IMPROVING THE RESPONSE TO CARDIAC ARREST

STUDIES ON ORGANISATIONAL AND EDUCATIONAL ASPECTS

Jouni Nurmi

ACADEMIC DISSERTATION

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**ABSTRACT**

**Aim:** To study the possibilities for improvement of response to cardiac arrest through organisation of rapid defibrillation, early recognition of pre-arrest signs, and national resuscitation guidelines.

**Materials and methods:** The adherence of health care professionals (n=136) to guidelines for placing defibrillation electrodes was studied in an observational study (Study I). The effect of different pictorial instructions for defibrillation electrode placement by untrained laypersons was evaluated in a randomised observational study (Study II). The effectiveness of laypersons and health care professionals as public access defibrillation (PAD) instructors, all receiving the same eight-hour training, was compared in a randomised trial including objective structured clinical examination (OSCE) of resuscitation skills of laypersons trained by the instructors (Study III). The prevalence of documented abnormal vital signs prior to cardiac arrest and the responses to these were studied by retrospective chart review in four hospitals (Study IV). Resuscitation practices in hospitals and health centres, especially concerning rapid defibrillation programmes, as well as the implementation of national resuscitation guidelines and use of medical emergency teams in hospitals, were assessed using a cross-sectional mail survey (Studies V, VI).

**Results:** Only 25% of the health care professionals placed both defibrillation electrodes correctly (within five centimetres from the recommended position). Significant differences were observed in the proportion of correctly placed electrodes by untrained laypersons, dependent on the pictorial instructions on the electrodes. The electrodes, with the pictures designed for the study which depicted the placement of the apical electrode presented in a lateral view, were more often placed correctly than any of the five tested commercial electrodes.

The mean OSCE score of resuscitation skills did not differ between subjects trained by a layperson or by a health care professional.

Of patients suffering a cardiac arrest on the general wards, 54% had documented abnormalities in their vital signs, documented an average of 3.8 hours before the arrest. Documented interventions made after measuring abnormal vital signs were uncommon and often overdue. The only vital signs measured at least once in the 24 hours (median) prior to the cardiac arrest were heart rate and blood pressure. Additionally, only three hospitals in Finland had a medical emergency team, which is called based on predetermined criteria.

In a majority of Finnish hospitals (67%), nurses, without the presence of a physician, could perform defibrillation on general wards. In other hospital areas, rapid defibrillation programmes were even more common. In the health centres, however, these were relatively rare (24%).
Compared with a questionnaire study, performed just after the publication of international Guidelines 2000 but before the publication of the national resuscitation guidelines in 2002, many resuscitation strategies recommended in the guidelines were more common in 2004 (Study VI). These included rapid defibrillation programmes, unified style for documentation of “do not attempt resuscitation” orders, and Utstein style data collection on resuscitation attempts. The majority of the hospitals had adopted the recommendation of using amiodarone for treatment of prolonged ventricular fibrillation.

**Conclusions:** The recommended placement of the defibrillation electrodes should be emphasised more in defibrillation training and in designing the pictorial instruction on the electrodes. After an eight-hour training course laypersons can efficiently teach skills needed for public access defibrillation, which enables more cost-effective implementation of public access defibrillation programmes.

Abnormal vital signs are frequently observed in patients on the wards prior to cardiac arrest, but interventions are often insufficient. Actions to improve the response to deterioration of vital functions, including medical emergency teams or education of ward staff, are needed.

Most hospitals have rapid defibrillation programmes outside the critical care areas, but these programmes are much less common in the health centres.

After the publication of the national resuscitation guidelines, certain resuscitation strategies in hospitals displayed marked change. Although other reasons for change, e.g. active marketing of automated external defibrillators cannot be excluded, the results encourage the publishing of resuscitation guidelines nationally.
LIST OF ORIGINAL PUBLICATIONS

This thesis is based on the following original publications, which will be referred to in the text by their Roman numerals I to VI.


Supplemented with additional data from Study VI.

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# Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>AED</td>
<td>Automated external defibrillator</td>
</tr>
<tr>
<td>AED-BLS</td>
<td>Basic life support including the use of an automated external defibrillator</td>
</tr>
<tr>
<td>AHA</td>
<td>American Heart Association</td>
</tr>
<tr>
<td>BLS</td>
<td>Basic life support</td>
</tr>
<tr>
<td>CI</td>
<td>Confidence interval</td>
</tr>
<tr>
<td>CPG</td>
<td>Clinical practice guidelines</td>
</tr>
<tr>
<td>CPP</td>
<td>Coronary perfusion pressure</td>
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<tr>
<td>CPR</td>
<td>Cardiopulmonary resuscitation</td>
</tr>
<tr>
<td>DNAR</td>
<td>Do not attempt resuscitation</td>
</tr>
<tr>
<td>EMS</td>
<td>Emergency medical services</td>
</tr>
<tr>
<td>EMT</td>
<td>Emergency medical technician</td>
</tr>
<tr>
<td>ERC</td>
<td>European Resuscitation Council</td>
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<tr>
<td>ICU</td>
<td>Intensive care unit</td>
</tr>
<tr>
<td>IHCA</td>
<td>In-hospital cardiac arrest</td>
</tr>
<tr>
<td>MET</td>
<td>Medical emergency team</td>
</tr>
<tr>
<td>NAS–NRC</td>
<td>National Academy of Sciences – National Research Council</td>
</tr>
<tr>
<td>NRCPR</td>
<td>National Registry of Cardiopulmonary Resuscitation</td>
</tr>
<tr>
<td>OHCA</td>
<td>Out-of-hospital cardiac arrest</td>
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<tr>
<td>PAD</td>
<td>Public access defibrillation</td>
</tr>
<tr>
<td>PEA</td>
<td>Pulseless electrical activity</td>
</tr>
<tr>
<td>ROSC</td>
<td>Return of spontaneous circulation</td>
</tr>
<tr>
<td>SCA</td>
<td>Sudden cardiac arrest</td>
</tr>
<tr>
<td>SD</td>
<td>Standard deviation</td>
</tr>
<tr>
<td>VF</td>
<td>Ventricular fibrillation</td>
</tr>
<tr>
<td>VT</td>
<td>Ventricular tachycardia</td>
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1. INTRODUCTION

