 693,494 inhabitants (January 1st, 2019) with 51% female population and 4.9% of the population over 80 years. Oslo has had a continuous population growth the last 20 years, mainly due to migration leading to a larger proportion of young adults 20–39 and lower proportion of children and adults >40 years compared to the rest of Norway. (189)

The city of Oslo has a one-tiered community-run EMS system. All acute care ambulances are manned with paramedics. A physician-manned ambulance (PMA) staffed by two paramedics and an anaesthesiologist functions on the same level as the regular paramedic-staffed ambulances and is located at one of the six ambulance stations spread across Oslo. The PMA operated on weekdays between 7:30 and 22:00 when the first studies in this dissertation was published, but the PMA is currently on service 24h/day.

All paramedics were trained to use defibrillators in manual mode. Endotracheal intubation was the standard method for securing the airways, followed by uninterrupted chest compressions with 10—12 interposed ventilations per minute. Nurses and paramedics staff in the dispatch centre were trained to provide CPR instructions when cardiac arrest is suspected.

Two ambulances were routinely dispatched when cardiac arrest was suspected. The physician-manned ambulance was dispatched whenever available. Both PMA and non-PMA were dispatched based on availability and location with the same dispatch criteria.

The paramedics and PMA physicians in Oslo are yearly certified in ALS. All paramedics are supposed to work a few shifts each year on the PMA as part of the quality improvement program of the EMS.

All hospitals in Oslo had goal directed post-resuscitation protocols including TTM for all actively treated unconscious patients regardless of initial rhythm or arrest aetiology. Pre-hospital 12 lead electrocardiogram (ECG) was routinely transmitted from all ambulances to

the cardiologist on call at OUH after return of spontaneous circulation (ROSC). If coronary angiography was indicated for possible subsequent percutaneous coronary intervention (PCI), patients were transported directly from the scene to one of two university hospitals with this capacity 24 h/day.
Data were collected retrospectively from all registered cardiac arrests from the local Utstein cardiac arrest forms, ambulance run sheets and computer-based time records from the dispatch centre. All data were thereafter categorized and analysed and complemented with patient records for admitted patients.

Three study periods were defined based on empiric knowledge from interventions implemented in the local EMS and in Oslo University Hospital Ullevål (OUHU) on defined points of the timeline. (Table 3) No power calculation was conducted during study planning as all patients meeting the inclusion criteria in predefined time periods were included.

The first period (1996-1998) was defined as a baseline. Patients in this group were treated by ALS providers trained according to the ERC 1992 guidelines. (133) Treatment of OHCA in this period was marked by a lot of unsuccessful shocks and long hands-off periods resulting in reduced overall vital perfusion.(85) No standardized post resuscitation care was present in the hospital treatment among admitted patients. Patients in the second group (2001-2003) were treated following implementation of nationally modified 2000 guidelines. (190-193) The Norwegian modification of guidelines consisted of three instead of one minute of CPR before and in between defibrillation attempts. This guideline aimed for an increased focus on quality of CPR, three minute periods of CPR before and in-between defibrillations to improve vital organ perfusion and optimize the relation between CPR and defibrillation. (90) Still, no changes in the in-hospital treatment provided for admitted patients were established. Patients during the last period (2004-2005), however, received in addition improved post-resuscitation care after implementation of a standardized post-resuscitation care protocol in 2002. (118) The goal of this treatment protocol was to reduce vital organ injuries (brain, heart) by optimizing hemodynamic and oxygenation, treat the cause of the arrest (reperfusion after acute ischemia) and initiate TTM (32-34 °C for 24hrs) as early as possible after ROSC and admission.

Locally adapted Utstein style forms, dispatcher recordings and ambulance-/hospital records were collected for each patient and reviewed. For all admitted patients, additional hospital records were obtained from the respective receiving hospitals. Primary outcome was survival to hospital discharge with a favourable neurological outcome (CPC 1 or 2).

7.3 Overview study periods Paper I

Study period	1	2	3
Time period	1996-1998	2001-2003	2004-2005
Guidelines	ERC 1992	ERC 2000*	ERC 2000*
Intervention	Baseline	Enhanced focus on CPR quality and defibrillation in EMS	Locally implemented a standardized in-hospital post resuscitation care protocol
Quality of care	- Poor CPR/ALS - Poor post-resuscitation care	- Poor CPR/ALS - Poor post-resuscitation care	- Good CPR/ALS - Good post-resuscitation care
**nationally modified 2000 guidelines, aiming diminished interruptions in chest compressions and transition from stacked shocks to single shocks every three minutes with high quality CPR between shocks*			

Table 3 - Overview study periods, paper I

7.4 Paper II

Out-of-hospital advanced life support with or without a physician: effects on quality of CPR and outcome.

Paper II is an observational study, designed and planned to examine if the involvement of a PMA affects CPR quality and outcome after OHCA in the local EMS system. Patients older than 18 years with non-traumatic OHCA of all causes in Oslo in a five-year period between 2003 and 2008 were included in this study. No power calculation was conducted as all patients meeting the inclusion criteria in the defined time frame were included. Many of these patients were also included in a randomized study evaluating the effects of intravenous drugs during cardiac arrest. (194)

During the study period the PMA operated from 7.30-22 on weekdays. Thus, OHCA occurring during nights or in the weekend were never treated with involvement from the PMA. During weekdays, the dispatch centre aimed to send the PMA to all OHCAs, but paramedics (non-PMA) may be dispatched first if they were closer to the patient and the PMA would be involved as a second responder when available. If the PMA was unavailable, or the OHCA occurred outside the operating hours for the PMA, two ambulances were dispatched directly to the patient.

Thus, included patients were retrospectively categorized into three groups based on whether they were treated by a PMA, a non-PMA or a PMA as second responder. These groups were formally compared. Patients being treated by a PMA as second responder is a highly selected sub-group where the presence of the PMA is requested by first arriving ambulance, and this group was therefore excluded from the comparative analysis due to potential highly confounding effects on outcome

Data were retrospectively collected from ambulance run sheets, Utstein cardiac arrest forms and patients records for admitted patients. Data on CPR quality was retrospectively viewed and annotated using CODE- STATTM 7.0 (Physio-Control, Redmond, WA, USA) for detection of ventilations and chest compressions by changes in TTI. Utstein style forms were compared with typical changes in CPR patterns in transthoracic impedance. For outcome data, additional hospital records were obtained. Primary end point was survival to hospital discharge. Secondary endpoints were quality of CPR and CPC score, with CPC of 1 or 2 defined as favourable outcome.

7.5 Paper III

Relationship between levels of CPR training, self-reported skills, and actual manikin test performance-an observational study.

Paper III is an observational simulation-based study, designed to compare a short course in life support training to a more extensive course, and to investigate if perceived and actual skills corresponded. The military population was chosen due to their homogeneous baseline demographics and strict standardized curricula for BLS training. This allowed for diminishing the inter-subject variability in the test model.

Norwegian soldiers receive a 40-hour first aid course compulsory for all military personnel during the first months of their training. The course includes 5 h of CPR training, consisting of a 2 h lecture and 3 h practical training with a manikin. The CPR training is in accordance with current Norwegian guidelines based on ERC BLS guidelines. (195)

Some designated soldiers attend the advanced first-aid training course, a 96-hour course for future army medics after the completion of the basic course. The advanced training curriculum includes 18 h CPR training, with 4 h lectures and 14 h manikin training. They are also given a brief introduction to basic airway adjuncts (the oropharyngeal and nasopharyngeal tube).

Participation in the study was voluntary with a potential bias that many of the participants were those interested in first aid. This was mitigated by not informing participants of the nature of the case in forehand.

The study objects were already trained in two different levels of life support and were categorized into groups according to their level of training. Group I (Basic 40-hour first aid course), group II (Advanced 96-hour first aid course). As some of the study participants on the advanced level training had additional courses, a third group were categorized; Group III (advanced first-aid training and additional courses).

Data collection was conducted in their home military base.

All participants completed a comprehensive questionnaire, mapping demographic variables, experience, training intervals and other known and possible confounders. They were thereafter tested in actual CPR performance in a single-rescuer BLS manikin scenario, using the Laerdal Resusci Anne Basic. Each participant reported their self-perceived preparedness about CPR and their CPR skills on a Likert based ten-point scale both before and after the manikin test. 1 point on this scale reported the lowest level of perceived skill and preparedness, 10 points was maximum reported perceived skill level and preparedness. (Table 4)

7.5.1 Test parameters for perceived and actual skills in Paper III

Pre-manikin test	**Manikin test**	**Post-manikin test**
Likert scale on preparedness to do CPR	*Single rescuer BLS scenario*	*Likert scale on CPR performance*
"Confident to examine a critically ill patient"	Compression rate 1st- 5th loop CPR	"Did a systematic assessment"
"Well trained in the CPR algorithm"	Effective ventilations	"Performed good quality CPR"
"Well prepared to do CPR"	Compression fraction	"Would perform the same on a real patient"
	Correct hand placement on chest	
	Correct compression depth	
	Total hands-off time	
	Time from verified cardiac arrest to start CPR	

Table 4 – Test parameters for perceived and actual skill in paper III

Data in the manikin test were mainly visually accessible parameters. Feasibility of the simple observational protocol was evaluated in a pilot study, with 10 nursing and 10 medical students, respectively. The feasibility study was set up to investigate the interobserver discrepancy.

This simple observational set-up with an ordinary manikin without skill meter and direct observation as evaluation method was a conscious decision. The study protocol aimed to examine the study objects in use of the manikin they used in their ordinary CPR training and test them in their own environment. This was considered valuable to diminish confounders from unfamiliar manikins and equipment.

Primary outcome was CPR quality in the manikin test, secondary outcome was correlation between perceived and objectively measured skills.

8 Statistical analyses

8.1.1 Paper I

All data were manually recorded in a spreadsheet (Microsoft Excel 2007) and analysed with SPSS 16.0.

Comparisons of continuous data were analysed with one-way ANOVA to determine if there were differences between the two intervention groups and the baseline group. Post hoc comparisons with Bonferroni test were conducted to examine if all groups were significantly different. To examine time trends over time periods categorical data were analysed using linear by linear associations. A p value of <0.05% was considered as significant.

8.1.2 Paper II

All data were manually recorded in a spreadsheet (Microsoft Excel 2007) and analysed with SPSS 16.0.

In paper II differences between the two pre-defined groups (PMA vs non-PMA) were analysed using chi-square test with continuity correction for categorical data, and Student's t-tests or Mann–Whitney U-tests for continuous data, as appropriate.

A stratification analysis using the Maentel–Haenzel method was performed to pinpoint effect modification at the multiplicative level using the Breslow and Day test of heterogeneity and to quantify confounders by comparing the adjusted Maentel–Haenzel odds ratio (OR) to the crude OR.

Adjustments for multiple confounders were done using unconditional logistic regression using a manual backward elimination procedure. An investigation of the correlation between potential confounders was performed

A p value <0,05 was considered significant.

8.1.3 Paper III

All data were manually recorded in a spreadsheet (Microsoft Excel 2010) and analysed with SPSS 22.0.

An a priori power analysis was conducted based on differences in a two-way feasibility study including student on two different levels in first-aid training. The sample size was powered to evaluate changes in CPR performance, and 101 participants were needed based on the results from the feasibility study.

All means and standard deviations (SD) were calculated for continuous variables, frequencies and proportions for categorical variables, and Chi-square test of independence for dichotomous variables, and one-way ANOVA and multivariate ANOVA (MANOVA) for normally distributed data.

Multivariable logistic regression models were fitted and tested on each outcome variable. Model calibration was tested with the Hosmer–Lemeshow test. The model was adjusted for potential confounders. OR with 95% confidence intervals (95 CI) were calculated for each outcome variable.

As the dependent variable in the self-reported skill rating analysis across level of training had more than one dependent variable, it was necessary to extend the one-way ANOVA to a MANOVA. This analysis was conducted with three levels of training (Group I-III) as the independent variable and self-reported skill rating from four different statements on a 10-point scale as the dependent variable, to test for differences between training levels and self-reported skill scores. Significant differences were analysed with Tukey test for post hoc comparisons.

A p value $<0,05$ was considered significant.

9 Summary of results

9.1 Paper I

A total of 1320 patients received ALS for OHCA during the three study periods. Age, gender and proportion of cardiac aetiology did not differ significantly between the three time periods. Response times increased from mean seven to nine minutes from the first and second to the last period (p<0,001). Over the same time period there was also a significant increase in unwitnessed arrests (p=0,02), arrests with initial non-shockable rhythms (p=0,039) and no significant increase in bystander CPR rates (p=0,84). (Figure 2)

Despite this, there was a non-significant trend towards increased rate of ROSC (p=0,058) and a significant increase in admission to ICU (p=0,04). Favourable neurological outcome (CPC 1-2) was significantly improved during the 9-year study period(p=0,001). (Figure 3)

There were significant increases in overall survival (p=0,002), survival with favourable neurological outcome (p=0,001) and increased survival in the subgroup of patients with VF and witnessed arrest (p=0,003). (Figure 3)

The increasing proportion of survivors with favourable neurological outcome, indicates that ALS training focusing on optimizing chest compressions by stressing the importance of adequate force and rate as well as limiting hands-off intervals in addition to implementation of standardized post-resuscitation care protocols have led to significantly improved outcome for patients with OHCA in Oslo.

9.1.1 Summary of descriptive data per time period Paper I.

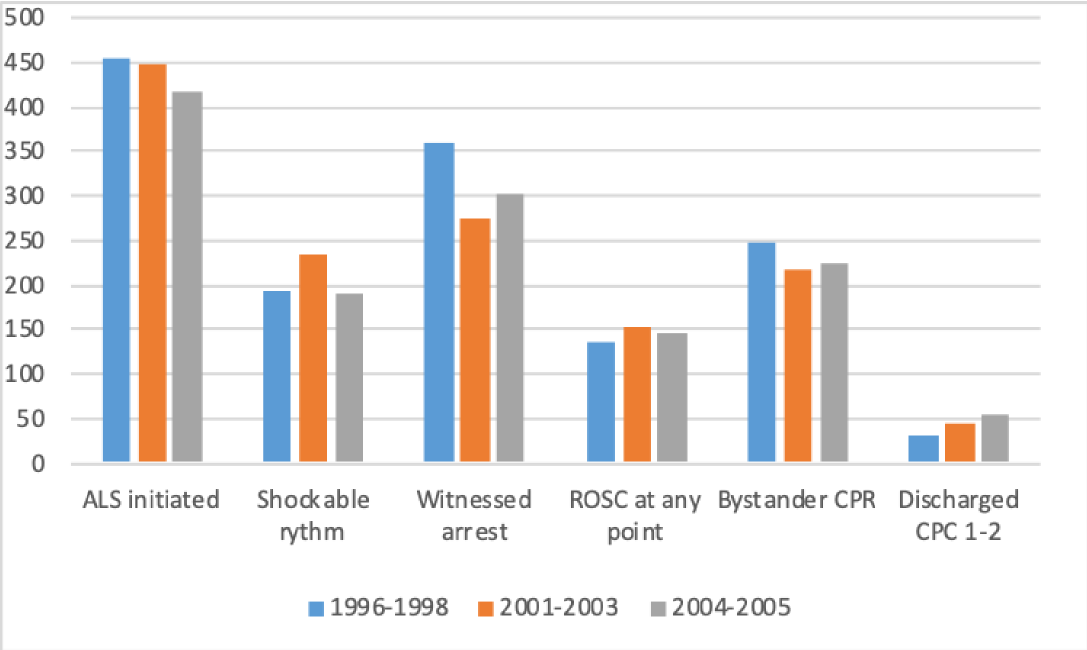

Figure 2 – Summary of descriptive data per time period paper I

9.1.2 Survival rate per initiated resuscitation (%) per time period

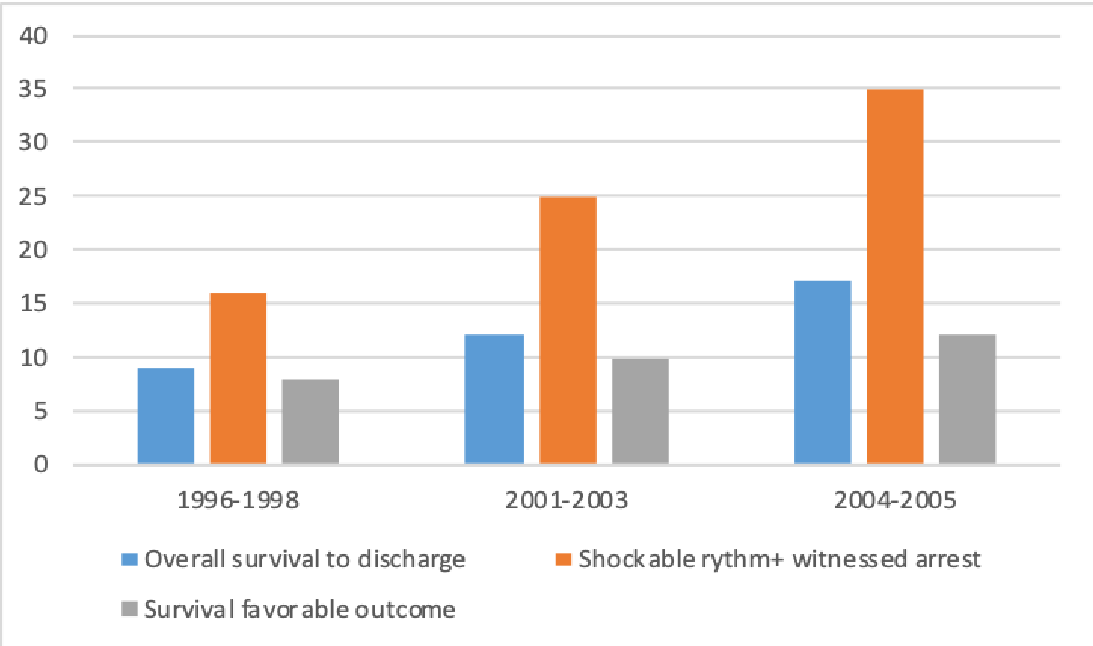

Figure 3 – Survival rate per initiated resuscitation (%) per time period

9.2 Paper II

A total of 1128 patients received ALS for OHCAs during the five-year study period. The PMA was dispatched as first responder to 21% of all OHCAs during the study period. Altogether 232 patients were treated by a PMA as first responder, and 741 were treated without any involvement from a physician. 155 patients were treated by a PMA as a second responder.