Sudden cardiac arrest (SCA) due to coronary disease is the single most important cause of death in the adult population of the industrialised world and it is most often associated with ventricular fibrillation (VF) \(^1\). Although highly reversible by rapid application of electric defibrillation, VF is otherwise fatal within minutes \(^2\). The outcome of SCA is generally poor and has stayed virtually unchanged over the last three decades \(^6\). Rapid defibrillation programmes, however, in the community as well as in the in-hospital setting have led to marked improvement in the rates of hospital discharge of successfully treated patients after cardiac arrest \(^10\). In order to implement widespread and successful public access defibrillation (PAD) programmes a very large number of people would need training in the use of a defibrillator, since successful cardiopulmonary resuscitation (CPR) and defibrillation requires adequate technical skills. Thus, strategies to increase capable instructors as well as prepare clear enough instructions to guide untrained responders to use a defibrillator as recommended are required. Rapid defibrillation programmes, in the hospital setting, have been recommended by several organisations but their implementation has been sporadic \(^15\). The extent of rapid defibrillation programme implementation in primary health care is unknown.

Most of the cardiac arrests occurring in hospitals are not sudden, and in fact, up to 84% of the patients suffering a cardiac arrest on the wards have documented abnormal vital signs hours before the arrest \(^16\). Some recent studies indicate that a relatively high proportion of these cardiac arrests could be avoided if adequate treatment is initiated promptly \(^24\). Recognition of clinical deterioration in the early stage requires sufficient observation practices and organised response to the abnormal observations on the wards. The prevalence of pre-arrest signs in Finnish hospitals and strategies of hospitals to response to these have not been evaluated.

Evidence-based guidelines for clinical practice are frequently published in various fields of medicine aiming at improving the quality of care. Studies have shown poor adherence to the guidelines in clinical practice, however \(^29\). In spite of the fact that the first resuscitation guidelines were published as early as in 1966 \(^30\) and considerable efforts have been made updating them frequently, very little is known about their impact on practice. Assessment, to determine the requirement of implementation interventions, is needed of the adherence of responders and organisations to the resuscitation guidelines. The resuscitation guidelines published nationally in guidelines series by a recognised medical society in collaboration with resuscitation council instead of separate guidelines by a resuscitation council alone may result in positive changes of resuscitation strategies of hospitals. Adherence to them has not been evaluated, however.
The aim of the current thesis was to study possibilities to improve the response to cardiac arrest at different levels of health care. Firstly, the performance of individual responders in placement of defibrillation electrodes was evaluated with reference to the adherence to the guidelines and pictorial guidance for untrained responders. Secondly, at the level of individual organisations, both PAD training issues of laypersons and ability of hospital organisation to respond to pre-arrest deterioration were studied. And thirdly, at the national level, the organisation of rapid defibrillation programmes in hospitals and health centres as well as changes in in-hospital resuscitation strategies after publication of national guidelines, were evaluated.
2. REVIEW OF THE LITERATURE

2.1. Sudden cardiac arrest

Ultimately, cardiac arrest will occur in every human, leading to death, the natural end of a life. Some SCAs, from potentially reversible causes, can be reversed by CPR. Without adequate and prompt treatment a SCA will develop into sudden death, and if from cardiac origin, to sudden cardiac death. Definitions used for sudden cardiac death by European Society of Cardiology is as follows: ‘natural death due to cardiac causes, heralded by abrupt loss of consciousness within one hour of the onset of acute symptoms; pre-existing heart disease may have been known to be present, but the time and mode of death are unexpected’ . The definition of sudden unexpected death in epidemiological studies utilizes wider time limitation: ‘death within 24 hours of symptom onset in a previously functional individual’ . Most out-of-hospital cardiac arrests (OHCAs) can be determined as SCA whereas most IHCAs are not sudden or unexpected.

Epidemiology and aetiology

The single most important cause of death in the adult population of the industrialised world is sudden cardiac death due to coronary disease. The estimated proportion of patients, who suffer a cardiac arrest of cardiac aetiology, which have VF at the time of collapse is about 80–90% . It is further estimated that the incidence of sudden cardiac death most likely ranges between 50 to 90 per 100,000 person-years . In an analysis of emergency medical services (EMS) treated cardiac arrests, in 35 communities in the United States, the annual incidence of SCA with any initial rhythm was approximately 55 per 100,000 persons, and the incidence of SCA with VF as initial rhythm was approximately 21 per 100,000 .

Far from all patients are attended by EMS since the majority of sudden cardiac deaths occur at home and most events are unwitnessed . The majority of sudden OHCAs treated by EMS are from cardiac origin, and most commonly caused by coronary artery disease and its complications, or by cardiomyopathies. Of patients experiencing sudden cardiac death, however, 20% to 40% do not have a history of heart disease.

In the past 30 years, due to improved primary and secondary prevention as well as treatment strategies, the mortality from coronary artery disease has markedly decreased. In Finland, the significant contribution to the overall coronary heart disease mortality rates among persons 35 to 64 years of age is the decline in out-of-hospital coronary heart disease deaths. Consequently, Kuisma and colleagues reported a significant reduction of 48% in the incidence of out-of-hospital VF from
1994 to 1999 in Helsinki. In Seattle, the incidence of out-of-hospital VF has decreased by as much as 56% in the period from 1980 to 2000. A report from Gothenburg, Sweden also documents a decrease in VF over 17 years from 39% to 32% of cardiac arrest patients despite a shortening of response time and increase in bystander CPR.

The most common non-cardiac aetiologies of EMS-treated cardiac arrests are trauma, non-traumatic bleeding, intoxication, near-drowning, pulmonary embolism, and malignancy. In these cases, VF or pulseless ventricular tachycardia (VT) are rarely observed as initial rhythm.

Pathophysiology of sudden cardiac arrest

Electrical activity. At least two mechanisms can lead to VF: ischemia from thrombosis in a coronary artery and arrhythmia arising from a chronic myocardial scar. During untreated VF, the morphology of the VF is initially coarse and becomes finer over time. The changes in VF morphology over time correlates with myocardial bioenergetic changes during VF. Using fast Fourier analysis, a processing method that enables dividing a periodic signal into its frequency components, these changes can be quantitatively characterised. The probability of return of spontaneous circulation (ROSC) after a defibrillation attempt can be predicted based on the median frequency of VF and other parameters with high a degree of assurance. When the duration of VF is prolonged for several minutes, the median frequency of VF is decreased from 11 Hz to about 9 Hz at 10 minutes, and it can be restored by CPR. Moreover, the restoration of VF morphology is associated with higher likelihood of successful defibrillation to a perfusing rhythm. The physiological and biochemical bases for the changes of VF morphology are not well understood.

Haemodynamics. A swine model showed that after initiation of VF, regardless of the cease of cardiac output, coronary perfusion pressure (CPP, pressure gradient between aorta and right ventricle) and carotid blood flow are maintained at a low level by the tonus of the arteries for four to five minutes. After this, a balance is reached between arterial and venous blood pressures and blood is pooled to the venous side. When chest compressions are initiated at this point the CPP falls to negative for one minute and a further 30 seconds of compressions are needed to produce a CPP of adequate level, i.e. 15 mmHg. The level of CPP achieved by CPR is strongly associated with the likelihood of ROSC. The minimum pressure needed for predictable ROSC in humans is a CPP of 15 mmHg.

During CPR in animal models, cardiac output achieved by chest compressions is estimated to be 30–50% and a stroke volume of 45% of baseline values. Stroke volume achieved by chest compressions is related to CPP and to the success of the resuscitation attempt. Interruption of chest compressions causes immediate loss of an adequate CPP, and when chest compressions are reinitiated it takes more than 30 seconds to make CPP positive again. Since extrathoracic organs receive perfusion
pressure and blood flow during both the compression and the decompression phases, the blood flow of these organs more rapidly begins after initiation of chest compressions compared with intrathoracic organs such as the heart. The relatively good flow to the brain during CPR compared with the heart, for example, may partially result from a collapse of jugular veins at the thoracic inlet caused by chest compression.

The physiological mechanisms behind the importance of CPP as a predictor of ROSC are not fully known. Some findings, mostly from animal studies, support the view that both the changes in effective filling pressure of the left ventricle and the metabolic state of the myocardium are critical. Mechanical contraction of the myocardium is dependent on the stretching of the myocytes, i.e. the preload. Within a physiological range, the increase in the force of contraction is caused by the increase of stretching. If stretching does not exceed a certain point, no contractility happens. The stretching of myocytes in the left ventricle is determined by effective distending pressure acting on the left ventricle at end diastole, i.e. pressure gradient across its wall. In the physiological situation when pericardial pressure and right ventricular pressure are very close to zero, the effective distending pressure of the left ventricle is very close to left ventricle end diastolic pressure. In untreated VF the blood flow continues until the pressure gradient between arterial and venous sides is lost, about four minutes, and blood is pooled to the right side of the circulation. A swine model showed right ventricle enlargement during the first minutes of VF, indicating a markedly raised right ventricular end diastolic pressure. Thus, in untreated cardiac arrest lasting over approximately four minutes, the pressure gradient over the wall of the left ventricle is decreased and the requirements for mechanical contraction after termination of VF are lost. This phenomenon is reversible if chest compressions are given without interruptions.