Patients treated in the PMA group were more likely to have a bystander witnessed arrest (p=0,036), a higher number of bystander CPR (p=0,027), and more initial shockable rhythms (p=0,012), compared to patients treated in the non-PMA group.

Because of the higher rate of shockable rhythms, the PMA group were obviously more likely to receive defibrillations. They were also more likely to receive medical interventions and ECG analysis after ROSC. (Figure 4)

CPR quality measures like hands-off ratio and pre-shock pauses were improved in the PMA group ($p<0.001$ for both parameters)

9.2.1 Medical interventions in PMA and non-PMA group in %

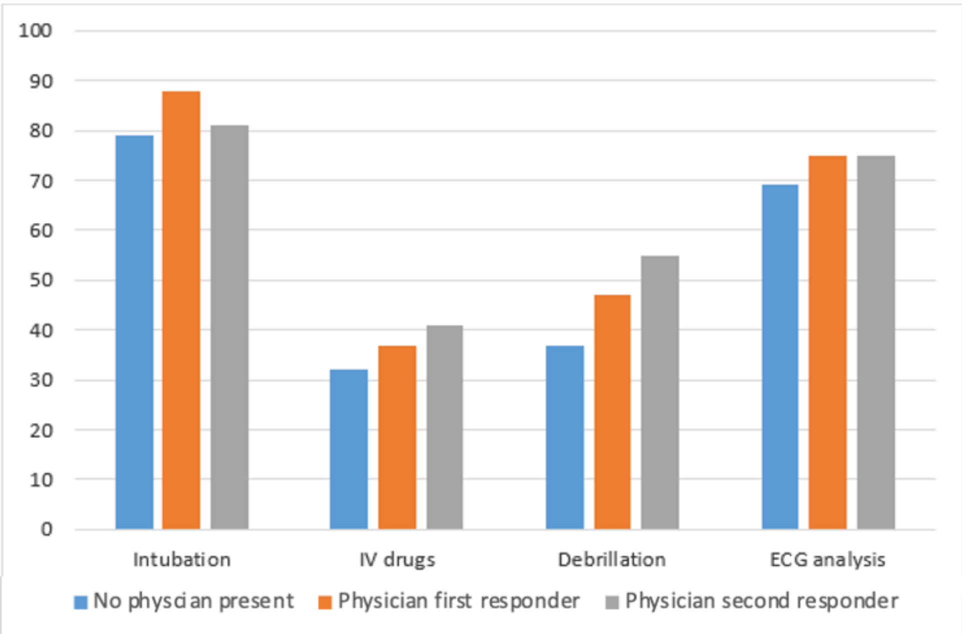

Figure 4 – Medical interventions in PMA and non-PMA group in %

Despite several positive prognostic factors such as higher bystander CPR rate , initial shockable rhythms, witnessed arrest and more medical interventions in the PMA group, there was no significant difference in overall survival (p=0.28), or survival with favourable neurological outcome (p=0.38) between patients being treated by the PMA as first responder or paramedic-manned ambulances within our EMS system. (Figure 5)

The subgroup of patients witnessed arrest with initial VF/VT did not either show increased overall survival when treated by the PMA(p=0,82)

9.2.2 Outcome variables in % in the PMA and non-PMA group

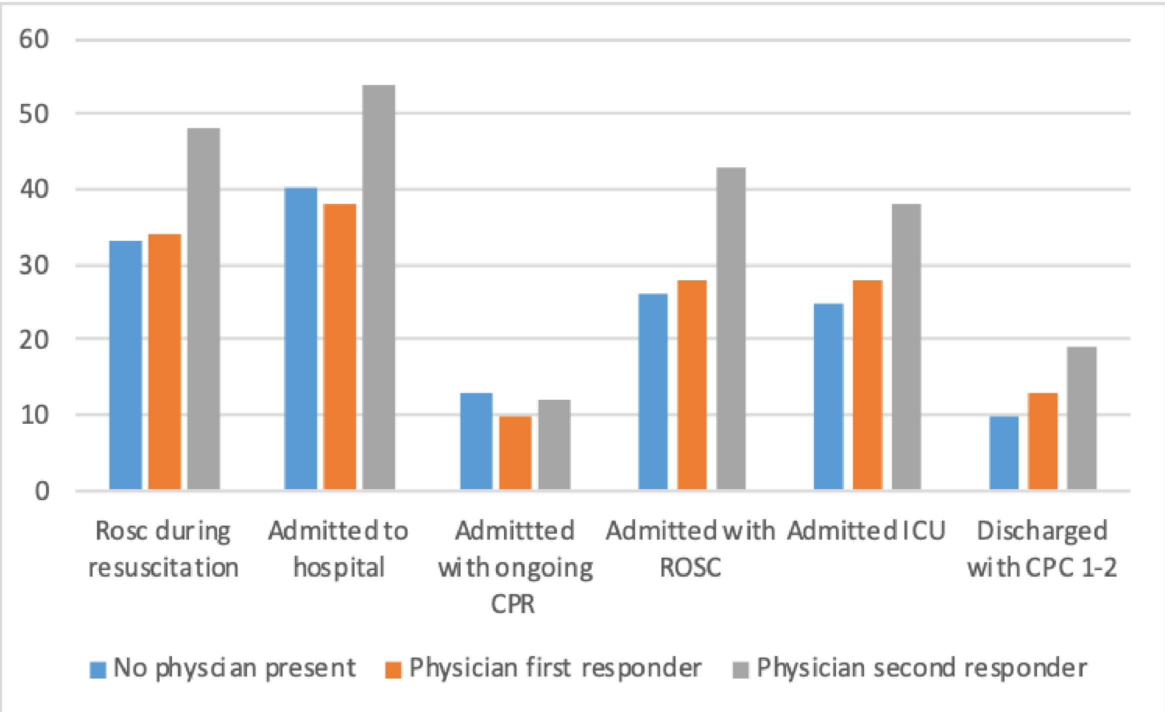

Figure 5 – Outcome variables in % in the PMA and non-PMA group

9.3 Paper III

In this simulation-based manikin model, comprehensive BLS training resulted in better CPR quality, particularly regarding ventilations and hands-on time (Figure 6 and 7). Compression rate during five loops of CPR, had an adequate rate (average 95-113 across all five loops) and was not significantly different between groups (p=0,310-0,603 through five loops). (Figure 7)

Total hands-off time and time from verified cardiac arrest to start CPR was significantly different between group I (basic level of first aid training) and group II (advanced level of first aid training) and III (advanced level of training with additional courses) (p=<0.001) but not between group II and group III(p=0,39). (Figure 6)

The most striking finding in this study was that adequate airway management and ventilation skills, as well as chest compression fraction and compression depth, were significantly related to level of first aid training. Participants with only a basic course in BLS provided significantly poor airway management compared to participants with advanced training level (p<0,001). (Figure 8)

Study objects on all levels of training showed overall good insight in own skills and limitations with statistically significant associations between self-reported and actual competence. The participants in group I (basic training) scored their own skills and preparedness significantly lower on the ten-point scale than groups II and III in all statements. both before and after test. In addition, group III (advanced training with additional courses) reported higher confidence in examining the critically ill patient and for preparedness in doing CPR before the manikin test than both groups I and II (advanced training).

9.3.1 Differences in hands-off time (in sec) and time from verified arrest to start CPR between groups (in sec)

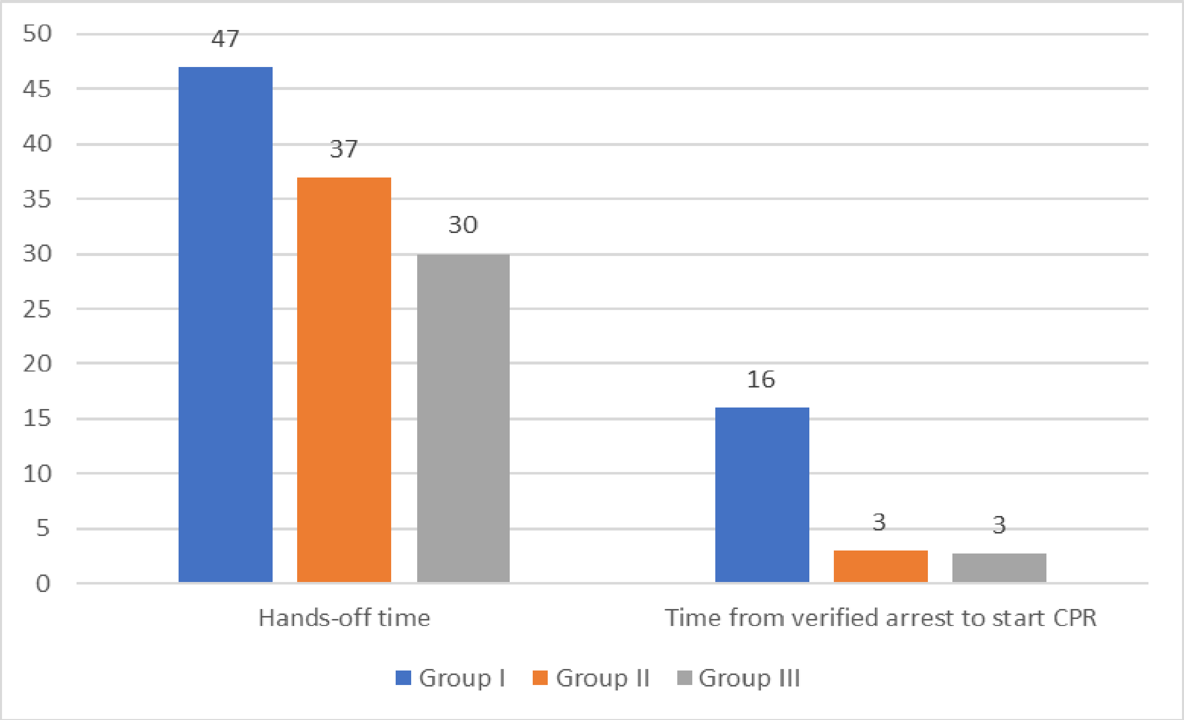

Figure 6 – Differences in hands-off time (in sec) and from time verified arrest to start CPR between groups (in sec)

9.3.2 Compression rate per minute in each group through five loops of CPR

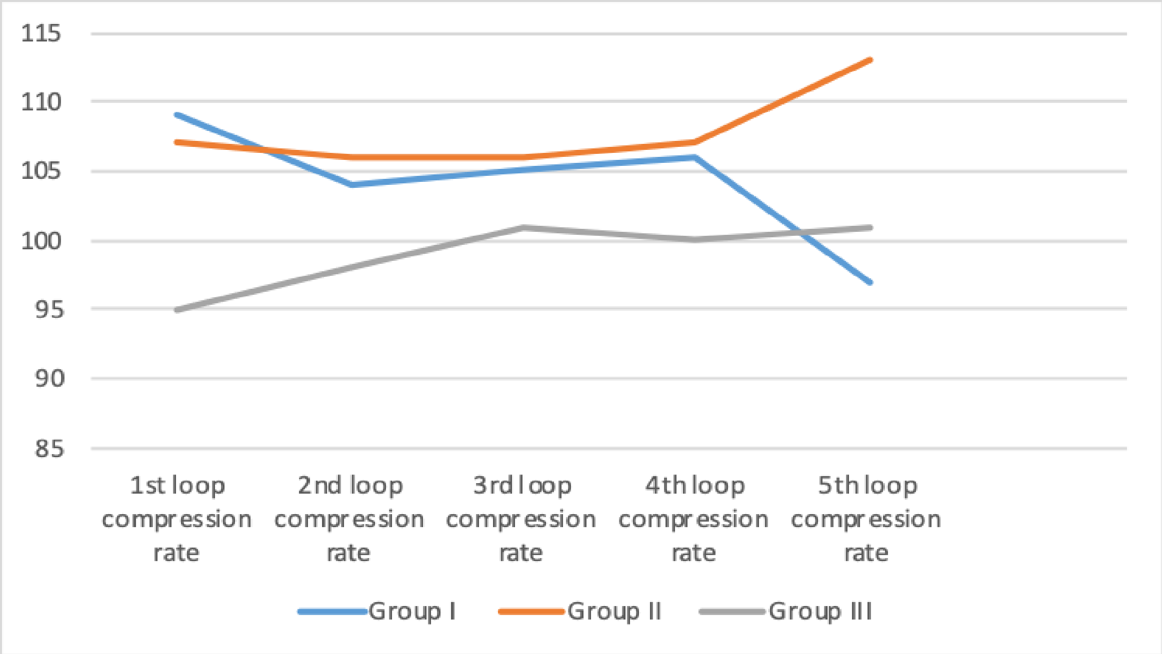

Figure 7 – Compression rate per minute in each group trough five loops of CPR

9.3.3 CPR quality parameters in % within each group

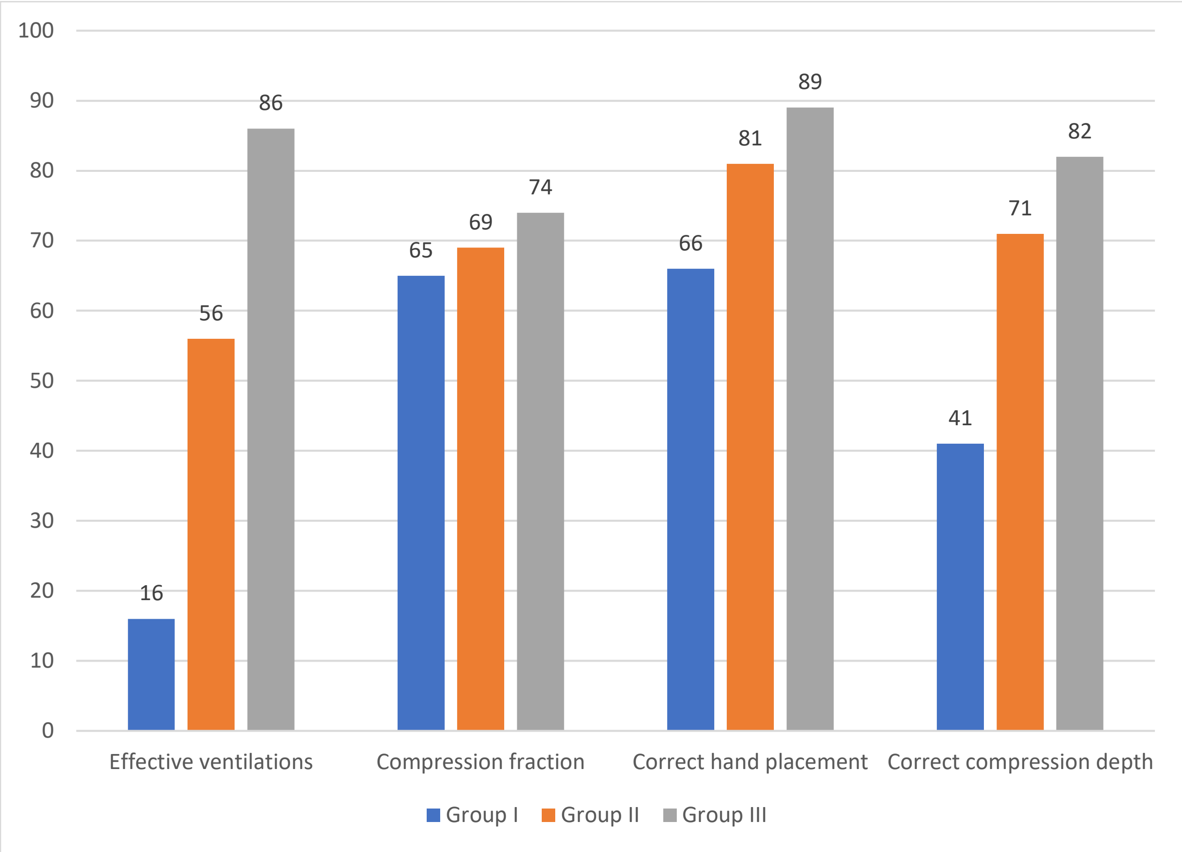

Figure 8 – CPR quality parameters in % within each group

10 Discussion

Survival and favourable neurological outcome after OHCA depend on a timely and tuned treatment chain. The capacity and quality of the system depend on each link, from BLS provided of bystanders, through the emergency dispatcher and ALS provided by EMS to the in-hospital treatment and post-resuscitation care. (71) Researchers and clinicians have been searching for modifiable factors for better outcome in OHCA for decades.