**Ischemic contracture.** The myocardium becomes stiff and firm after prolonged global ischemia. The current evidence suggests that cross bridge formation between actin and myosin due to ischemia-induced depletion of adenosine triphosphate is the cause of this contracture. Presence of stiff myocardium is not dependent only on length of the ischemic period but also on temperature, myocardial hypertrophy, VF during arrest, the degree of acidosis, and, possibly, the treatment. Animal studies demonstrated that ischemic contracture develops only after the beginning of chest compressions, suggesting that reperfusion may be essential to the development of ischemic contracture. The ischemic myocardial contracture, characterised by progressive thickening of the left ventricular wall with reduction in ventricular cavity size, is a gradually progressive process rather than an all-or-nothing phenomenon and is possibly reversible in the early stage. Thus, ventricular preload is altered and the stroke volume achieved by chest compressions is decreased. Ischemic contracture further reduces coronary perfusion through increasing coronary vascular resistance.

**Metabolic changes.** When cardiac arrest has lasted for approximately 10 minutes, circulating metabolic factors, due to tissue injury from global ischemia and
reperfusion, can cause additional injury beyond the effect of local or focal ischemia. Cellular studies suggest that a marked proportion of cell death may occur in a reperfusion phase rather than during ischemia, and that reperfusion conditions can influence reperfusion injury\(^69\). Mechanisms of reperfusion injury may include at least the release of radical oxygen species, entry of calcium into cells, and inflammation \(^70,71\). An immunological profile resembling that of sepsis, with high levels of circulating cytokines, the presence of endotoxin in plasma, and the dysregulated production of cytokines, have been found in patients admitted to the hospital after OHCA \(^72,73\).

**Implications to CPR.** Since marked changes occur in hemodynamics, metabolism and electrical activity during cardiac arrest and the resuscitation attempt, a time-sensitive approach to the treatment has been proposed \(^71\). This three-phase model, described by Weisfeldt and Becker \(^71\), includes an electrical phase (from the time of cardiac arrest to approximately 4 minutes following arrest), a circulatory phase (4–10 minutes), and a metabolic phase (beyond 10 minutes of arrest). The optimal treatment of a cardiac arrest patient in each of these phases may be different.

**Treatment and outcome**

Studies reported OHCA\(^s\) treated by EMS have a wide range of outcomes. The proportion of primary survivors, i.e. the patients that have achieved ROSC long enough to be admitted to a hospital, vary from 9% to 65% \(^36,34,75\). The proportion of secondary survivors, i.e. patients discharged from hospital alive, however, is lower, 1% to 31% \(^36,34,75\). Wide variation in outcome is attributed to differences in EMS systems and factors of in-hospital treatment of patients admitted to hospital after successful resuscitation from OHCA \(^76\). Variation occurred also in the inclusion criteria of different studies. To make OHCA studies more comparable, the American Heart Association (AHA), the European Resuscitation Council (ERC), the Australian Resuscitation Council, and the Canadian Heart and Stroke foundation published recommendations for reporting in 1991 \(^77\). Well-recognised factors associated with good outcome of OHCA are: witnessed arrest, bystander CPR and VF as initial rhythm, and for VF patients, a short interval between collapse and defibrillation \(^32\).

The current approach in treatment of cardiac arrest is divided into basic life support (including non-invasive airway management, artificial respirations, chest compressions, and defibrillation) and advanced life support (including invasive airway management, intravenous fluids and drugs, and treatments targeted to the cause of cardiac arrest) \(^78\). The value of chest compressions and ventilations has been well demonstrated: when these interventions are started within four minutes after collapse, the likelihood of survival to hospital discharge doubles \(^79\). The bystander CPR is also strongly associated with health-related quality of life of the survivors \(^80\). These interventions appear to be highly effective even when performed by an untrained bystander guided by an emergency medical dispatcher \(^81\). Defibrillation is definitive treatment for VF or pulseless VT and its effectiveness is highly time-sensitive. Improved secondary survival rates have been demonstrated in out-of-
hospital settings after early defibrillation by both lay and professional responders. Rapid defibrillation is also highly effective in in-hospital settings though the evidence is not as abundant as in out-of-hospital settings. In contrast to the basic life support interventions, an incremental benefit of advanced life support for patients suffering OHCA is unestablished. Generally, the outcome after OHCA has not improved in the last few decades. Rapid defibrillation programmes, however, have improved the outcome of a relatively small proportion of patients. The patients with VF as an initial rhythm who collapse at a site with a public access defibrillation (PAD) programme showed a rate of survival to hospital discharge of over 50%. Moreover, long-term survival of promptly defibrillated patients is comparable to that of controls patients whose hearts have not arrested, and the quality of life among the majority of survivors is similar to that of the general population.

2.2. In-hospital cardiac arrest

Unlike patients suffering an OHCA, most patients receiving a resuscitation attempt in hospitals have asystole or pulseless electrical activity (PEA) as the initial rhythm, and their cardiac arrest is not sudden. PEA is a brief and common phase in clinical death from any of a variety of tissue hypoxic/anoxic insults and it occurs before decay to asystole but after loss of consciousness, ventilatory drive, and circulation. The aetiology and pathophysiological mechanisms of cardiac arrest of those patients who receive a resuscitation attempt in the hospital are not well documented. The causes of arrest on general wards, however, appear to be mostly respiratory, metabolic or multiple, and only in minority of cases cardiac origin.

Soon after introducing closed chest cardiac massage and external defibrillation in 1950s, results of CPR were excellent with a survival rate of 70% in one of the first case series. CPR was, however, performed only on monitored patients, e.g. in operating and recovery rooms. Subsequently, resuscitation has been attempted on a noticeable proportion, up to 44%, of all patients having cardiac arrest in hospitals and outcome of IHCA is currently lower than in the 1960s. In the largest outcome after IHCA report, by the National Registry of Cardiopulmonary Resuscitation (NRCPR), of 14,720 patients receiving a resuscitation attempt in 207 hospitals only 17% survived to hospital discharge. Most other studies showed an outcome comparable to NRCPR data. Of the recent studies, Sahlgrenska Hospital in Gothenburg, Sweden reported the best outcome, with a discharge rate of 38%. In that study, a remarkably high proportion (51%) of the patients receiving a resuscitation attempt had VF/VT as the initial rhythm and the interval from collapse to first defibrillation was short.
2.2.1. Signs and symptoms prior to in-hospital cardiac arrest

Prior to IHCA, up to 84% of patients have physiological deteriorations that are detected and documented by medical and nursing staff. Similar observations occur in regard to patients undergoing unplanned admission to an intensive care unit (ICU). The frequency of individual symptoms or abnormal vital signs varies between hospitals and studies. In the largest prospective study performed in 90 hospitals in the UK, Australia, and New Zealand, including 638 events comprised of IHCA, deaths, and unplanned ICU admissions, 79.4% of patients suffering a cardiac arrest had documented abnormal physiology before the event and the most common antecedents were hypotension and fall of the level of consciousness. In all these studies only measured and documented vital signs were included, and thus the actual prevalence of pre-arrest signs is most certainly higher. Of the patients suffering an IHCA, those with prior documented abnormal vital signs have a less favourable outcome.

Two prospective studies have been performed to evaluate the predictive value of selected clinical observations and their association to mortality. In a study by Goldhill and co-workers, from UK, data on vital signs of 433 in-patients were collected on a single morning and the primary endpoint was 30-day mortality. A study by Buist and co-workers from Australia, used a similar kind of method, but included over 6,300 patients during a 33-week-period and the endpoint was in-hospital mortality. The values of vital signs defined as normal varied between these studies, for example a respiratory rate of 6–30 min⁻¹ was defined as normal in the study by Buist and co-workers whereas 10–19 min⁻¹ was normal in the Goldhill study. Both studies found that simple physiological observations, including consciousness, heart rate, systolic blood pressure, respiratory rate, and oxygen saturation, identify high-risk hospital in-patients. In the study by Buist and co-workers, an abnormality in any of these observations was associated with a 6.8-fold mortality. These observations seem to be sensitive for detection of the patients at risk, since in the study by Goldhill and co-workers, 30-day mortality was only 0.7% in patients with no abnormalities, 4.4% with one, 9.2% with two, and 21.3% with three or more abnormalities.

Often insufficient actions are taken after recognition of abnormalities in vital signs, despite the fact that up to 60% of arrests on general hospital wards have potentially correctable antecedent events, such as hypoxia and hypotension. Many studies have documented very high preventable death rates in hospitals delivering acute care, regardless of the fact that the most important interventions to prevent severe deterioration of a patient may be relatively simple. The discussed reasons for providing suboptimal care for patients deteriorating on the wards include, for example, reduced number and lack of experience of staff, hierarchical medical systems, and increasing specialisation in medicine.
Medical Emergency Team

Various attempts to improve the identification and management of critically ill in-patients have occurred in recent years. Education in identifying and managing a patient who already is, or is in danger of becoming critically ill has been given through an one-day multi-professional ALERT™ course in UK. Another approach is the launching of the concept of MET, or its modifications.

Most hospitals have cardiac arrest teams but these are relatively ineffective and expensive, and cannot answer the problem of preventing the arrests. For example, in the study by Soar and colleagues, all survivors of IHCA were resuscitated by first responders, i.e. ward nurses, before the cardiac arrest team arrived. The concept of MET was first introduced in Liverpool Hospital, Sydney in 1990 to supersede the existing cardiac arrest team. This team was modelled on the principles of the early recognition and rapid response used to manage severe trauma, and it consisted of medical and nursing staff trained in the principles of resuscitation. Hospital staff may call the MET using predefined criteria including specific conditions and abnormalities in vital signs or laboratory tests. After the introduction in Australia, the concept has been adopted elsewhere with minor modifications and with different names, e.g. patient-at-risk team, critical care liaison service, and critical care outreach. In all these models calling the team is based on triggering criteria, and there is emphasis on support for those responsible for patients on the wards in the form of facilitation of early ICU admission, prevention of cardiac arrest, and prevention of unnecessary admissions.