Oslo had relatively high bystander rates and the last links in chain of survival concerning ALS and post-resuscitation care were considered weak links before quality improvements interventions. Study I aimed to measure effects of quality improvements efforts in ALS quality and post arrest care. (85, 196)

The main focus on different modifiable factors of the treatment chain in OHCA has shifted in resuscitation guidelines over time, and the papers in this thesis reflects chronologically the changes in emphasized areas from a strong focus on the advanced parts of the treatment (*paper I and II*) to provision and quality in CPR from bystanders (*paper III*).

10.1 Paper I:

Patients from the first period (1996-1998) in *paper I* were treated following the 1992 ERC guidelines. The 1992 resuscitation guidelines focused on the ALS part of treatment of OHCA, and intubation and intravenous drugs were brought forward in the cycle of events. (57) The guidelines were not designed to fit automated defibrillators and much emphasis was on the ALS providers' ability to analyse and interpret heart rhythm. It was also short time between shocks (one minute), and three stacked shocks. (197) This resulted in diminished focus on CPR and poor ALS performance in Oslo EMS, with long periods of hands-off time without perfusion to vital organs and few successful shocks. (85) Data from other EMS systems in the same time period showed similar findings when advanced procedures as intravenous lines delayed first shock and transport after ROSC. (145) There was no standardized protocol for in-hospital treatment after ROSC and TTM was not in use for post arrest patients in this period (118, 157) From the 1998 guidelines more attention was given to the chest compressions, both rate and quality. New BLS guidelines emerged in 1998, but focus was still on ALS and improvement of the advanced part of the treatment chain. (198, 199) The survival had remained approximately unchanged for 30 years, (9) and inspired local initiatives to improve quality of ALS in Oslo EMS to increase survival with favourable outcome. Poor ALS quality was documented in initial investigations. (122, 123) An American study from 1999, showed improved outcome when high quality CPR were provided before the first shock in VF patients,(91) and researchers continued to aim for strategies to improve the ratio between CPR and shock to decrease hands-off time.

Evidence- based medicine was increasingly emphasized, and more attention was given to evidence-based implementation towards the end of 1990. The 2000 Guidelines had increased focus on chest compression quality. A Norwegian modification of three min CPR prior to defibrillation was implemented due to findings in local studies before 2001. (85, 90, 200) Training, treatment and education in Oslo EMS were based on the modified 2000 guidelines after the implementation in 2001, and training focused on adequate compression force and rate and limiting hands-off time. Data from Oslo showed shorter hands-off time after this change in focus, (201) and the time after this change in training was selected as the second study period (2001-2003), in order to investigate the effect of change in focus. The Oslo EMS implemented a strategy to improve the ALS quality by providing performance-based feedback, presenting the performance evaluation to the CPR-providers with focus on areas in need of improvement. (202) The first study period (1996-1998) was defined the baseline group, and we did find increased overall survival to discharge (7-11%) and increased survival with favourable outcome (6-9%) after the efforts to increase quality in CPR in EMS from first to second study period.

There was still no standardized post-resuscitation care in the second study period. In 2003 there were no new changes in the prehospital ALS protocol, but a standardized post-resuscitation care protocols had been implemented in 2002 at OUHU who received the vast majority of OHCA patients in Oslo, but also within 2003 at other receiving hospitals in Oslo. (118) The last study period followed this implementation of a post-resuscitation protocol (2004-2005). OHCA patients from this period were therefore treated with both more emphasis on high quality CPR, with diminished hands-off time and nationally modified 2000 guidelines, and the new hospital treatment protocol after ROSC. (118) Post-resuscitation care was still not emphasized in the resuscitation guidelines, and the implementation was a local initiative in Oslo. The most marked increase in survival and favourable outcome was in the last study period, after implementation of post-resuscitation care protocols for patients obtaining ROSC after CPR, especially for cardiac arrest with cardiac aetiology and initial VF.

Targeted temperature management remains important, but there is now an option to target a temperature of 36°C instead of the previously recommended 32–34°C based on findings from the TTM trial. (119) Noteworthy, the recently released publication from the HYPERION study showed significantly better neurological outcome with TTM at 33°C compared to normothermia in patients with non-shockable rhythms. (203). The TTM 2 study, comparing TTM at 33°C with a control group with avoidance of fever (< 37.8 °C), will probably give more answers in the bright future. A large study from the Swedish Cardiac arrest registry with almost 60 000 OHCA victims from 1992 to 2011 supports our findings of increased survival over time. In the long-term perspective 30-day survival more than doubled. As in our population, the increase in survival was most marked among patients with a shockable rhythm and thereby probably cardiac aetiology. Even though the study reports improved quality in all links of the chain of survival the most marked increase in survival was after implementation of post-cardiac arrest care in the 2010 ERC guidelines. (204) Similar results are also found outside the Nordic countries. A comprehensive American study from 2011 showed a large increase in survival after implementation of bystander CPR training programs, focus on and retraining in limiting hands-off time in EMS and implementation of therapeutic hypothermia after ROSC. (205)

With increased focus on the importance of documenting treatment quality in resuscitation research, it seems likely that a better understanding of the association between the CPR quality metrics, treatment after ROSC and survival to hospital discharge will become clearer as new evidence emerges. (206)

10.2 Paper II:

The role of a physician in the pre-hospital arena has been debated the last 40 years (207, 208). These studies, including *paper II* were limited by retrospective, non-randomized design and a chance of selection bias and type II errors. The external validity is also questionable in such studies as EMS differs a lot around the world, and results from one system does not necessarily apply directly to another. Several studies have tried to evaluate the effect of physicians in pre-hospital emergency care by analysing across different systems and thereby examine the entire system rather than the effect of the physicians' presence on scene.(209, 210) OHCA patients is a heterogeneous group of patients with several known and unknown confounding factors that are difficult to adjust for completely. These comparisons are challenging to analyse as there are likely many confounders and differences between systems.

Large multi-centre RCTs are difficult to conduct in this group of patients, as both the ethical and organizational aspects are difficult to defend as the availability of physician manned ambulances are limited in general.

Previous studies have reported that physicians are more efficient in managing procedures such as ECG analysis and endotracheal intubation and are more likely to comply with treatment guidelines than other ambulance personnel. (146, 211) Even though there was no difference in outcome with or without a physician, better quality of ALS in patients treated by a PMA was shown . It is, however, impossible to conclude if the improved quality of CPR was due to the physician, or whether it was due to the initial presence of 3–4 professionals on the PMA vs. only two on the first responding non-PMA.

The results indicated that high quality ALS can be achieved in the out-of-hospital setting by experienced EMT/paramedics and anaesthesiologists. Having a defined leader may add significant knowledge and framework for the team, and this has been shown to be an important factor when improving quality in other areas of clinical medicine. (212)

A Danish review from 2009 showed evidence for increased survival in trauma patients but weaker evidence for increased survival in OHCA in PMA. (213) Recent data from Norway show significant better outcome when treated by a PMA in rural areas but not urban areas in western Norway, and thereby supports the present results from the urban EMS in Oslo. (214)

These findings may be due to longer response and transport times, and the fact that many rural areas have one ambulance manned by two EMT/paramedics available to dispatch to OHCA patients and an extra, skilled person will be of great value in a resuscitation situation.

A recent nation-wide observational study from Denmark, showed non-significant but positive associations to ROSC and 30 days survival when treated by a PMA, but less certainty on 1-year survival. (215) In all of Spain, EMS is led by physicians, and in a recently published large registry study OHCA survival with CPC 1-2 reached an average overall survival of 11%, just slightly better than the average worldwide survival regardless of PMA or not, it is important to mention a relatively low bystander CPR rate in this study, only 24%. (208)

We currently lack consistent evidence that an OHCA treated by a physician as first responder results in better outcome. Physicians as an isolated factor of impact in prehospital emergency medicine are difficult to address. A physician can be a valuable resource in environments and settings were sharing of knowledge and experience is appreciated. But a physician can also be a disturbing element for the EMT/paramedics if the cooperation and communication is dysfunctional.

10.3 Paper III:

The latest guidelines revisions shifted focus to the immediate minutes after an OHCA. Guidelines had developed into a strong emphasis on a strict dispatcher protocol to recognize cardiac arrest and on bystanders providing high quality CPR. The importance of early uninterrupted chest compressions was emphasized, (195, 216) and into the bystander and lay peoples role in recognizing and treating OHCA.

Immediate initiation of CPR and early defibrillation have repeatedly been shown to increase survival. (10) Long response time intervals to arrival of health professionals have historically been a major obstacle to survive OHCA, it is therefore absolutely necessary to involve the laypersons closest to the patient as an important part of the treatment of OHCA patients. The chance of survival falls by an estimated 5% for each minute that passes between collapse and the start of CPR. (100) Bystander CPR is a straight-forward and potent intervention that can more than double the chance of survival. (74)

Several studies have revealed an increase in bystander CPR during the last decade. (74, 217, 218) The bystander CPR rate in Stavanger, Norway increased from 60 to 73% from 2001 to 2008. (27) It is questionable if the increase in bystander CPR represents an actual increase in bystanders' willingness to do CPR, or a result of EMS reporting and logistics. It is also reason to believe that bystander CPR rates increased after development of strict protocols in dispatcher assisted CPR and a strong focus on the dispatcher in the 2010 guidelines. (219)

Nonetheless, several national initiatives have been undertaken around the world to increase bystander CPR rates. This includes CPR training in elementary and high schools, mandatory first aid classes before getting driver's license and an increase in voluntarily first aid classes in for example sport clubs. (220-223) A large nationwide Danish study showed increased bystander CPR rates from 21 to 45% and better outcome after national initiatives as mentioned above over a ten-year study period. (80)

In *paper III* it was shown that 99-100% of the soldiers were willing to do CPR in real life, and 16% of the total population reported that they had provided CPR in real life. A recent Norwegian telephone-based survey supports strong willingness to act in an emergency (90%), and as high as 43% had been exposed to situations were first-aid was provided (not exclusively CPR). (131) Another study on high school students in Tromsø showed that 8% had provided CPR or watched other bystanders providing CPR in real life. 83% of the student were willing to provide CPR if needed. (224) These findings support the importance of training the public in CPR. The quality of CPR provided by bystanders are difficult to measure in real life scenarios. Both bystander CPR rates and quality of bystander CPR is desirable to increase as this point of the treatment chain is of crucial importance of patient outcome in OHCA. Participants with only BLS training demonstrated relatively poor airway management skills and used too much time on ventilations, in addition to a decreased compression fraction. The study objects performed overall good quality compressions through five loops regardless of training level. This findings of high quality compressions are supported by an earlier single-rescuer study were paramedics provided high quality compression for as long as 10 minutes without rest. (126)

Airway management is technically challenging, and several studies from early and mid-2000 confirm the complexity of providing ventilations, (225-227) supports this. Compression-only CPR has been discussed as an alternative for conventional CPR in bystander provided BLS. A large propensity score-matched cohort showed compression-only CPR is an acceptable alternative for laypeople responding to bystander witnessed OHCA of presumed medical origin. (228) A recent systematic review showed that laypersons providing compression-only CPR spend less time starting compressions and obtain better CPR quality.(229)

Study objects trained on the most basic level of BLS training used inexpedient much time from recognized cardiac arrest to start of CPR, when providing conventional CPR. AHA BLS 2015 guidelines recommends compression-only CPR for untrained lay rescuers, with or without dispatch assistance. (116) Similar recommendations are stated in the ERC guidelines' update from 2017. "All CPR providers should perform chest compressions for all patients in cardiac arrest. CPR providers trained and able to perform rescue breaths should perform chest compressions and rescue breath" (230)

A meta-analysis on three randomized trials including both witnessed and unwitnessed OHCA investigated survival to discharge finds better outcome for the compression-only CPR group when performed by an untrained bystander due to low quality of ventilations and long interruptions in compressions while performing ventilations. (231) The present findings support these results, as the CPR providers on the basic level of training (group I) shows severe difficulties in airway management, less successful ventilations and lower compression fraction than the CPR providers trained on the advanced level. On the other hand, the same most basic trained bystanders provide good quality compressions. The very latest ILCOR recommendations still suggest that trained bystanders provide ventilations, while untrained bystanders should focus on compressions with or without guidance from a dispatcher. (232) A systematic review showed the importance of compressions on survival with favourable neurological outcome in adult OHCA patients treated with 30:2 compression-ventilation ratio compared to 15:2. (233)

Compression-only CPR is easier to learn and perform than conventional CPR and may increase the willingness to provide CPR and thereby increase bystander rate. It is reason to believe that relatively untrained bystanders may be able to perform high quality compression-only CPR, as they performed so well in chest compressions. The question is if ventilation training should be more emphasized in the BLS courses, or if the conventional BLS courses should be more comprehensive to ensure that the participants learns how to ventilate a cardiac arrest patient or if the cost-benefit ratio is so high that only compression-only CPR should be taught in the short BLS courses. First aid classes and BLS training is often a matter of resources, time and interest from the public. Even though the study objects showed good insight in their own skill level, less than half of the participants trained on the most basic level was interested in more CPR training. The present study did not address the background of the low interest in more CPR training, but they showed such good insight to own limitations in skill level. A possible explanation may be the lack of customizing of CPR courses to skill level in the young military population, or that they consider it unlikely to ever get use of CPR. Anyhow, the strong correlation between perceived and actual skill level may help course providers to tailor CPR courses to the participants, to strengthen weak part of the CPR performance in each participant and make courses efficient and maybe more interesting for the young population.

This is important feedback for BLS instructors and program developers, who can customize courses from the learners own self-assessment and highlight weak parts of training especially in short, low budget courses including ventilation training and maybe emphasize ventilations in course participants who find that more challenging than the chest compressions.

11 Methodological considerations and limitations

11.1 Paper I and II

The first two papers were based on data derived from the Oslo cardiac arrest registry. Even though the registry data were recorded prospectively, the data were partly intended for clinical use and not only for research. Several clinicians were involved in data recording, and the forms were often completed after the time-critical resuscitation efforts had taken place, thus making them prone for recall bias. The included patients were also heterogeneous, and it is impossible to eliminate unknown confounders. However, the chosen statistical methods aimed to reduce the magnitude of this problem but could not eliminate it.

Presumably, the registry-based design was the only feasible method, as changes in clinical resuscitation protocols were impossible to predict in advance, and the patients could neither be randomised to receive either PMA or standard ambulance-based treatment. For this reason, the chosen design, with all its shortcomings, was a pragmatic approach that made the study possible.

To reduce the effect of statistical regression (the effect of time on data) a linear by linear associations for trends over time was used. Furthermore, the study was performed in a single EMS. Because EMS vary in terms of organisation and setting, generalization of the results to other organisations may be limited, depending on the organisation.

11.2 Paper III

Theoretically, questionnaires may have limitations, like misinterpretations and socially desirable answers. A ten-point rating scale may be weighted differential from person to person, and even though the ten-point Likert scale is validated, it is still room for discrepancy in interpretation of the scale between study objects.

This design was still chosen due to the number of participants needed to compare the skills of different training levels, and it was impossible to use more advanced qualitative methods for so many participants.

Furthermore, simple observation-based recording of CPR skills was used, instead of automatic recording of CPR data. The latter was not available at the military camp when it was possible to perform the study with the desired number of volunteers. The inter-observer variability was assessed in small-scale pilot studies and was found to be acceptable for relevant CPR quality indicators. This method is of course limited by manual observations which could be biased.

12 Conclusion

The goal in treatment of OHCA is survival with favourable neurological outcome. CPR is the hallmark of cardiac arrest management. Training bystanders is crucial to increase the bystander provided CPR with good quality. The training should be of sufficient extent to ensure ability to airway management, but even short courses prepare the provider to do high quality compressions. Targeted attempts on quality improvement in ALS such as focus on CPR quality and standardizing post-arrest care in our local chain of survival showed increased survival rate with favourable outcome. Efforts on raising quality in throughout treatment chain for OHCA patients is important and may contribute to higher survival rates and more favourable neurological outcome.

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Papers

Paper I: Improving outcome after out-of-hospital cardiac arrest by strengthening weak links of the local Chain of Survival; quality of advanced life support and post-resuscitation care

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Clinical paper

Improving outcome after out-of-hospital cardiac arrest by strengthening weak links of the local Chain of Survival; quality of advanced life support and post-resuscitation care☆

Inger Lund-Kordahl[a], Theresa M. Olasveengen[a,b,*], Tonje Lorem[a], Martin Samdal[c], Lars Wik[b,d], Kjetil Sunde[e]

[a] Institute for Experimental Medical Research, Oslo University Hospital Ulleval, N-0407 Oslo, Norway
[b] Department of Anaesthesiology, Oslo University Hospital Ulleval, N-0407 Oslo, Norway
[c] Medical Faculty, University of Oslo, N-0316 Oslo, Norway
[d] National Competence Centre for Emergency Medicine, Oslo University Hospital Ulleval, N-0407 Oslo, Norway
[e] Surgical Intensive Care Unit, Oslo University Hospital, Ulleval, N-0407 Oslo, Norway

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ABSTRACT

Background: Survival after out-of-hospital cardiac arrest (OHCA) depends on a well functioning Chain of Survival. We wanted to assess if targeted attempts to strengthen the weak links of our local chain; quality of advanced life support (ALS) and post-resuscitation care, would improve outcome.

Materials and methods: Utstein data from all OHCAs in Oslo during three distinct 2-year time periods 1996–1998, 2001–2003 and 2004–2005 were collected. Before the second period the local ALS guidelines changed with increased focus on good quality chest compressions with minimal pauses, while standardized post-resuscitation care including goal directed therapy with therapeutic hypothermia and percutaneous coronary intervention was added in the third period. Additional *a priori* sub-group analyses of arrests with cardiac aetiology as well as bystander witnessed ventricular fibrillation/tachycardia (VF/VT) arrests with cardiac aetiology were performed.