Various scoring systems and trigger criteria have been developed to screen patients at risk of a cardiac arrest or serious deterioration. MET trigger criteria are kept simple in most hospitals, as shown in Table 1, and there is little variation in

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<thead>
<tr>
<th>Airway</th>
<th>Respiratory distress</th>
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<tr>
<td></td>
<td>Threatened airway</td>
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<tr>
<td>Breathing</td>
<td>Respiratory rate &gt; 30 min⁻¹</td>
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<tr>
<td></td>
<td>Respiratory rate &lt; 6 min⁻¹</td>
</tr>
<tr>
<td></td>
<td>SaO₂ &lt; 90% on oxygen</td>
</tr>
<tr>
<td></td>
<td>Difficulty to speak</td>
</tr>
<tr>
<td>Circulation</td>
<td>Systolic blood pressure &lt; 90 mmHg despite treatment</td>
</tr>
<tr>
<td></td>
<td>Pulse rate &gt; 130 min⁻¹</td>
</tr>
<tr>
<td>Neurology</td>
<td>Any unexplained decrease in consciousness</td>
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<td></td>
<td>Agitation or delirium</td>
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<td></td>
<td>Repeated or prolonged seizures</td>
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<tr>
<td>Other</td>
<td>Concern about patient</td>
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<td></td>
<td>Uncontrolled pain</td>
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<td></td>
<td>Failure to respond to treatment</td>
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<td></td>
<td>Unable to obtain prompt assistance</td>
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</table>

Table 1. The trigger criteria for Medical Emergency Team (MET) by Buist et al.²⁵
triggering limits \textsuperscript{24,25,28,108,116,120,121}. In addition to objective vital sign values, most criteria contain the criteria ‘staff member is worried about patient’. Scoring systems like the Modified Early Warning Score \textsuperscript{122}, the Patient-At-Risk Team protocol \textsuperscript{117}, and Critical Care Outreach Team scoring system \textsuperscript{119} would also allow use of a tiered response \textsuperscript{22}. The sensitivity and specificity of the Modified Early Warning Score to screen patients who will suffer a cardiac arrest or need ICU admission has been validated within patients admitted to a district general hospital through the emergency department \textsuperscript{123}.

Several studies on the effect of MET on in-hospital mortality and IHCA rate have been published (Table 2), but most include historical control groups \textsuperscript{24-28,121} and only one is randomised \textsuperscript{124}. The results of before-and-after studies mostly favour the MET. For example, in a study by Bellomo and colleagues \textsuperscript{24}, performed in a major teaching hospital, introducing MET was associated with a 65% reduction in cardiac arrests and a 26% reduction in the overall hospital death rate, equivalent to three lives per 1,000 admissions. Conversely, the recently published cluster-randomised trial, including over 125,000 patients in 23 hospitals, did not find a difference between MET hospitals and control hospitals in composite primary outcome (including cardiac arrest, unexpected death, or unplanned ICU admission) \textsuperscript{124}. The implementation of MET, however, was not fully successful in the intervention hospitals, since it was, called to only 30% of patients fulfilling the calling criteria and who were subsequently admitted to the ICU. On the other hand, in the control hospitals, about half of the cardiac arrest team calls were not associated with a cardiac arrest or death. According to the authors the MET calling rate could have been raised by a sophisticated, broad-based, and continued educational approach using academic detailing, educationally influential opinion leaders, or timely reminders \textsuperscript{124}.

Introduction of MET is claimed to be associated with heavy workload of the team. A study by Kenward and colleagues \textsuperscript{121} showed that the number of MET calls in a 700-bed general hospital during one year was 136. Higher rates, however, have been reported in a tertiary referral centre: 800 calls in a year in a 580-bed hospital \textsuperscript{120}. Variation in call volume may be partly caused by differences in calling criteria and also by adherence of the staff to the calling criteria. Furthermore, often only simple interventions are required to reverse deterioration \textsuperscript{24,121}.

The MET system also provides an opportunity to identify patients for whom a “do not attempt resuscitation” (DNAR) order should be considered \textsuperscript{130,121}. In a study by Kenward and colleagues \textsuperscript{122} a DNAR decision was made for 25% of the patients seen by MET. MET responses can also be used to detect medical error and to identify and modify processes of care that underlie those errors \textsuperscript{125}.

**“Do not attempt resuscitation” orders**

When modern CPR was introduced, it was designed to rescue patients experiencing a SCA due to arrhythmia \textsuperscript{126}. At first, CPR was provided only in a few hospital areas
Table 2. Studies on the effects of medical emergency team (MET) on the rate of cardiac arrests and deaths in hospitals.

<table>
<thead>
<tr>
<th>Author and year</th>
<th>Country</th>
<th>Setting</th>
<th>Design</th>
<th>Admissions or patients</th>
<th>Cardiac arrests / 1000 admissions</th>
<th>Deaths / 1000 admissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bristow et al. 2000</td>
<td>Australia</td>
<td>One hospitals with MET and two with cardiac arrest team</td>
<td>Cohort comparison after casemix adjustment</td>
<td>50,942</td>
<td>5.1</td>
<td>3.3*</td>
</tr>
<tr>
<td>Buist et al. 2002</td>
<td>Australia</td>
<td>One university hospital</td>
<td>Prospective before-and-after</td>
<td>42,164</td>
<td>3.77</td>
<td>2.05*</td>
</tr>
<tr>
<td>Bellomo et al. 2003</td>
<td>Australia</td>
<td>One university hospital</td>
<td>Prospective before-and-after</td>
<td>42,011</td>
<td>3.0</td>
<td>1.1*</td>
</tr>
<tr>
<td>Kenward et al. 2004</td>
<td>UK</td>
<td>One district general hospital</td>
<td>Prospective with historical control group</td>
<td>107,000</td>
<td>2.6</td>
<td>2.4</td>
</tr>
<tr>
<td>Bellomo et al. 2004</td>
<td>Australia</td>
<td>One university hospital</td>
<td>Prospective before-and-after (major surgery)</td>
<td>2,183</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DeVita et al. 2004</td>
<td>USA</td>
<td>Three contiguous hospitals</td>
<td>Retrospective, before and after calling criteria</td>
<td>199,024</td>
<td>6.5</td>
<td>5.4*</td>
</tr>
<tr>
<td>Hilmann et al. 2005</td>
<td>Australia</td>
<td>24 hospitals of different levels</td>
<td>Cluster-randomised controlled trial</td>
<td>125,000</td>
<td>Baseline: 2.6</td>
<td>Study: 1.6†</td>
</tr>
</tbody>
</table>

*Statistically significant difference between with and without MET
†Statistically significant difference between baseline and study
In death rate in trial by Hilmann et al. patients with pre-existing not for resuscitation order were excluded.
with defibrillators and skilled personnel, and the outcome of CPR was very good with a discharge rate as high as 70%. Since CPR is more widely used nowadays and targeted to the patients suffering cardiac arrest from several causes, the survival rate is clearly lower. CPR should, as any traumatic medical intervention, not be undertaken if the outcome is predictable and very poor, however. To target resuscitation efforts to the patients with a realistic chance of a life of reasonable length and quality, and to withhold futile resuscitation attempts of patients who are dying or do not wish to be resuscitated, DNAR policy has been instituted in many hospitals. The formerly used term “do not resuscitate” did not clearly describe the limited chance of survival.

Patients having a DNAR-order are typically older and with poorer functional capacity. The use of DNAR-orders is variable and the studies show that also reasons other than medical futility affect the decisions to withhold CPR. For example, the study by Goodlin and co-workers showed marked variation in the use of CPR among hospitals as well as patients with different diagnoses, race, sex, and age. Although association of certain patient characteristics, co-morbid condition and arrest variables with low discharge rate has been documented, none of the scoring systems developed to help in decision-making on resuscitation have been validated in a large general in-hospital population.

Most Finnish hospitals (91%) have a DNAR policy. In a study performed in four secondary hospitals in Finland, 85% of patients dying without resuscitation being initiated had a DNAR order made prior to the cardiac arrest. The Finnish national resuscitation guidelines include recommendation that resuscitation should not be initiated if the patient is not expected to benefit from it, and that DNAR orders should be clearly documented in patient charts and communicated to the staff responsible for the care of the patient. These guidelines do not give recommendation to the decision-making process, unlike, for example, guidelines in the UK.

## 2.3. Defibrillation

Although the exact electrophysiological mechanism is still not completely understood, electrical defibrillation of VF has been used for several decades. VF is produced by irregular, self-sustained propagation of electric activation wave fronts through the heart ventricle. The wave front will propagate into recovered excitable cardiac tissue. If enough current is delivered through the chest during VF, a majority of ventricular cells will be depolarised. When cardiomyocytes are depolarised, they are unexcitable during the refractory period, which prevents continuation re-entry of wave fronts and thus VF is terminated.
Table 3. Factors affecting transmyocardial current and thus the success of a defibrillation attempt.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Ref. No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strength of shock</td>
<td>2</td>
</tr>
<tr>
<td>Transthoracic impedance</td>
<td></td>
</tr>
<tr>
<td>Phase of respiration</td>
<td>143</td>
</tr>
<tr>
<td>Chest size</td>
<td>150, 151</td>
</tr>
<tr>
<td>Number and strength of previous shocks</td>
<td>150</td>
</tr>
<tr>
<td>Electrode-skin interface</td>
<td></td>
</tr>
<tr>
<td>Electrode size and design</td>
<td>143, 150, 153, 144</td>
</tr>
<tr>
<td>Conductive gel application</td>
<td>144</td>
</tr>
<tr>
<td>Pressure on electrodes</td>
<td>157–160</td>
</tr>
<tr>
<td>Evaporation of defibrillation pads</td>
<td>156</td>
</tr>
<tr>
<td>Orientation of paddles</td>
<td>155</td>
</tr>
<tr>
<td>Chest hairs</td>
<td>159–160</td>
</tr>
<tr>
<td>Fraction of transmyocardial current</td>
<td></td>
</tr>
<tr>
<td>Electrode size</td>
<td>143</td>
</tr>
<tr>
<td>Electrode placement</td>
<td>144, 145</td>
</tr>
</tbody>
</table>

Determinants of success of defibrillation attempt

Termination of VF depends on transmyocardial current density sufficient to depolarise simultaneously a critical mass of the ventricle tissue \(^{138,139}\). Some of the clinically observed defibrillation failures, however, may not be due to shock inability to terminate the re-entry but awoken focal activity of the ventricle immediately after the shock, especially with shock strengths near to the defibrillation threshold \(^{140}\). The transmyocardial current represents only a relatively small proportion of the transthoracic current, approximately 4% \(^{141,142}\). The rest of the electric current goes through parallel pathways, i.e. thoracic cage and lungs, which shunt current from the heart. The transthoracic current is proportional to the energy output of the defibrillator and inversely proportional to transthoracic impedance \(^{2}\). The overview of factors affecting the transmyocardial current is shown in Table 3.