Results: ALS was attempted in 454, 449, and 417 patients with OHCA in the first, second and last time period, respectively. From the first to the third period VF/VT arrests declined (40% vs. 33%, $p = 0.039$) and fewer arrests were witnessed (80% vs. 72%, $p = 0.022$) and response intervals increased (7 ± 4 to 9 ± 4 min, $p < 0.001$). Overall survival increased from 7% (first period) to 13% (last period), $p = 0.002$, and survival in the sub-group of bystander witnessed VF/VT arrests with cardiac aetiology increased from 15% (first period) to 35% (last period), $p = 0.001$.

Conclusions: Survival after OHCA was increased after improving weak links of our local Chain of Survival, quality of ALS and post-resuscitation care.

1. Introduction

Guidelines for cardiopulmonary resuscitation are developed in order to improve survival after cardiac arrest. Despite evolving evidence-based guidelines for cardiopulmonary resuscitation (CPR),[1,2] survival rates after out-of-hospital cardiac arrest (OHCA) has not improved much.[3,4] The Chain of Survival concept of early access, early CPR, early defibrillation and good post-resuscitation care is the documented and recommended guide for improving outcome after OHCA.[1,2,5] Documenting Utstein data for OHCA is a useful tool for evaluating and critically assessing the local Chain of Survival in an emergency medical service (EMS), identifying areas in need of improvement in order to increase survival after OHCA.[6]

In Oslo, Norway, survival to hospital discharge for OHCA of cardiac aetiology has been below 10% for the last 30 years.[7–9] In the time period from 1996 to 1998 the ALS providers in the Oslo EMS were trained according to 1992 guidelines,[10] resulting in poor ALS quality with long periods without vital organ perfusion and few shocks resulting in return of spontaneous circulation (ROSC).[8] In 2001 the 2000 international guidelines[11,12] were implemented with a modification consisting of increased focus on chest compression quality including 3 min periods of CPR before and between defibrillations, based on findings from local ALS studies.[8,13] The main aim of these changes was to optimize vital organ perfusion

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* Corresponding author at: Institute for Experimental Medical Research, Oslo University Hospital Ulleval, Kirkeveien 166, N-0407 Oslo, Norway.
Tel.: +47 22119690; fax: +47 23016799.
E-mail address: t.m.olasveengen@medisin.uio.no (T.M. Olasveengen).

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by minimizing interruptions in chest compression and more reasonable timing of defibrillations,[14] defined as improving the third link in our local Chain of Survival. A standardized post-resuscitation treatment protocol including therapeutic hypothermia and percutaneous coronary intervention (PCI) was implemented in 2003 to strengthen the last link.[15]

Through implementation of new and modified guidelines and evolving scientific evidence, our local Chain of Survival was thereby changed throughout this 9-year period, with special focus on the last two links. The first period (1996–1998) had poor ALS quality and post-resuscitation care, the second period (2001–2003) had good ALS quality but poor post-resuscitation care, and the third period (2004–2005) had both good ALS quality and post-resuscitation care. In the present study we wanted to evaluate if these temporal changes strengthened our local Chain of Survival and impacted on outcome after OHCA.

2. Methods

2.1. Description of Oslo

The city of Oslo covers 454 km^2 and has 548,617 inhabitants (January 1st 2007) with 51% female population and 4.4% of the population over 80 years. Oslo has had a continuous population growth the last 20 years, mainly due to migration leading to a larger proportion of young adults 20–39 and lower proportion of children and adults >40 years compared to the rest of the country.[16]

2.2. Description of EMS and in-hospital treatment

The city of Oslo has a one-tiered community run EMS system. All acute care ambulances are manned with paramedics. On weekdays between 7:30 and 22:00, a physician-manned ambulance staffed by two paramedics and an anaesthesiologist functions on the same level as the regular paramedic staffed ambulances. All paramedics are trained to use defibrillators in manual mode. Endotracheal intubation is the standard method for securing the airways, followed by uninterrupted chest compressions with 10––12 interposed ventilations per minute. Nurses and paramedics staff in the dispatch centre are trained to provide CPR instructions when cardiac arrest is suspected.

2.3. Study design and recruitment

All patients older than 18 years suffering from non-traumatic OHCA of all causes from February 19th 1996 to February 18th 1998 (first period), May 1st 2001 to 30 April 2003 (second period) and January 1st 2004 to December 31st 2005 (third period) were retrospectively studied. During the first period (1996–1998) ambulance personnel were trained to provide ALS according to the 1992 Guidelines[10] and there was no standardized post-resuscitation care at any of the five receiving hospitals. Modified 2000 Guidelines[11,12] with more focus on chest compression quality and 3 min of CPR prior to defibrillation were implemented prior to the second period (2001–2003) to improve prehospital ALS quality, but there was still no standardized post-resuscitation care. In the third period (2004–2005) there were no additional changes in the prehospital ALS protocol, but similar standardized post-resuscitation care protocols had been implemented in all seven receiving hospitals in Oslo.[15] The post-resuscitation protocols are applied to all patients regardless of initial rhythm or aetiology if active treatment is desired. If coronary angiography and/or percutaneous coronary intervention (PCI) is indicated, patients are directly transported from the scene to one of the two hospitals with this capacity (24 h/day).

2.4. Data collection

Locally adapted Utstein style forms, dispatcher recordings, and ambulance-/hospital records were collected and reviewed. Automated, computer-based time records from the dispatch centre supplement ambulance run sheets with regards to response intervals (time from call received to ambulance arrival). For all admitted patients, additional hospital records were obtained from the respective receiving hospitals. Outcome categories were non-survival/survival to hospital discharge with cerebral performance categories (CPC).[6] CPC 1 and 2 were defined as favourable neurological outcome.

2.5. Statistical analysis

Statistical calculations were performed using a spreadsheet program (Excel 2007, Microsoft Corp, Redmond, WA, USA) or a statistical software package (SPSS 16.0, SPSS Inc., Chicago, IL, USA). Values for parametric data are given as means with standard deviations. Comparisons of continuous data were analyzed by one-way ANOVA for parametric data. Post hoc comparisons were conducted using the Bonferroni test. Response intervals are reported for non-ambulance witnessed arrests. Categorical data were analyzed using linear by linear associations for trends over time periods. p-Values ≤ 0.05 were considered significant.

3. Results

During the three study periods, altogether 1320 patients received ALS for OHCA. The Utstein style results from the three study periods are reported in Table 1.

3.1. Demographic Utstein data

A one-way between groups ANOVA was conducted to explore differences in age and response intervals between the three study periods. Age did not differ significantly ($p = 0.88$) between the three periods, but there were significant differences in response intervals ($p < 0.001$). Post hoc comparisons showed a significantly shorter mean response interval for the first period (7 ± 4) than both the second (9 ± 4, $p < 0.001$) and the third period (9 ± 4, $p < 0.001$), but the two latter periods did not differ significantly ($p = 1.00$). There was a decline in witnessed arrests after the first period; 80%, 62% and 73%, $p = 0.022$ and a gradual decline in initial VF/VT; 40%, 37% and 33%, $p = 0.039$, in the first, second and third period, respectively (Table 1).

3.2. Overall outcome

There was a non-significant trend to increased rate of ROSC (30%, 34% and. 36%, respectively, $p = 0.058$) and a significant increase in admission to ICU (23%, 29% and 29%, respectively, $p = 0.040$), across the three time periods. There was also significantly improved overall survival to hospital discharge across the three time periods with 7%, 10% and 13% survival in the first, second and third period, respectively ($p = 0.001$). Survival with favourable neurological outcome (CPC 1–2) was also significantly improved (6%, 9% and 12%, in the three periods, respectively, $p = 0.001$). Favourable survival among those admitted to ICU was 26%, 30% and 43% in the three periods, respectively ($p = 0.005$) (Table 1).

3.3. Sub-group analysis

In the first *a priori* sub-group analysis of patients with arrests of cardiac origin survival to hospital discharge was 9%, 12% and 17% in the first, second and third period, respectively

Table 1
Demographic characteristics and overall outcome.

	1996–1998	2001–2003	2004–2005	p-Value
ALS initiated	454	449	417	
Age	65 ± 18	64 ± 18	65 ± 17	0.88
Gender (%male)	329 (72)	323 (72)	293 (70)	0.48
Cardiac aetiology	313 (69)	349 (78)	281 (67)	0.76
Location				
Home	226 (50)	291 (65)	224 (54)	0.20
Public	168 (37)	112 (25)	143 (34)	0.34
Other/unknown	60 (13)	46 (10)	50 (12)	0.55
Initial rhythm				
VF/VT	181 (40)	164 (37)	138 (33)	0.039
Asystole	192 (42)	233 (52)	189 (45)	0.33
PEA/other/unknown	81 (18)	52 (12)	90 (22)	0.17
Witnessed arrest	361 (80)	276 (61)	302 (72)	0.022
Bystander CPR	248 (55)	217 (48)	225 (54)	0.84
Response interval[a]	7 ± 4	9 ± 4	9 ± 4	<0.001
ROSC at any time point	135 (30)	153 (34)	149 (36)	0.058
Admitted to ICU[b]	102 (23)	128 (29)	119 (29)	0.040
Discharged	31 (7)	45 (10)	54 (13)	0.002
CPC 1–2[c]	26 (6)	38 (9)	51 (12)	0.001
CPC 3–4	5	4	3	
Discharged (CPC 1–2)/admitted ICU	25%	30%	43%	0.005

All variables given as numbers (percentages in parenthesis) except age and response interval (mean ± SD). p-Values are obtained from linear by linear associations for trend over time periods for categorical data and from ANOVA for continuous data. ALS: advanced life support; VF: ventricular fibrillation; VT: ventricular tachycardia, PEA; pulseless electrical activity; CPR: cardiopulmonary resuscitation; ROSC: return of spontaneous circulation; ICU: intensive care unit; CPC: cerebral performance category. Response interval: time from call received to ambulance arrival.

[a] Ambulance witnessed arrests excluded from analysis.
[b] Missing information for 8 patients in the second time period.
[c] CPC score missing for 3 patients in the second time period.

Table 2
Outcome for cardiac arrest patients with cardiac aetiology.

	1996–1998	2001–2003	2003–2005	p-Values
ALS initiated	313	349	281	
ROSC at any time point	110 (35)	126 (36)	114 (41)	0.18
ICU[a]	84 (27)	106 (31)	92 (33)	0.12
Discharged	29 (9)	40 (11)	49 (17)	0.003
CPC 1–2[b]	25 (8)	34 (10)	46 (16)	0.001
CPC 3–4	4	4	3	
Discharged (CPC 1–2)/admitted ICU	30%	33%	50%	0.005

All variables given as numbers (percentages in parenthesis). p-Values are obtained from linear-by linear associations for trend over time periods. ALS: advanced life support; ROSC: return of spontaneous circulation; ICU: intensive care unit; CPC: cerebral performance category.

[a] Missing information for 4 patients in the second time period.
[b] CPC score missing information for 2 patients in the second time period.

($p = 0.003$). Survival with favourable neurological outcome was 8%, 10% and 16% in the three time periods, respectively ($p = 0.001$) (Table 2).

In the second *a priori* sub-group analysis; bystander witnessed cardiac arrests with cardiac aetiology and initial VF, overall survival to hospital discharge increased from 16% in the first period to 25% in the second period and 35% in the third period ($p = 0.001$). Survival with favourable neurological outcome for this sub-group was 14%, 22% and 33% ($p = 0.001$) in the three time periods, respectively (Table 3).

Table 3
Outcome for patients with witnessed VF cardiac arrest with cardiac aetiology.

	1996–1998	2001–2003	2003–2005	p-Value
ALS initiated	142	110	92	
ROSC at any time point	72 (51)	70 (64)	59 (64)	0.029
ICU	59 (42)	61 (55)	54 (59)	0.007
Discharged	22 (15)	27 (25)	32 (35)	0.001
CPC 1–2[a]	20 (14)	24 (22)	30 (33)	0.001
CPC 3–4	2	2	2	
Discharged (CPC1-2)/admitted ICU	34%	40%	56%	0.021

All variables given as numbers (percentages in parenthesis). p-Values are obtained from linear-by linear associations for trend over time periods. ALS: advanced life support; ROSC: return of spontaneous circulation; ICU: intensive care unit; CPC: cerebral performance category.

[a] CPC score missing information for 1 patient in the second time period.

4. Discussion

Despite an increase in negative prognostic factors such as more unwitnessed non-VF arrests and increased response intervals, outcome was significantly improved during our 9-year study period. The greatest improvements in survival were seen in bystander witnessed VF/VT arrests of cardiac origin, which may be considered the most homogenous and therefore easiest comparable group of patients within the cardiac arrest population.[6] Continuous focus on the importance of a well functioning Chain of Survival with specific strategies to improve quality of care during ALS and post-resuscitation has lead to significantly improved outcome of patients with OHCA in Oslo.

Our findings are in accordance with recent studies reporting temporal improvements in survival within two different EMS systems.[17,18] A study from Seattle reported cumulative effect of four EMS program changes with overall survival to hospital discharge improving from 31% to 45% during a 30-year period in patients with witnessed VF arrest.[17] Their local Chain of Survival was strengthened by focusing on the second and third links with strategies to provide early basic life support (BLS) through telephone assisted CPR and early defibrillation through public access defibrillators and equipping first responders with defibrillators.[17] Similarly, a large-scale population-based study from Japan reported improved survival during an 8-year period after implementing changes to the first three links in their local Chain of Survival.[18] By training lay persons in BLS, introducing telephone assisted CPR, placing public access defibrillators and training emergency medical technicians in defibrillation, tracheal intubation and administration of adrenaline, they saw increased neurological intact survival (from 6% to 16%) for patients with witnessed VF arrest.[18]

While these studies focused on improving the first links in the Chain of Survival,[17,18] we focused on the two last links; improving quality of ALS and post-resuscitation care. With high rates of bystander CPR in our EMS (above 50%),[7–9] the last two links were considered to be our weakest. Although none of the ALS components such as drug administration, intubation or advanced airway management have been documented to improve survival,[19,20] quality of ALS is believed to be important for outcome after cardiac arrest.[21–23] During implementation of the modified 2000 guidelines[11,12] ALS training focused on optimizing chest compressions by stressing the importance of adequate force and rate as well as limiting hands-off intervals. Recent studies documenting the quality of chest compressions in our EMS,[14,24] have demonstrated improvements compared to chest compression quality prior to implementation of the 2000 guidelines.[8] It seems reasonable to conclude that improvements to our ALS protocol seem to have contributed in improving outcome.

However, the increase in survival was most prominent for the third time period, demonstrating the importance of improved post-resuscitation care treatment. After implementation of a standardized post-resuscitation protocol including therapeutic hypothermia, frequent use of coronary angiography/PCI, early optimization of hemodynamic, metabolism and seizure control, favourable survival rates among patients with witnessed VF arrests admitted to ICU increased from 34% in the first period to 56% in the third period. This correlates well with improvements seen in two randomized controlled trials for similar sub-groups evaluating the effect of therapeutic hypothermia where survival from ICU improved from 33–45% to 54–59% with hypothermia.[25,26] Optimizing post-resuscitation care has been shown to be of great importance for survival, and implementation of this crucial in-hospital treatment varies immensely between hospitals.[27–29]

In order to continuously improve outcome from cardiac arrest in any EMS system, attention should be paid to all aspects of the Chain of Survival. Resuscitation Outcomes Consortium Investigators have recently published that there are large regional variation in OHCA incidence and outcome,[30] and in a previous review overall outcome for OHCA was reported to vary between 2–11% for EMS systems with median response intervals of 8–9 min.[31] With a response interval of 9 min, outcome for our EMS has moved from mid-range to top-end of this scale. Such system variations may make a huge impact on results from multicenter intervention clinical trials, and institutions should be encouraged to identify and improve weak links in their Chain of Survival to optimize quality of care before new interventions are introduced and investigated.

Important challenges remain in our EMS, and the increasing response intervals are particularly concerning. Having a one-tired centralized system might have left our EMS system vulnerable to the increasing traffic development seen during the past decade, and it is hoped that current attempts to de-centralize the ambulance service will partly remedy this trend. Emergency medical dispatch and EMS organization also need to be thoroughly evaluated to ensure timely and optimal resource allocation and provision of useful bystander telephone assistance.

Increasing response intervals could partly explain the reduction in VF arrests, although other reports of declining VF arrests have been attributed both to a reduction of absolute incidence of VF due to improved preventive measures,[32,33] as well as an absolute increase in cardiac arrest of non-cardiac origin.[32,34] The decline in witnessed arrests might indicate that the cardiac arrest population is indeed changing, and that the classic scenario with a witnessed arrest of cardiac origin is indeed becoming less common.

Some limitations need to be addressed. We cannot be certain that the improved survival during the study period is solely due to the specific attempts to strengthen our local Chain of Survival described. With continuous focus on quality of ALS, improving out-of-hospital care could be contributing to improvements seen in both periods. The effects of specific interventions cannot be evaluated as this was a before and after observational study which most likely also includes a variety of confounding factors with the progression of time. However, as stated in an editorial by Olson and Fontanarosa,[35] observational outcome studies with historical controls have advantages as the same site and population is used and selection bias is avoided. While data for two of the study periods were prospectively collected, the data from the second period (2001–2003) was retrospectively collected. Finally, this is a single centre study and the results may not be generalized to systems with different training, infrastructure, treatment protocols or quality of ALS.

5. Conclusion

The increasing proportion of survivors with favourable neurological outcome, both overall and for all sub-groups, indicates that the strengthening of the last two links in our local Chain of Survival has lead to significantly improved outcome for patients with out-of-hospital cardiac arrest.

Contributions

Lund-Kordahl and Olasveengen have full access to all generated data and take full responsibility for the integrity of the data and the accuracy of the data analysis. Olasveengen and Sunde have contributed to the concept and design of the study. Acquisition of data was performed by Wik, Lund-Kordahl and Lorem. Analysis and interpretation of the data were done by Lund-Kordahl, Olasveengen and Sunde. Lund-Kordahl, Olasveengen and Sunde have drafted the manuscript. Critical revision of the manuscript for important intellectual content was done by Lorem, Samdal and Wik. Olasveengen and Sunde supervised the study.

Paper II: Out-of-hospital advanced life support with or without a physician: Effects on quality of CPR and outcome

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Clinical paper

Out-of hospital advanced life support with or without a physician: Effects on quality of CPR and outcome☆

Theresa M. Olasveengen[a,*], Inger Lund-Kordahl[b], Petter A. Steen[c], Kjetil Sunde[a]

[a] Institute for Experimental Medical Research and Department of Anesthesiology, Oslo University Hospital, Ullevaal, N-0407 Oslo, Norway
[b] Institute for Experimental Medical Research, Oslo University Hospital, Ullevaal, N-0407 Oslo, Norway
[c] University of Oslo, Faculty Division UUH, and Ambulance Department, Oslo University Hospital, Ullevaal, N-0407 Oslo, Norway

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ABSTRACT

Background: The presence of physicians is believed to facilitate optimal management of out-of-hospital cardiac arrest, but has not been sufficiently documented.

Methods: Adult non-traumatic cardiac arrests treated by Oslo EMS between May 2003 and April 2008 were prospectively registered. Patients were categorized according to being treated by the physician-manned ambulance (PMA) or by regular paramedic-manned ambulances (non-PMA). Patient records and continuous electrocardiograms (ECGs) with impedance signals were reviewed. Quality of cardiopulmonary resuscitation (CPR) and clinical outcomes were compared.

Results: Resuscitation was attempted in 1128 cardiac arrests, of which 151 treated by non-PMA and PMA together were excluded from comparative analysis. Of the remaining 977 patients, 232 (24%) and 741 (76%) were treated by PMA and non-PMA, respectively. The PMA group was more likely to have bystander witnessed arrests and initial VF/VT, and received better CPR quality with shorter hands-off intervals and pre-shock pauses, and having a greater proportion of patients being intubated. Despite uneven distribution of positive prognostic factors and better CPR quality, short-term and long-term survival were not different for patients treated by the PMA vs. non-PMA, with 34% vs. 33% ($p = 0.74$) achieving return of spontaneous circulation (ROSC), 28% vs. 25% ($p = 0.50$) being admitted to ICU and 13% vs. 11% ($p = 0.28$) being discharged from hospital, respectively.

Conclusions: Survival after out-of-hospital cardiac arrest was not different for patients treated by the PMA and non-PMA in our EMS system.

1. Introduction

Sudden death due to out-of-hospital cardiac arrest (OHCA) remains a major health issue with estimated 275,000 cardiac arrest cases in Europe each year. Survival rates varies between countries, cities and emergency medical service (EMS) systems, at least partly depending on local differences in the chain of survival.[1]

Early defibrillation and chest compressions are the only pre-hospital interventions documented to actually increase survival to hospital discharge,[2] and advanced life support (ALS) options such as intravenous drug administration and advanced airway management have yet to prove their positive impact on survival.[3,4] In general, improving quality of pre-hospital care is believed to improve outcomes from OHCA,[5] but efforts with automated feedback, structured post-event debriefing and performance-based retraining have also not showed any improvement in survival.[5–8]

The role of a physician in the pre-hospital arena is under debate, and to date no randomized, controlled studies have been performed to evaluate effects of having a physician present during cardiac arrest. A recent review evaluating physician involvement in pre-hospital care, concluded that there was limited evidence for increased survival for cardiac arrest patients treated by physicians in the pre-hospital setting.[9]

In the present study we aim to compare quality of CPR and outcome for patients treated with and without involvement from the physician-manned ambulance within our EMS system.

2. Materials and methods

2.1. Description of emergency medical services (EMS) and in-hospital treatment

The city of Oslo has a one-tiered centralised EMS system run by Oslo University Hospital, Ullevaal (OUH) for a population of

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* Corresponding author. Tel.: +47 23016837; fax: +47 23016799.
E-mail address: t.m.olasveengen@medisin.uio.no (T.M. Olasveengen).

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540,000. Since 1967 a physician-manned ambulance (PMA) staffed by two paramedics and an anaesthesiologist has functioned on the same level as regular paramedic staffed ambulances (non-PMA), and is located at one of the six ambulance stations spread across the city. The anaesthesiologist was either Board certified or in the last year of training, and half of them were very actively involved in resuscitation research. The PMA operates on weekdays between 7:30 and 22:00. Two ambulances are routinely dispatched when cardiac arrest is suspected. The physician-manned ambulance is dispatched whenever available. Both PMA and non-PMA are dispatched based on availability and location with the same dispatch criteria.

The paramedics and PMA physicians in Oslo are yearly certified in ALS by their own ALS instructors (all paramedics). All paramedics have to work a few shifts yearly on the PMA as part of the quality improvement program of the EMS. Until January 2006 the staff followed International Guidelines 2000 for ALS[10] with the modification that patients with ventricular fibrillation (VF) or pulseless ventricular tachycardia (VT) received three minutes of CPR before first shock and between unsuccessful series of shocks.[11] Guidelines 2005[12] were implemented January 2006 with the same modification of three minute periods of CPR.[13] Defibrillators in manual mode are used, and endotracheal intubation is standard for securing the airways.

All hospitals in Oslo have goal directed post-resuscitation protocols including therapeutic hypothermia for all actively treated unconscious patients regardless of initial rhythm or arrest ethiology.[14] Pre-hospital 12 lead electrocardiogram (ECG) is routinely transmitted from all ambulances to the cardiologist on call at OUH after return of spontaneous circulation (ROSC). If coronary angiography is indicated for possible percutaneous coronary intervention (PCI), patients are transported directly from the scene to one of two university hospitals with this capacity 24 h/day.

2.2. Study design and recruitment

All patients older than 18 years with non-traumatic OHCA of all causes in Oslo between 1 May 2003 and 28 April 2008 were prospectively registered in our cardiac arrest registry. The patients were retrospectively categorized into three groups: (1) treated by the PMA arriving as 1st responder (PMA group), (2) treated by a non-PMA assisted by the PMA as 2nd responder (non-PMA/PMA group) and finally, and (3) only non-PMAs present (non-PMA group). The first and last group was compared formally as there is a highly selected sub-group within the second group containing patients where the presence of the PMA is requested by first arriving ambulance.

The majority of these patients were also included in a randomized study evaluating the effects of intravenous drugs during cardiac arrest (registered at clinicaltrials.gov NCT00121524). The randomized study was approved by the regional ethics committee. The present retrospective analysis of already collected registry data required no further ethics approval.

2.3. Equipment and data collection

Standard LIFEPAK 12 defibrillators (Physio-Control, Medtronic, Redmond, WA, USA) were used. ECGs with transthoracic impedance signals from LIFEPAK 12 are routinely transferred to a server at The National Competence Center for Emergency Medicine (Oslo, Norway) following cardiac arrest. Utstein cardiac arrest forms[15] routinely filled out by paramedics were submitted along with a copy of the ambulance run sheet. Automated, computer-based dispatch centre time records supplement ambulance run sheets with regards to response intervals. For all admitted patients, additional hospital records were obtained.

Primary end point was survival to hospital discharge. Secondary endpoints were quality of CPR and neurologic outcome at hospital discharge, using cerebral performance category (CPC) from 1 to 4.[15] Having CPC 1 and 2 are defined as a favourable survival. The CPC score was evaluated by TMO based on hospital records while blinded to patient category.

2.4. Data processing

Data from each case were viewed and annotated using CODE-STAT™ 7.0 (Physio-Control, Redmond, WA, USA) for detection of ventilations and chest compressions by changes in transthoracic impedance. Written information from patient report forms and locally adapted Utstein style forms were compared with typical changes in CPR patterns as shown using CODE-STAT™ 7.0. Time without spontaneous circulation, time without compressions during time without spontaneous circulation (hands-off time), pre-shock pauses, compression rate and actual number of compressions and ventilations per minute were calculated for each episode. Hands-off ratio is defined as hands-off time divided by total time without spontaneous circulation.

2.5. Statistical analysis

Demographic and clinical data are presented as means ± standard deviation (SD), medians with 95% confidence interval (CI) or proportions. Differences between the two pre-defined groups were analysed using chi-squared with continuity correction for categorical data, and Students' t-tests or Mann–Whitney U-tests for continuous data as appropriate. A stratification analysis using the Maentel–Haenzel method was performed with a heterogeneity test to pinpoint effect modification at the multiplicative level using the Breslow and Day test of heterogeneity and to quantify confounders by comparing the adjusted Mantel–Haenzel OR to the crude OR.[16,17] Adjustment for multiple confounders was done using unconditional logistic regression using a manual backward elimination procedure. An investigation of the correlation between potential confounders was performed. p-Values less than 0.05 were considered significant.

3. Results

Resuscitation was attempted in 1128 cardiac arrests during the 5-year study period. Two hundred and thirty-two were treated primarily by the PMA (PMA group) and 741 were treated without any involvement from the PMA (non-PMA group). In 155 cases the PMA was dispatched to assist a non-PMA (non-PMA/PMA group). This group included a highly selected cohort where the PMA was called out to assist with stabilisation and transport to hospital after ROSC. While results are reported for the non-PMA/PMA group, it is therefore not included in the comparative analysis (Tables 1–4).

Patients in the PMA group were more likely to have a bystander witnessed arrest in a public place, a higher number of bystander CPR and more initial VF/VT (Table 1). On the other hand, the non-PMA group had more ambulance witnessed arrest, and a slightly shorter response time and time to initiation of ALS (Table 1). As a result of increased incidence of initial shockable rhythms, patients in the PMA group were more likely to be defibrillated and receive amiodarone intravenously (Table 2). The use of epinephrine was similar in both groups (Table 2). Quality of CPR was better in the PMA group compared to patients in the non-PMA group with median hands-off intervals 0.10 (95% CI 0.09, 0.13) vs. 0.17 (95% CI 0.16, 0.18) and median pre-shock pauses 4 s (95% CI 3, 8) vs. 16 s (95% CI 14, 17), respectively (Table 2). Eighty-eight percent of patients in the PMA group were intubated compared to 77% in the non-PMA group ($p = 0.001$) (Table 2).

Table 1
Demographic characteristics and quality of cardiopulmonary resuscitation (CPR).

	No physician present (n = 741)	Physician 1st responder (n = 232)	No vs. 1st physician (p-value)	Physician 2nd responder (n = 155)
Age (years)	65 ± 17	63 ± 18	0.11	65 ± 18
Males (%)	501 (68)	160 (69)	0.76	115 (74)
Cardiac aetiology (%)	497 (67)	168 (72)	0.16	114 (74)
Location of arrest				
Home	444 (60)	107 (46)	<0.001	83 (55)
Public	200 (27)	104 (45)	<0.001	61 (39)
Other	96 (13)	20 (9)	0.097	11 (7)
Bystander witnessed	403 (54)	145 (63)	0.036	100 (65)
Ambulance witnessed	111 (15)	9 (4)	<0.001	19 (12)
Bystander BLS	387 (52)	141 (61)	0.027	92 (59)
Initial rhythm				
VF/VT	220 (30)	90 (39)	0.012	67 (43)
Asystole	356 (48)	97 (42)	0.11	59 (38)
PEA	163 (22)	44 (19)	0.37	28 (18)
Response time (min)	9 (8, 9)	9 (9, 10)	0.011	8 (8, 9)
Time from arrest to ALS[a]	11 (10, 11)	11 (10, 12)	0.058	9 (7, 10)

VF = ventricular fibrillation, VT = pulseless ventricular tachycardia, PEA = pulseless electrical activity, ALS = advances life support IV = intravenous, and ECG = electrocardiogram. All categorical variables given as numbers (percentages in parenthesis). Continuous variables are given as means ± standard deviation when normally distributed (age) and as medians with 95% confidence intervals when non-normally distributed (response time, time from arrest to ACLS). Differences between groups were analysed using chi-squared with continuity correction for categorical data, and Students' t-tests or Mann–Whitney U-tests for continuous data as appropriate.

[a] Data missing for 123 patients in the no physician group 39 in the 1st responder group and 29 in the 2nd responder group.

There were no significant differences in short-term or long-term survival in the PMA vs. non-PMA group with 34% vs. 33% (p = 0.74) achieving ROSC, 28% vs. 25% (p = 0.50) being admitted to ICU and 13% vs. 11% (p = 0.28) being discharged from hospital alive, respectively (Table 3). Among the survivors, 94% and 96%, respectively, had a favourable outcome (CPC 1 and 2) at discharge. There were no differences in in-hospital treatment such as therapeutic hypothermia or angiography/PCI between the groups (Table 3).

Initial VF/VT, therapeutic hypothermia, intubation, age and time from arrest to ALS were found to be potential confounders and included in logistic regression analysis. The adjusted effect (odds ratio of survival with CPC 1–2) of being treated by the PMA was 1.35 (95% CI 0.71, 2.60, p = 0.36). Initial VF/VT and therapeutic hypothermia were associated with improved outcome, while intubation, increasing age and time from arrest to ALS ≥ 12 min were associated with worse outcome (Table 4).

In a pre-defined sub-group of patients with bystander witnessed VF/VT arrests with cardiac aetiology 62% vs. 55% (p = 0.50) achieved ROSC, 54% vs. 50% (p = 0.61) were admitted to ICU and 31% vs. 28% (p = 0.82) were discharged from hospital alive, in the PMA and non-PMA groups, respectively (Table 5).

4. Discussion

We could not demonstrate that the presence of a physician on-site during OHCA improved outcome, even with better quality of CPR for the physician-manned ambulance (PMA).

Two smaller pseudo-randomized studies have previously evaluated the effect of PMA within one EMS system.[18,19] Hampton and colleagues reported trends towards improved survival in patients treated by a PMA during a 20-month period in the 1970s. There were issues with regard to selection bias as not all cases were randomized, and it is unclear how this study applies to *current* EMS systems.[18] In an opposing study from Taiwan survival tended to improve in patients treated by non-PMA. Again it is difficult to conclude as the overall survival rate for their system was only 1.4%,

Table 2
Quality of pre-hospital advanced life support (ALS).

	No physician present (n = 741)	Physician 1st responder (n = 232)	No vs. 1st physician (p-value)	Physician 2nd responder (n = 155)
Intubation	582 (79)	205 (88)	0.001	126 (81)
IV drugs	240 (32)	85 (37)	0.26	63 (41)
Epinephrine	321 (44)	97 (42)	0.68	86 (57)
Atropine	179 (25)	52 (23)	0.61	46 (31)
Amiodarone	52 (7)	35 (15)	<0.001	27 (18)
ECG available for analysis	509 (69)	174 (75)	0.078	116 (75)
Defibrillation	276 (37)	109 (47)	0.009	83 (55)
No. of shocks when defibrillated	2 (2, 3)	3 (2, 3)	0.48	3 (2, 3)
CPR time (min)	18 (17, 20)	16 (15, 17)	0.017	19 (17, 20)
Hands-off ratio	0.17 (0.16, 0.18)	0.10 (0.09, 0.13)	<0.001	0.14 (0.11, 0.16)
Compression rate	117 ± 9	116 ± 10	0.29	115 ± 11
Compressions (min^{-1})	93 (92, 95)	101 (98, 103)	<0.001	95 (93, 97)
Ventilations (min^{-1})	11 ± 4	12 ± 4	<0.001	11 ± 4
Pre-shock pause (s)	16 (14, 17)	4 (3, 8)	<0.001	7 (4, 13)

IV = intravenous, ECG = electrocardiogram, and Hands-off = proportion of time without chest compressions during the resuscitation effort. All categorical variables given as numbers (percentages in parenthesis). Continuous variables are given as means ± standard deviation when normally distributed (compression rate and ventilations per minute) and as medians with 95% confidence intervals when non-normally distributed (no. of shocks, CPR time, hands-off ratios, compressions per minute and pre-shock pauses). Differences between groups were analysed using chi-squared with continuity correction for categorical data, and Students' t-tests or Mann–Whitney U-tests for continuous data as appropriate.

Table 3
In-hospital treatment and outcome.

	No physician present (n = 741)	Physician 1st responder (n = 232)	No vs. 1st physician (p-value)	Physician 2nd responder (n = 155)
Any ROSC during resuscitation	242 (33)	79 (34)	0.74	75 (48)
Admitted to hospital	293 (40)	88 (38)	0.72	84 (54)
With ROSC	195 (26)	66 (28)	0.58	66 (43)
With ongoing CPR	98 (13)	22 (10)	0.16	18 (12)
Admitted to ICU	186 (25)	64 (28)	0.50	59 (38)
Awake on admission ICU	27 (15)	8 (13)	0.84	6 (10)
Therapeutic hypothermia	110 (60)	37 (58)	0.90	44 (75)
Angiography/PCI	81 (44)	32 (50)	0.47	27 (46)
No. of days in ICU[a]	4 (3, 4)	5 (3, 7)	0.19	6 (3, 7)
Discharged alive	78 (11)	31 (13)	0.28	29 (19)
Discharged with CPC 1–2	75 (10)	29 (13)	0.38	24 (16)
CPC 1	65	26		22
CPC 2	10	3		2
CPC 3	1	2		5
CPC 4	2	0		0
Discharged if admitted ICU	42%	48%	0.40	49%

IV = intravenous, ROSC = return of spontaneous circulation, CPR = cardiopulmonary resuscitation, ICU = intensive care unit, PCI = percutaneous coronary intervention, and CPC = cerebral performance score. All categorical variables given as numbers (percentages in parenthesis). No. of days in ICU is not normally distributed, and is given as median with 95% confidence intervals. Differences between groups were analysed using chi-squared with continuity correction for categorical data, and Mann–Whitney *U*-test for no. of days in ICU. Proportions of "awake on admission to ICU", "therapeutic hypothermia", "Angiography/PCI" and "number of days in ICU" are reported for patients admitted ICU only.

[a] Data missing for 6 patients in the no physician group and 2 patients in both physician 1st responder and 2nd responder groups.

and all seven survivors in this study were discharged in a vegetative state.[19]

The rationale for believing that the presence of a physician would improve outcome in cardiac arrest relies heavily on the belief that advanced procedures such as advanced airway management and intravenous drug treatments are advantageous. This assumption has not been scientifically validated. There are no randomized controlled studies reporting improved outcome with any of the aspects of ALS. A large before and after study in 17 cities failed to document any benefit of implementing ALS protocols.[4] A retrospective registry study found both intubation and intravenous drug treatment to be independent predictors of poor outcome in out-of-hospital cardiac arrest,[3] and there is concern that current ALS protocols might be too complicated in the typical chaotic and stressful out-of-hospital setting.

Previous studies have reported that physicians are more efficient in managing procedures such as ECG analysis and endotracheal intubation,[20,21] and are more likely to comply with treatment guidelines than other ambulance personnel.[22] We found that CPR quality measures such as hands-off ratio and pre-shock pauses were improved when treated by the physician-manned ambulance, and the frequency of endotracheal intubation was higher. Having a defined team leader with experience and knowledge to provide oversight during resuscitation could explain increased focus on quality of care with fewer pauses in chest compressions. Assistance with difficult procedures such as endotracheal intubation would be expected to yield higher intubation rates. However, we cannot conclude that the improved quality of CPR necessarily was due to the physician as such, as it might be due to the initial presence of 3–4 persons on the PMA vs. only 2 persons on the first responding non-physician-manned ambulance (non-PMA). Yet a non-PMA will essentially always be supported by a second and sometimes third ambulance within few minutes while the PMA will be the only responder in 2/3 of cardiac arrest cases.

The higher quality of CPR for the PMA did not lead to a significant increase in survival. As overall quality of CPR was very good in both groups compared to previous publications,[23,24] and the number of patients in the study is limited, we cannot exclude that this is due to a type II error statistically.

Our study design is limited to evaluating effects of physician presence on-site on quality of care and outcome for cardiac arrest patients, not of overall effects of having motivated physicians involved in pre-hospital care. It is possible that the most valuable effect of pre-hospital physicians is providing up-to-date knowledge, good quality training and motivation to improve quality of care in an entire EMS system. In Oslo resuscitation researchers have been actively involved as pre-hospital physicians for four decades. Several studies have attempted to evaluate the effect of physicians in pre-hospital emergency care by comparing different systems rather than the effect of the physicians' presence on scene within

Table 4
Sub-group analysis: bystander witnessed, initial VF/VT arrest with cardiac aetiology.

	No physician present (n = 139)	Physician 1st responder (n = 65)	No vs. 1st physician (p-value)	Physician 2nd responder (n = 44)
Any ROSC during resuscitation	77 (55)	40 (62)	0.50	34 (77)
Admitted to hospital	83 (60)	45 (69)	0.25	37 (84)
With ROSC	65 (47)	34 (52)	0.56	33 (75)
With ongoing CPR	18 (13)	11 (17)	0.59	4 (9)
Admitted to ICU	68 (50)	35 (54)	0.61	29 (66)
Discharged alive	39 (28)	20 (31)	0.82	18 (41)
Discharged with CPC 1–2	38 (27)	19 (29)	0.91	15 (34)
Discharged if admitted ICU	47%	44%	1.00	62%

ROSC = return of spontaneous circulation, CPR = cardiopulmonary resuscitation, ICU = intensive care unit, and CPC = cerebral performance score. All categorical variables given as numbers (percentages in parenthesis). Differences between groups were analysed using chi-squared with continuity correction.

Table 5
Adjusted effect on survival with favourable neurological outcome (CPC 1–2) when controlling for confounders.

	Odds ratio		
	Survival	95% CI	*p*-Value
Treated by PMA	1.35	(0.71, 2.60)	0.36
Initial VF/VT	11.45	(5.96, 22.00)	<0.001
Therapeutic hypothermia	8.45	(4.51, 15.84)	<0.001
Intubation	0.13	(0.07, 0.26)	<0.001
Age (per increased year)	0.96	(0.95, 0.98)	<0.001
Time from arrest to ALS ≥ 12 min	0.31	(0.15, 0.63)	0.001
Ambulance witnessed	2.76	(1.30, 5.88)	0.009

CPC = cerebral performance category, PMA = physician-manned ambulance, VF = ventricular fibrillation, VT = pulseless ventricular tachycardia, ALS = advanced life support, and 95% CI = confidence interval.

one system.[25–27] These comparisons are difficult to interpret as there might be other differences between systems in a variety of factors such as; population demographics, response intervals, organization, training methods, and in- and out-of-hospital treatment protocols.

With our cardiac arrest populations becoming older and less likely to have easily resuscitated VF arrests, it becomes increasingly problematic to continue to evaluate quality of care using survival statistics across timelines and different EMS systems. Better tools are needed to develop and formally evaluate pre-hospital quality of care strategies in an effort to both improve outcome and secure the best possible utilization of limited pre-hospital resources.

Some limitations must be addressed. This is a single centre study and the results may not be generalized to other EMS systems with different training, infrastructure and treatment protocols. Also, this was an observational study limited by selection bias and uneven distribution of important prognostic factors, and the results must be evaluated accordingly. Quality of CPR could not be assessed in the ~25–30% of cases where ECGs were missing. However, there were no indications of selection bias in the cases with missing ECGs as they had comparable characteristics and outcome compared to the cases with available ECGs. Finally, a type II error cannot be ruled out. In order to show that the observed difference between the groups is statistically significant, a new study of 8000 patients would be needed.

5. Conclusions

There was no difference in outcome between patients being treated by the physician-manned ambulance or paramedic-manned ambulances within our EMS system.

Conflict of interest

Olasveengen has received speakers' fee from Medtronic (Oslo, Norway) and research support from Laerdal Medical Corporation (Stavanger, Norway). Steen is a member of the board of directors for Laerdal Medical and The Norwegian Air Ambulance. Sunde and Lund-Kordahl have no conflicts to declare.

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Paper III: Relationship between level of CPR training, self-reported skills, and actual manikin test performance—an observational study

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Relationship between level of CPR training, self-reported skills, and actual manikin test performance—an observational study

Inger Lund-Kordahl[1], Maria Mathiassen[1], Jørgen Melau[2], Theresa Mariero Olasveengen[3,4], Kjetil Sunde[4,5] and Knut Fredriksen[1,6*]

Abstract

Background: Quality of bystander cardiopulmonary resuscitation (CPR) skills may influence out of hospital cardiac arrest (OHCA) outcomes. We analyzed how the level of CPR training related to indicators of good CPR quality and also the relationship between self-reported skills and actual CPR performance.

Methods: Two hundred thirty-seven persons trained in standardized BLS curricula were divided into three groups according to the level of training: *group I* (40 h basic first aid training), *group II*, and *group III* (96 h advanced first aid, group III had also some limited additional life support training courses). We recorded the participants' real-life CPR experience and self-reported CPR skills, and then assessed selected CPR quality indicators on a manikin. The data were analyzed with multivariate logistic regression. Differences between groups were analyzed with ANOVA/MANOVA.

Results: Out of 237 participants, 125 had basic training (group I), 84 reported advanced training (group II), and 28 advanced training plus additional courses (group III). Group II and III had shorter start-up time, better compression depth and hand positioning, higher fraction of effective rescue ventilations, shorter hands-off time, and thus a higher chest compression fraction. Chest compression rate did not differ between groups. The participants in group I assessed their own skills and preparedness significantly lower than groups II and III both before and after the test. In addition, group III reported higher confidence in examining the critically ill patient and preparedness in doing CPR before the manikin test than both groups I and II. However, the observed differences between groups II and III in self-reported skills and preparedness were not statistically significant after the test.

Conclusion: As expected, higher levels of BLS training correlated with better CPR quality. However, this study showed that ventilations and hands-on time were the components of CPR that were most affected by the level of training. Self-assessments of CPR ability correlated well to actual test performance and may have a role in probing CPR skills in students. The results may be important for BLS instructors and program developers.

Keywords: Cardiopulmonary resuscitation, Bystander, Basic life support, BLS training, Competence, Chest compressions

* Correspondence: knut.fredriksen@uit.no
[1]Anaesthesia and Critical Care Research Group, Department of Clinical Medicine, UiT The Arctic University of Norway, N-9037 Tromsø, Norway
[6]Division of Emergency Medical Services, University Hospital of North Norway, N-9038 Tromsø, Norway
Full list of author information is available at the end of the article

Background

How to further improve survival after out of hospital cardiac arrest (OHCA) remains a challenge. One of the most important strategies is to identify the arrest immediately and initiate cardiopulmonary resuscitation (CPR). Large registry studies from Sweden and Denmark have recently shown how early CPR markedly improves not only good functional survival, but also reduce the amount of nursing home admissions in resuscitated patients [1–3]. Other recent studies have demonstrated that bystander CPR rates may be increased by nationwide campaigns and concomitantly lead to at least doubled survival from OHCA [1, 3–5]. Importantly, CPR quality affects OHCA outcome. Both adequate compression depth and rate as well as a high compression fraction (the proportion of the CPR time spent on chest compressions) have been shown to correlate with return of spontaneous circulation [6–8].

Consequently, CPR training for the public is of utmost importance. Bystanders trained in CPR are three times as likely to perform CPR than those untrained [9] Several different courses and options for teaching CPR are available today. Shorter CPR courses and self-instruction videos have been developed to increase the dissemination of CPR training to the public. It has been shown that chest compression quality and defibrillator use is maintained with shorter courses [10, 11]. The current guidelines therefore support simpler courses as acceptable alternatives for low-risk bystanders and in resource-limited settings [12]. However, the effect of reducing the length of CPR courses on real-life CPR quality or patient outcomes is not well known. A recent study from the Swedish OHCA registry showed increased 30 days survival when medically educated bystanders provided CPR compared to laymen bystanders, thereby suggesting that improved CPR training programmes for laypeople could improve CPR outcomes [13].

Knowledge about which parts of the training that could be improved may enable program developers to tailor courses to the needs of laypeople. However, to our knowledge, there are no controlled studies that have investigated the relationship between training level and actual performance in the different constituents of the CPR protocol. For this reason, we decided to systematically study the relationship between performance in the different parts of CPR and the length of training programs. Unfortunately, it is difficult to measure this effect directly, and thus investigators often choose to use subjective self-assessment of acquired skills as a surrogate measure. However, very little is known also about how self-assessment of skills compares with actual CPR performance.

In the present study, we aimed to analyze how the different constituents of CPR are affected by the level of training by investigating CPR providers with different length of training in otherwise comparable programs. Since we used self-assessments of skills as part of this investigation, we also aimed to systematically establish how well the participants' self-assessment of their own skills actually related to test performance.

Methods

Participants

To recruit study participants with different CPR training length, but with otherwise comparable training programs, we invited 237 soldiers (both conscripted and professional) from the Norwegian armed forces. All participants were included from one single military camp, and all had received basic life support (BLS) training on an either basic or advanced level from the same courses.

The CPR training was in accordance with Norwegian guidelines based on 2010 ERC guidelines [14]. The participants were divided into three groups according to the amount of training. Group I had received a 40 h first aid course compulsory for all military personnel. The course included 5 h of CPR training, consisting of a 2 h lecture and 3 h practical training with a manikin. Participants with advanced training had received a 96 h course for future army medics, but some of these had experienced substantial additional training. For this reason, they were divided into group II (advanced course alone) and group III (advanced course and, in addition, other civilian and/or military life support courses). The advanced training curriculum included 18 h CPR training, with 4 h lectures and 14 h manikin training. Soldiers in groups II and III were also given a brief introduction to basic airway adjuncts (the oropharyngeal and nasopharyngeal tube) and assessment of respiratory distress, including needle decompression of a tension pneumothorax.

Data collection and definitions

All participants filled out a comprehensive questionnaire designed to explore demographic parameters, additional training, and experience with CPR in real life and selected aspects of theoretical knowledge of life support. After the questionnaire, we tested the actual performance of all participants in an OHCA single-rescuer BLS manikin scenario, using the Laerdal Resusci Anne Basic (Laerdal Medical AS, Stavanger, Norway). The test included five loops of 30 compressions and two mouth-to-mouth ventilations, and the details of the scenario were unknown to the participants before they entered the room finding an unresponsive manikin on the floor. Three of the authors (ILK, MM, and JM) individually assessed the participant's performance by direct observation, two observers squatting by the side of the manikin and one standing. The investigators did not provide any feedback during the scenario and were unaware of the participant's level of training during the assessment. Each participant reported their self-perceived preparedness to do CPR and CPR skills on a ten-point scale using four statements about their CPR skills both before and after the manikin test.

Hands-off time and compression rate were recorded using manual counting and stopwatches. The inter-observer difference was ≤ 2 s, and we recorded the average when the assessments differed. We calculated chest compression rate from the average time used for 30 compressions during all cycles. Hand placement and compression depth were assessed and recorded independently by the observers through direct observation. Correct hand placement was defined as the lower third of the sternum in the center of the chest in all five algorithm loops, and the desired compression depth was defined as 5–6 cm vertical hand movement, measured from a point on the upper hand in centimeters during all five loops. For this reason, a vertical 20-cm scale was placed in front of the manikin for comparison, in a position where it did not provide any help to the participants.

We defined a visible rise of the manikin's chest as adequate ventilation and defined the time used for airway management and ventilation as the time from the last compression in the loop until the start of the first compression in the following loop. Chest compression fraction was the time used on chest compressions, divided by the time from the first compression to the last ventilation in the scenario. Start-up time was the time from the participant recognized that the manikin was unresponsive and not breathing to the first performed chest compression.

Feasibility testing of the assessment protocol

The questionnaire and the feasibility of the simple observational protocol was evaluated in a pilot study on ten nursing and medical students before the main study was initiated (data not presented). We concluded that three trained observers were needed to assess and record the scenario data and that it was feasible to measure compression depth within 1 cm inter-observer variation and time measurements within 2 s inter-observer variation. However, the method did not allow us to reliably assess ventilation volume, and insufficient or excessive ventilation volumes were not recorded. After minor corrections, we evaluated the revised questionnaire and scenario as feasible.

Statistical analysis

We estimated the necessary sample size to 101 participants in each group, which at a two-sided 5% significance level would provide at least 90% power to detect a relevant difference in CPR skill performance.

The feasibility study had revealed a 20% difference in compression fraction and 40% in effective ventilations between groups, and we based the sample size calculations on the difference in compression fraction. A post hoc power calculation for groups II and III showed an acceptable power of 93%, given a 5% significance level and effect size of $f = 0.25$.

We calculated means and standard deviations (SD) for continuous variables, frequencies, and proportions for categorical variables, chi-square test of independence for dichotomous variables, and one-way analysis of variance (ANOVA) and multivariate analysis of variance (MANOVA) for normally distributed data. We report descriptive characteristics as means ± SDs for continuous variables and as proportions for binary variables.

We fitted multivariable logistic regression models and tested them on each outcome variable: effective ventilations, hands-off time < 7 s per loop, compression fraction > 0.7, correct hand placement, and compression depth. Model calibration was tested with the Hosmer–Lemeshow test. The exposition variable in this model was level of training (I–III) in the first model and self-reported skill rating (1–10) in the second. These models intended to show the impact of higher level of training on CPR performance in the first and association between perceived and actual CPR skills in the latter.

We adjusted for potential confounders. Time since last training has a known effect on CPR performance, and we investigated if the significant effect of the exposition variable (level of training) changed when adjusted for this variable alone, before adjusting for all variables in the model. Odds ratios (OR) with 95% confidence intervals (CI) were calculated for each outcome variable.

One-way multivariate ANOVA was conducted with three levels of training (groups I–III) as the independent variable and self-reported skill rating on a 10-point scale as the dependent variable, to test for differences between training levels and self-reported skill scores. Significant differences were analyzed with Tukey test for post hoc comparisons.

Results

Of the included 237 soldiers, 125, 84, and 28 were in groups I, II, and III, respectively. The groups differed in several baseline characteristics (Table 1), as groups II and III had more female participants than group I. In addition, only members of groups II and III had provided CPR in real cardiac arrest situations, and groups II and III were significantly more positive to receive additional training than group I. BLS training within the last 3 months was also more common in groups II and III, but participants in all groups expressed the same willingness to perform CPR if needed in a real-life emergency.

When assessing time usage and CPR quality during the test scenario, we found a shorter time to initiation of CPR, higher fraction of effective rescue ventilations,

Table 1 Characteristics of the participants by level of training group

	Group I (*n* = 128)	Group II (*n* = 84)	Group III (*n* = 28)	*p* value
Age (years)	19.9 ± 1.0	19.7 ± 1.2	23.5 ± 3.0	< 0.001
Male gender	116 (90)	57 (66)	18 (64)	< 0.001
Provided CPR in real life	0	6 (7)	9 (32)	< 0.001
Time since training (months)	5.7 ± 3.0	1.9 ± 2.3	2.8 ± 2.0	< 0.001
Conscripted soldiers	128 (100)	79 (73)	0	< 0.001
Would like more CPR training	50 (39)	57 (70)	21 (75)	< 0.001
Real life lifesaving first aid	6 (4)	57 (84)	21 (75)	< 0.001
< 3 months since last training	42 (33)	71 (85)	16 (57)	< 0.001
Willing to do CPR in a real life situation	127 (99)	82 (98)	28 (100)	0.998

Group I: basic level of life support training, group II: advanced level of training, and group III: advanced level plus additional courses. Age and time since training is givens as mean ± SD, percent of *n* in parentheses for all other variables

shorter hands-off time, and thus a higher chest compression fraction in groups II and III vs group I (Table 2). In addition, compression depth and hand positioning were better in groups II and III, but chest compression rate was close to 100 compressions per minute for all groups.

Because of the differences in baseline characteristics, we adjusted the results for age, gender, additional training, and time since last training, and the OR for effective ventilations, time use for ventilations, and chest compression fractions were still significantly better with advanced level of training following adjustment (Table 3). Hand placement and chest compression depth were also significantly better in groups II and III vs group I after adjustments. The most pronounced difference between the two groups (Table 1) was time since last CPR training, but we found the same significant differences when adjusting for this confounder alone, before adjustment for all variables (Table 3).

Study objects on all levels of training showed overall good insight in own skills and limitations with significant associations between self-reported and actual competence for all quality indicators except “bends to check breathing”. Even the association between “I am well prepared in the CPR algorithm” and “Time spent on two ventilations” and the association between “I performed good quality CPR” and the quality indicators “Compression rate through five loops” and “Time spent on two ventilations”, that were not statistically significant before adjustment, became significant after adjustment for confounders (Table 4).

Table 2 CPR quality indicators between groups with different training levels

	Group I (*n* = 128)	Group II (*n* = 82)	Group III (*n* = 28)	*p* value
Compression rate[a] First loop CPR	109 ± 29.1	107 ± 20.3	95 ± 27.9	0.036
Compression rate[a] Second loop CPR	104 ± 26.9	106 ± 16.0	98 ± 24.5	0.365
Compression rate[a] Third loop CPR	105 ± 26.0	106 ± 16.9	101 ± 18.3	0.603
Compression rate[a] Fourth loop CPR	106 ± 26.3	107 ± 18.3	100 ± 21.3	0.310
Compression rate[a] Fifth loop CPR	97 ± 26.8	113 ± 22.5	110 ± 27.3	$p < 0.001$
Effective ventilations (%)[b]	16.4	56.1	85.7	$p < 0.001$
Compression fraction[c]	0.65 ± 0.3	0.69 ± 0.3	0.74 ± 0.1	$p < 0.001$
Correct hand placement on chest (%)[d]	66.4	81.7	89.4	$p = 0.019$
Correct compression depth (%)[e]	40.6	71.4	82.1	$p < 0.001$
Total hands-off time (s)	47.0 ± 15.0	37.0 ± 12.8	30.3 ± 9.2	$p < 0.001$
Time from verified cardiac arrest to start CPR (s)	16.0 ± 12.8	3.0 ± 2.7	2.7 ± 1.2	$p < 0.001$

All results are shown as mean ± SD or %, and *p* is calculated with one-way ANOVA for continuous data and chi-square test of independence for associations between categorical data
CPR cardiopulmonary resuscitation
[a]Chest compressions per minute
[b]Elevation of thorax on manikin during rescue breaths
[c]Time fraction used on compressions during five loops of 30:2
[d]Lower third of sternum in centre of thorax
[e]Compression depth 5–6 cm

Table 3 Relationship between self-reported skills and observed skills

	Statements reported before manikin scenario		Statements reported after manikin scenario	
	"I feel confident to examine a critical ill patient"		"I did a good and systematic assessment of the patient"	
	OR (CI) unadjusted	OR (CI) adjusted	OR (CI) unadjusted	OR (CI) adjusted
Opens airway	1.50 (1.30–1.80)	1.36 (1.13–1.63)	1.30 (1.20–1.50)	1.10 (1.09–1.19)
Bends to check breathing	0.93 (0.70–1.30)	0.85 (0.60–1.18)	0.90 (0.70–1.20)	0.84 (0.61–1.16)
	"I am well trained in the CPR algorithm"		"I performed good quality CPR"	
	OR (CI) unadjusted	OR (CI) adjusted	OR (CI) unadjusted	OR (CI) adjusted
Effective ventilations	1.58 (1.34–1.87)	1.56 (1.29–1.89)	1.44 (1.25–1.67)	1.44 (1.20–1.70)
Compression fraction > 0.7	1.18 (1.03–1.36)	1.14 (1.02–1.33)	1.25 (1.11–1.42)	1.20 (1.05–1.37)
Time spent on two ventilations < 6 s	1.11 (0.96–1.30)	1.09 (1.11–1.18)	1.02 (0.89–1.16)	1.14 (1.05–1.20)
Compression rate 100–120 through five loops	1.21 (1.05–1.39)	1.23 (1.06–1.42)	1.03 (0.92–1.15)	1.18 (1.15–1.23)
Compression depth 5–6 cm	1.23 (1.05–1.30)	1.25 (1.06–1.47)	1.17 (1.04–1.33)	1.19 (1.04–1.37)
Correct hand placement	1.28 (1.10–1.50)	1.28 (1.08–1.50)	1.19 (1.04–1.37)	1.18 (1.02–1.37)

Skills are self-reported on a 10-point scale. The relationship between self-reported skills and actual performance is given as odds ratio (OR) and presented unadjusted and adjusted for the variables "level of training," "time since training," and "gender."
CI 95% confidence interval, *CPR* cardiopulmonary resuscitation

The participants in group I assessed their own skills and preparedness significantly lower than groups II and III in all statements, both before and after test. In addition, group III reported higher confidence in examining the critically ill patient and for preparedness in doing CPR before the manikin test than both groups I and II. However, the observed differences in self-reported skills and preparedness between groups II and III after finishing the manikin test were not statistically significant (Table 4).

Discussion

It is not surprising that a higher level of training leads to better CPR performance in a test scenario. However, the results presented here show that adequate airway management and ventilation skills, as well as chest compression fraction, depend significantly more on training level than other parts of CPR. Chest compression rates were similar, but also chest compression depth and hand placement were better in participants with high level of training. Importantly, all participants had received a rather brief (2–4 h) theoretical introduction to CPR, but the duration of the practical training differed significantly between basic and advanced levels of training.

Thus, we suggest that the results presented herein support the notion that enough time for practical training in these particular skills should be provided. In addition, the two groups with the most advanced course had received more training in handling respiratory distress and simple airway adjuncts. This both increased the time used on airway and ventilation training and probably gave them a broader knowledge of this topic. It is therefore likely that it may have contributed to the

Table 4 MANOVA on differences between groups in self-reported skills

Self-reported skills	MANOVA (mean ± standard deviation)				Follow-up univariate ANOVA	Tukey's post hoc test		
	Group I[a]	Group II[b]	Group III[c]	*p* value	*p* value	Group I vs. group II (*p* value)	Group III vs. group I (*p* value)	Group III vs. group II (*p* value)
"Confident to examine a critical ill patient"	4.29 ± 1.67	5.92 ± 1.92	7,00 ± 2,26	< 0.005	< 0.005	< 0.005	< 0.005	0.022
"Well trained in CPR algorithm"	6,81 ± 1.83	7.87 ± 1.72	8.75 ± 1,20	< 0.005	< 0.005	< 0.005	< 0.005	0.062
"Well prepared to do a CPR"	6,84 ± 2,04	7,60 ± 1.76	8.64 ± 1.28	< 0.005	< 0.005	< 0.005	< 0.005	0,033
"Did a systematic assessment"	3.91 ± 1.40	7.5 ± 2.12	6.1 ± 1.30	< 0.005	< 0.005	< 0.005	< 0.005	0.069
"Performed good quality CPR"	5.61 ± 1.40	8.12 ± 1.71	7.13 ± 2.10	< 0.005	< 0.005	< 0.005	< 0.005	0.091
"Would perform the same on a patient"	6.72 ± 1.50	8.73 ± 1.81	6.12 ± 2.10	< 0.005	< 0.005	< 0.005	< 0.005	0.073

Figures presented as mean ± SD
[a]Group I: basic level of life support training
[b]Group II: advanced level of training
[c]Group III: advanced level plus additional courses.
MANOVA multivariate analysis of variance, *CPR* cardiopulmonary resuscitation

airway and ventilation support skills they demonstrated in the test scenario in the present study.

It may be difficult to compare groups with different levels of training because of the diversity in BLS courses. We selected Norwegian military personnel as study objects, because the armed forces train large groups of personnel in life support simultaneously. They use highly standardized curricula and training methods, and the training reaches clearly pre-defined standards at different levels. We believe that we have compared groups that are more homogenous than they would have been with other potential study objects.

Increased emphasis has been placed on shorter courses in the last years, in particular to meet the needs for BLS training in school curriculums, driver training, and at workplaces [12]. The results of the present study suggest that short courses with less time for practical manikin training may negatively affect important markers for good quality CPR. This must be weighed against the risk of less bystander CPR rates in the society if there are no simple and less time-consuming courses. However, an earlier study showed that bystander CPR of low quality (judged by a physician on the scene) gave the same outcome as no bystander CPR at all, and bystander CPR rated as good quality resulted in higher survival [15].

In the present study, the quality of almost all chest compression and ventilation parameters was better in the group with the highest level of training. Especially the ventilation part was inappropriate in group I. Maintaining an open airway and performing rescue ventilations is a complex part of the CPR algorithm, and our results support that more time should be devoted to this part during training. This is also important because it indirectly improves the chest compression fraction, which is known to increase return of spontaneous circulation and survival from OHCA [7, 8].

Indeed, airway handling is particularly challenging for laypersons; in addition, mouth-to-mouth ventilation is considered repulsive by some, and laypersons often fear that it might transfer contagious diseases [16–18]. For this reason, CPR protocols without ventilations have been suggested (CC only CPR) [19–22]. However, outcome studies comparing CC only CPR and conventional CPR are mostly observational, mainly before-after studies, and with low level of evidence [19]. Thus, the International Liaison Committee on Resuscitation (ILCOR) still recommends that "trained and willing" providers should provide rescue breaths for adult patients, based on concerns that CC only CPR might be insufficient where EMS response intervals are long and for all asphyxial cardiac arrests. Adequate airway opening and ventilations are therefore still important parts of CPR, but the knowledge about laypersons' ability to provide successful ventilations is limited [19]. Also, international guidelines have maintained rescue breaths as part of the algorithm for trained providers because of a presumed benefit in children and in asphyxial cardiac arrest that is especially important in the less developed parts of the world [19]. Of great importance, a recently published multicentre randomized trial that compared conventional 30:2 CPR with uninterrupted CPR also supported this view [23]. All together, ventilation is still an important part of CPR, and rescue breaths should be taught. However, our findings might be used as support for CC only CPR for those with little training in ventilation management. Poor ventilations do not help, will probably lead to harm due to lower hands-on fractions, and might increase the risk of regurgitation and subsequent aspiration.

We have corrected our results for known confounders, but it is reasonable to believe that level of training also may correlate with personal interests in first aid, and perhaps a stronger motivation to help those in need of BLS. The effect of this confounder is difficult to evaluate. People choosing comprehensive courses and additional first aid training may be more likely to help because of their personal attitude. On the other hand, this can be hard to distinguish from the motivating effect of repeated and good quality training. Our study cannot fully resolve this complex question.

Even though experimental settings, like the present model, may allow us to investigate individual aspects of CPR performance, it remains to show how this relates to real life CPR situations. Some authors have pointed to the importance of teaching self-efficacy, i.e., non-technical first aid skills, including helping behavior in real-life medical emergencies [20, 24, 25]. Self-efficacy may be important, but studies about whether self-efficacy training actually changes helping behavior have given conflicting results. As direct observational studies of real-life performance and self-efficacy in CPR situations are difficult to arrange, and realistic manikin tests of large groups of CPR providers are demanding, the evaluation of acquisition of skills during training has commonly been based on the students' own perception of skills. However, the reliability of self-assessment of the student's own CPR training is largely unknown, and for this reason, we probed this relationship and its correlation to level of training in order to evaluate the responses from our questionnaire.

Previous educational, psychological, and sociological studies on higher education and post-graduate medical training suggest that self-reported skills do not necessarily reflect actual skills [26–28]. However, study design, the level of the students, and the field of study are all important for the relationship [26]. In our analysis of individual indicators for good quality CPR, only one skill did not show significant agreement with self-assessment. This skill was "bend to check breathing," and the lack of correlation may theoretically be attributed to the scenario situation, as participants may have regarded as implicit that the manikin was in cardiac arrest. In contrast, the more technically demanding chest compressions and ventilations showed significant correlation. We conclude that our findings suggest that self-assessments may be used to map the students' CPR knowledge, e. g., ahead of a course in order to tailor CPR programs to meet the individual learner's needs.

The use of a simple manikin without automatic recording of performance parameters may seem to be a limitation. These were the same as the manikins used during training, and the setup is feasible even in low resource settings. Furthermore, the test setting was evaluated thoroughly in a small-scale pilot and we included only parameters that we found could be reliably evaluated in the described study model. We also acknowledge that it may depend on experienced facilitators whose individual accuracy and reproducibility should be assured in beforehand. Finally, we have considered the fact that the military life support training focuses on trauma, particularly on combat-related trauma, but the courses did teach CPR the same way as civilian courses. We therefore believe that the present results are relevant also for the civilian population.

Conclusions

In the present manikin model, comprehensive BLS training resulted in better CPR quality, particularly regarding ventilations and hands-on time. We also found a significant relationship between self-perceived and actual skills.

Abbreviations

AED: Automatic external defibrillator; ANOVA: Analysis of variance; BLS: Basic life support; CC only CPR: Chest compression only CPR; CI: Confidence interval; CPR: Cardiopulmonary resuscitation; ERC: European Resuscitation Council; ILCOR: International Liaison Committee on Resuscitation; MANOVA: Multivariate analysis of variance; OHCA: Out of hospital cardiac arrest; OR: Odds ratio; SD: Standard deviation

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Availability of data and materials

The original data will be available from the UiT Open Research Data repository.

Authors' contributions

ILK and KF conceived and designed the study. ILK, MM, and JM were responsible for the pilot studies and the data acquisition in the main study. ILK performed the statistical analyses. ILK, TMO, KS, and KF contributed to the data analysis and interpretation. ILK and KF drafted the manuscript and revised it together with TMO and KS. All authors have approved the final version of the manuscript.

Ethics approval and consent to participate

The Regional Ethics Board of North Norway concluded that the study did not need an ethical approval (2014/351), and all participants contributed voluntarily and signed an informed consent form.

Consent for publication

Not applicable

Competing interests

The authors declare that they have no competing interests.

Publisher's Note

Author details

[1]Anaesthesia and Critical Care Research Group, Department of Clinical Medicine, UiT The Arctic University of Norway, N-9037 Tromsø, Norway. [2]Division of Pre-hospital Services, Vestfold Hospital Trust, N 3103 Tønsberg, Norway. [3]Norwegian National Advisory Unit for Prehospital Emergency Care (NAKOS), Oslo University Hospital, Oslo, Norway. [4]Department of Anaesthesiology, Division of Emergencies and Critical Care, Oslo University Hospital, Oslo, Norway. [5]Institute of Clinical Medicine, University of Oslo, Oslo, Norway. [6]Division of Emergency Medical Services, University Hospital of North Norway, N-9038 Tromsø, Norway.

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Appendix

Observation form CPR for Paper III

OBSERVASJONSSKJEMA HLR

IDENTITET:

……………………...…………………..…..

TILKALLER HJELP/ ringer 113:

- ❑ JA
- ❑ NEI

ÅPNER LUFTVEIENE:

- ❑ JA
- ❑ NEI

SJEKKER OM PASIENTEN PUSTER

- ❑ JA
- ❑ NEI

TID FRA VERIFISERT HJERTESTANS TIL START HLR: ________________________

KOMPRESJONER/VENTILASJONER:

- ❑ 30:2
- ❑ 15:2
- ❑ KONTINUERLIGE KOMPRESJONER
- ❑ STARTER IKKE

VENTILASJONER

(Tid i minutter og sekunder anvendt fra opphold kompresjoner, gjennomførte ventilasjoner til kandidaten starter igjen, i en korrekt loop ventileres det 2 ganger pr loop. Dersom kandidaten ventilerer kun en gang eller mer enn to, noteres tiden for dette, og det markeres i margen antall ventilasjoner)
5 sløyfer:

1: _______ 2: _______ 3: _______ 4: _______ 5: ______

KOMPRESJONER

(Tid i minutter og sekunder anvendt fra start kompresjoner til stopp kompresjoner i hver loop, hver loop er 30 kompresjoner i en korrekt loop. Noen vil anvende 15 kompresjoner, da noteres tiden brukt for 15 kompresjoner)

5 sløyfer:

1: _______ 2: _______ 3: _______ 4: _______ 5: _______

HÅNDPLASSERING UNDER KOMPRESJONER:

- ❑ Midtlinje, nedre 1/3 av sternum
- ❑ For høy plassering
- ❑ For lav plassering
- ❑ Utenfor midtlinjen

KORRIGERING AV PLASSERING PÅ STERNUM

- ❑ Plasseringen korrigeres fra feil til korrekt plassering i løpet av 5 sløyfer.
- ❑ Plasseringen korrigeres fra korrekt til feil plassering i løpet av 5 sløyfer.
- ❑ Feil plassering på sternum gjennom alle 5 sløyfer.
- ❑ Korrekt plassering på sternum gjennom alle 5 sløyfer.

KOMPRESJONSDYBDE (visuelt vurdert):

- ❑ 5 – 6 cm
- ❑ Under 5 cm
- ❑ Over 6 cm

KOMPRESJONSDYBDE GJENNOM 5 SLØYFER

- ❑ Mer korrekt kompresjonsdybde gjennom 5 sløyfer
- ❑ Mindre korrekt kompresjonsdybde gjennom 5 sløyfer
- ❑ Under 5 cm gjennom alle 5 sløyfer
- ❑ Over 6 cm gjennom alle 5 sløyfer

VENTILASJONER/INNBLÅSNINGER:

- ❑ Gjennomfører ventilasjoner
- ❑ Ingen ventilasjoner

KVALITET VENTILASJONER:

- ❑ Effektive (thoraxløft)
- ❑ Ineffektive

ANNET:

Information and demographics for Paper III

Kunnskaper og holdninger til livreddende førstehjelp hos ungt militært personell i Norge.

Vi er to leger ved Universitetssykehuset i Nord-Norge som sammen med Professor Knut Fredriksen jobber med et forskningsprosjekt om livreddende førstehjelp. I den forbindelse ønsker vi å kartlegge kunnskapsnivå og holdninger til å gi førstehjelp blant militært personell i Norge.

Ved å studere disse forholdene blant militært personell som har sanitetsopplæring på forskjellige nivåer, vil vi forsøke å danne oss et bilde av hvordan situasjonen er blant deres alders- og yrkesgruppe i Norge.

Alle besvarelser blir behandlet anonymt, og det betyr at din besvarelse ikke kan spores tilbake til deg etter at den er levert.

Man vet lite om kunnskapsnivå og holdninger til å utføre livreddende førstehjelp blant unge mennesker i Norge, og undersøkelser i andre land har vist store forskjeller. Vi trenger bedre kjennskap til dette for å kunne forbedre opplæringen i førstehjelp. Uten gode førstehjelpere vil den profesjonelle innsatsen nesten alltid komme for seint, og det vil være svært vanskelig å redde liv.

Vi håper at du tar deg tid til å besvare denne undersøkelsen. Du vil da bidra til å øke kunnskapen innen dette feltet. Det tar bare ca 10 minutter å svare på spørsmålene.

På forhånd takk for bidraget.

Med vennlig hilsen

Inger Lund-Kordahl,
Maria Mathiassen, Knut Fredriksen, Seksjonsoverlege
Akuttmedisinsk avdeling, UNN Tromsø, og Det Medisinske Fakultet, Universitetet i Tromsø.

DET MEDISINSKE FAKULTET
Anestesiavdelingen
Universitetet i Tromsø, 9037 Tromsø, telefon 77 62 84 40, telefax 77 62 61 92, e-mail: knut.fredriksen@unn.no
Førsteamanuensis II dr med Knut Fredriksen

Om deg selv:

Alder: ……………………...…………………...

Kjønn: ☐ Mann ☐ Kvinne

På hvilket trinn har du gjennomført og bestått sanitetsopplæring gjennom Forsvaret?

- ☐ Trinn 1-2
- ☐ Trinn 3
- ☐ Trinn 4
- ☐ Trinn 5

Hvor lenge siden er det sist du hadde sanitetsopplæring/kurs gjennom Forsvaret?

- ☐ Under 1 måned
- ☐ 2-3 måneder
- ☐ 3-5 måneder
- ☐ Over 6 måneder

Har du vært gjennom resertifisering av din sanitetsutdannelse i Forsvaret?

- ☐ Ja
- ☐ Nei

Dersom du er resertifisert, oppgi dato for siste resertifisering ____________________

Dersom du har du sivil helsefaglig utdannelse, spesifiser under.

- ☐ Ambulansearbeider /paramedic
- ☐ Hjelpepleier/omsorgsarbeider
- ☐ Sykepleier/vernepleier
- ☐ Annet, spesifiser her ______________________________

Del 1:

1. Har du lært hvordan man utfører hjerte-lungeredning (HLR) i Forsvaret? (sett ett eller flere kryss)

- ☐ Ja, i sanitetsopplæringen.
- ☐ Ja, i annen sammenheng, spesifiser gjerne ___________________________
- ☐ Nei

2. Har du hatt kurs i HLR utenom opplæringen i Forsvaret? (sett ett, ingen eller flere kryss)

- ☐ Gjennom Røde Kors
- ☐ Gjennom Norsk Luftambulanse
- ☐ Gjennom jobb
- ☐ Annet, spesifiser gjerne her: ……………………………………………………………………………….

3. Dersom du ikke har hatt kurs i HLR utenom Forsvaret, hva er årsaken til dette? (sett ett kryss for det som passer best)

- ☐ Liten interesse
- ☐ Liten tid
- ☐ Usikker på hvor man tar slike kurs
- ☐ Kostnad

4. Ønsker du mer opplæring/kurs i HLR?

- ☐ Ja
- ☐ Nei

5. Dersom du svarte ja i spørsmål 4, hva er grunnen til dette? (sett ett kryss for det som passer best)

- ☐ Hjertesykdom i nær familie
- ☐ Ønske om å bidra til å redusere dødsfall i hjertestans
- ☐ Annet, spesifiser gjerne her: ………………………………………………………………………………..

6. Synes du opplæring i HLR bør være obligatorisk i samfunnet? (sett ett eller flere kryss)

- ☐ Ja, i skolen
- ☐ Ja, for å få førerkort til bil
- ☐ Ja, kursing bør inngå i arbeidsliv
- ☐ Nei, HLR-kurs bør være helt valgfritt

7. Har du vært i en situasjon hvor noen har hatt hjertestans og behov for HLR?

- ☐ Ja
- ☐ Nei

8. Dersom du svarte ja i spørsmål 7, gjorde du da noen av følgende livreddende tiltak? (sett ett, ingen eller flere kryss)

- ☐ Ringe etter ambulanse
- ☐ Brystkompresjoner
- ☐ Munn-til-munn metode

9. Føler du at du har nok kunnskap til å kunne gi HLR i en situasjon med hjertestans?

- ☐ Ja
- ☐ Nei

10. Føler du at opplæringen du har fått i HLR gjennom sanitetsopplæringen har gjort deg godt rustet til å bidra i hjertestanssituasjoner?

- ☐ Ja
- ☐ Nei

Del 2:

1. Hvilket nummer ringer du for å tilkalle ambulanse? Skriv her: ………………………

2. Hvor stor andel av de som får hjertestans utenfor sykehus i tror du overlever? (sett ett kryss)

- ☐ Omtrent 35 %
- ☐ Omtrent 1 %
- ☐ Omtrent 10 %

3. Hvor mye øker sjansen for å overleve ved hjertestans utenfor sykehus dersom den livløse får god HLR før ambulansepersonell kommer til? (sett ett kryss)

- ☐ Den fordobles
- ☐ Overlevelsen påvirkes lite så lenge ambulansen kommer fort
- ☐ Den femdobles

4. Du er alene og finner en tilsynelatende livløs voksen person. Hva gjør du? (sett ett kryss)

- ☐ Starter øyeblikkelig brystkompresjoner
- ☐ Sjekker bevissthet, åpner luftveiene og ser om pasienten puster
- ☐ Sjekker puls

5. Det viser seg at personen puster, men ikke reagerer når du snakker til han. Hva gjør du? (sett ett kryss)

- ☐ Starter øyeblikkelig brystkompresjoner
- ☐ Legger personen i stabilt sideleie og ringer etter ambulanse
- ☐ Sjekker puls

6. Du er alene og finner en middelaldrende person som ikke puster og ikke reagerer når du snakker til han. Hva gjør du først? (sett ett kryss)

- ☐ Starter munn-til-munn metode
- ☐ Starter øyeblikkelig brystkompresjoner
- ☐ Ringer etter ambulanse

7. Du bestemmer deg for å utføre HLR. Hvilken av de følgende kombinasjoner vil du velge? (sett ett kryss)

- ☐ Først 30 brystkompresjoner, deretter 2 innblåsinger, i repeterende runder
- ☐ Først 30 brystkompresjoner, deretter 5 innblåsinger, i repeterende runder
- ☐ Først 2 innblåsinger, deretter 30 brystkompresjoner, i repeterende runder

8. Hvor lang tid bør man bruke pr innblåsning når man gjør hjerte-lunge-redning? (sett ett kryss)

- ☐ 1-2 sekunder
- ☐ 3-4 sekunder
- ☐ 8-10 sekunder

9.Hvilket tempo skal man ha på brystkompresjonene? (sett ett kryss)

- ☐ 60 pr minutt
- ☐ 75 pr minutt
- ☐ 100 pr minutt

10. Hvor dypt ned i brystkassen skal kompresjonene gå når man gir hjertekompresjoner?

- ☐ 2-3 cm
- ☐ 5-6 cm
- ☐ 7-8 cm

11. Hvor skal man plassere hendene når man utfører brystkompresjoner?

- ☐ To fingerbredder opp fra brystbensspissen
- ☐ Midt på brystkassen
- ☐ Mellom 4 og 5 ribben tellt ovenifra

12. Hva er riktig prosedyre for HLR på barn?

- ☐ 1:5
- ☐ 30:2
- ☐ 2:15

13. Hvilke av disse tre påstandene er riktig?

- ☐ På slutten av hver brystkompresjon skal hendene ikke utøve noe trykk på brystkassen
- ☐ På slutten av hver kompresjon skal hendene utøve ett lett trykk på brystkassen
- ☐ På slutten av hver kompresjon skal hendene utøve et solid trykk på brystkassen

14. Hvor lenge skal du holde på med HLR?

- ☐ I minimum 30 minutter
- ☐ Til hjelp kommer og overtar
- ☐ Du må stoppe hvis du knekker ribben på pasienten

15. Hvis to førstehjelpere er tilstede hvordan bør man fordele arbeidet?

- ☐ En utfører innblåsninger og en annen utfører kompresjoner
- ☐ En utfører all HLR og den andre sørger for å holde unna publikum og ta imot ambulansen
- ☐ En utfører innblåsninger og en annen utfører kompresjoner. Man bør bytte ca hvert andre minutt.

Del 3:

1. Er du villig til å gi HLR dersom du er vitne til en hjertestans? (sett ett kryss)

- ☐ Ja
- ☐ Nei

2. Dersom du svarte nei i spørsmål 1, hva er grunnen til dette? (sett kryss for det som passer best)

- ☐ Har for liten kunnskap innen HLR
- ☐ Frykt for å skade den livløse
- ☐ Frykt for smittefare
- ☐ Annet, spesifiser gjerne her: ……………………………………………………………………………………

Viktig info

I de følgende spørsmål vil vi presentere noen ulike situasjoner med hjertestans hvor HLR vil være aktuelt. Etter hver tekst vil du få flere svaralternativer, og vi ønsker at du krysser av for det eller de tiltak du er villig til å gjøre i den enkelte situasjon. Du kan altså sette flere kryss. Dersom ingen av alternativene passer for deg, setter du ingen kryss.

Situasjon A:

Du sitter i stuen hjemme og ser på tv. Plutselig hører du et brak fra kjøkkenet. Du stormer inn, og finner et nært familiemedlem liggende livløs på gulvet. Familiemedlemmet puster ikke. Du er alene i huset. Hva er du villig til å gjøre?

- ☐ Ringe etter ambulanse
- ☐ Utføre brystkompresjoner
- ☐ Utføre munn-til-munn metode

Situasjon B:

Du er på et stort kjøpesenter og må besøke toalettet. Der finner du en livløs og ukjent person liggende på gulvet .Vedkommende puster ikke, og du får ingen kontakt. Han ser litt uflidd ut og du får øye på en sprøyte hengende i underarmen hans. Du mistenker straks at det dreier som om en narkotikaoverdose. Hva er du villig til å gjøre?

- ☐ Ringe etter ambulanse
- ☐ Utføre brystkompresjoner
- ☐ Utføre munn-til-munn metode

Situasjon C:

Du er ute og slår plenen en sommerdag. Plutselig kommer en liten jente løpende. Hun roper at venninnen ligger på bakken og ikke vil våkne. Du løper bort til den livløse jenta, som ikke puster. Hva er du villig til å gjøre?

- ☐ Ringe etter ambulanse
- ☐ Utføre brystkompresjoner

Situasjon D:

Du går hjem fra butikken en kveld. Foran deg ser du en veltet gåstol og på bakken ligger en eldre kvinne. Hun ser ut til å være i åttiårene. Hun verken puster eller er kontaktbar, og du ser at hun har noe oppkast rundt munnen. Hva er du villig til å gjøre?

- ☐ Ringe etter ambulanse
- ☐ Utføre brystkompresjoner

☐ Utføre munn-til-munn metode

☐ Utføre munn-til-munn metode

Situasjon E:

Du sykler hjem en sen kveld. En moped kjører raskt forbi deg. Plutselig mister føreren kontrollen og kolliderer inn i en lyktestolpe. Føreren blir kastet av og hjelmen sprekker idet han treffer bakken. Du stormer til og finner en tydelig skadet ungdom med mye blod i ansiktet. Den skadete puster ikke og du får ingen kontakt med han. Hva er du villig til å gjøre?

☐ Ringe etter ambulanse

☐ Utføre brystkompresjoner

☐ Utføre munn-til-munn metode

Situasjon F:

Du er ute på ski i lysløypa en kveld. En skiløper i voksen alder renner raskt forbi deg, men faller plutselig om i neste motbakke. Du stormer til og ser at han ikke puster. Hva er du villig til å gjøre?

☐ Ringe etter ambulanse

☐ Utføre brystkompresjoner

☐ Utføre munn-til-munn metode

3. Dersom du ikke ville utføre munn-til-munn metoden i en eller flere av situasjonene over, hva er grunnen til dette? (sett ett kryss for det som passer best)

☐ Frykt for smittefare

☐ Synes det er ekkelt å utføre

☐ Føler jeg ikke behersker munn-til-munn metoden godt nok, og er derfor redd for å gjøre feil

☐ Annet, spesifiser gjerne her: ……………………………………………………………………………………….

4. Dersom det ble anbefalt at kun medisinsk personell skulle utføre munn-til-munn metode, og du bare måtte utføre brystkompresjoner samt ringe etter hjelp, ville det da være lettere for deg å sette i gang livreddende førstehjelp?

☐ Ja

☐ Nei

Ditt studie ID nr…………………………………………..

Pre- and post test rating for Paper III

Pretest Likert skala for vurdering av antatte egne ferdigheter og holdninger

1 Jeg føler meg godt forberedt for å gjøre en primær undersøkelse av en hardt skadd pasient

Helt uenig—1—2—3—4—5—6—7—8—9—10—Helt enig

2 Jeg føler meg godt forberedt for å gjøre en primær undersøkelse av en kritisk syk pasient

Helt uenig—1—2—3—4—5—6—7—8—9—10—Helt enig

3 Jeg er godt kjent med de driller som gjelder for den primære vurdering av en hardt skadd pasient

Helt uenig—1—2—3—4—5—6—7—8—9—10—Helt enig

4 Jeg er godt kjent med prinisippene for basal hjerte-lunge-redning

Helt uenig—1—2—3—4—5—6—7—8—9—10—Helt enig

5 Jeg føler meg godt forberedt til å utføre basal hjerte-lunge-redning på en person som faller om på gaten

Helt uenig—1—2—3—4—5—6—7—8—9—10—Helt enig

6 Jeg føler meg godt forberedt til å gjøre livreddende tiltak på en pasient som er hardt skadd i felt

Helt uenig—1—2—3—4—5—6—7—8—9—10—Helt enig

Post-test likert skala for vurdering av egne ferdigheter og holdninger

1. Jeg føler at jeg fikk gjort en god og systematisk vurdering av den kritisk syke pasienten

Helt uenig—1—2—3—4—5—6—7—8—9—10—Helt enig

2. Jeg føler at jeg fikk gjort en god og systematisk vurdering av den hardt skadde pasienten

Helt uenig—1—2—3—4—5—6—7—8—9—10—Helt enig

3. Jeg føler at jeg fikk brukt drillen jeg har lært da jeg vurderte og behandlet den hardt skadde pasienten.

Helt uenig—1—2—3—4—5—6—7—8—9—10—Helt enig

4. Jeg føler at jeg fikk gjort god hjerte-lunge-redning

Helt uenig—1—2—3—4—5—6—7—8—9—10—Helt enig

5.Jeg føler at jeg ville gjort de samme vurderinger og tiltak dersom en pasient falt om på gaten som jeg gjorde i testscenariet.

Helt uenig—1—2—3—4—5—6—7—8—9—10—Helt enig

6. Jeg føler at jeg ville gjort de samme vurderinger og tiltak om en person ble skadet i felt som jeg gjorde i testscenariet.

Helt uenig—1—2—3—4—5—6—7—8—9—10—Helt enig