The ratio of transmyocardial current to transthoracic current is decreased if very large electrodes are used \(^{143}\) or the electrodes are placed inadequately \(^{144,145}\). The current is shunted from the heart by low impedance pathways along the chest wall, when electrodes are placed too closely \(^{144}\). Also incorrect application of conductive gel between electrodes may provide a low impedance pathway \(^{144}\). Clinical trials show that electrode position is an important determinant of the success of cardioversion for atrial fibrillation \(^{146–148}\). The optimal placement of electrodes, however, differs for electrical cardioversion of atrial fibrillation and for defibrillation of VF \(^{147}\). In comparison to older guidelines, the Guidelines 2000 recommend a more lateral placement of the apical electrode, “to the left of the nipple with centre of the electrode in the mid-axillary line” \(^{78}\).

At a fixed level of energy, the current delivered to the patient is dependent on the transthoracic impedance \(^{2,143,149}\), which depends on many aspects (Table 3). The transthoracic impedance varies depending on the chest size \(^{150,151}\), more than on the
body weight. Also the size of defibrillation electrodes significantly affect the transthoracic impedance, e.g., electrodes of 13 cm in diameter reduce the transthoracic impedance by 21% when compared with 8.5 cm electrodes. Too large electrodes, however, decrease the current density of the heart. Factors other than size, in the design of the electrodes, also affect the transthoracic impedance. If paddles are used for defibrillation the transthoracic impedance can be reduced by placing the rectangular paddle in apical position longitudinally rather than transversally, by applying conductive gel between the paddle and the skin or using non-evaporated conductive pads, and by applying sufficient pressure to the paddles. When using either paddles or self-adhesive electrodes shaving of the hirsute chest also decreases the transthoracic impedance. Other factors affecting the transthoracic impedance include phase of respiration as well as number, strength, and time interval of repeated shocks. There is no difference in the transthoracic impedance between self-adhesive electrodes and paddles used with gel pads. The waveform of the defibrillation shock has an effect on defibrillation success. In a meta-analysis of seven studies including 1129 patients, a 200 J biphasic shock reduced the risk of post-first shock asystole or persistent VF by 81% compared with a 200 J monophasic shock. All those studies were, however, performed in patients who underwent electrophysiological procedures or implantable defibrillator testing, and thus, had minimal delay from onset of VF to defibrillation. A randomised multi-centre study comparing 150 J biphasic shocks with 200 to 360 J monophasic shocks in OHCA has shown superior defibrillation, higher survival to hospital admission, and better neurological function at discharge with application of biphasic waveform. Another randomised study demonstrated greater efficacy of the first shock by biphasic waveform in comparison with the monophasic waveform in OHCA. At present, no certain evidence exists of clinical superiority of one type of biphasic waveform over another.

The defibrillation threshold is increased when the duration of VF is more than 30 to 60 seconds, possibly through intracellular accumulation of potassium, and usage of antiarrhythmic drugs such as lidocaine. Catecholamines, on the other hand, are known to decrease the defibrillation threshold.

Even if defibrillation successfully terminates the VF, spontaneous circulation does not always return. In fact, post-defibrillation asystole or PEA occurs in up to 60% of patients with out-of-hospital VF. Immediately after onset of VF a defibrillation shock, in a great majority of cases, restores circulation. Animal studies clearly demonstrated, however, after a few minutes of untreated VF defibrillation most often results in PEA or asystole, but chest compressions and adrenaline, given before defibrillation, increase the likelihood of the ROSC. A decrease in probability of defibrillation success over time has also been shown in humans. Until 1980, resuscitation guidelines recommended artificial breathing and chest compressions to be given prior to defibrillation. The guidelines published in 1980, however, recommended immediate performance of defibrillation if the duration of untreated VF is less than two minutes and in guidelines from 1986 until present,
immediately when a defibrillator is available regardless of the duration of VF. Despite demonstration of the fact that the time interval from the beginning of VF to the first defibrillation attempt is the most important factor associated with survival of cardiac arrest patient, delaying defibrillation and priming the heart by chest compressions, artificial ventilations, and possibly vasopressors may lead to a better outcome in the cases of prolonged VF. Cobb and co-workers reported that implementation of a pre-hospital protocol, including three minutes of basic CPR before defibrillation, improved outcome of patients who had an EMS response interval longer than four minutes. In the patients who had a shorter than four minutes EMS response interval no observation of change in outcome occurred. Wik and colleagues carried out a randomised trial comparing immediate defibrillation and three minutes of basic CPR before defibrillation. In this study, which included 200 patients, the patients with a response interval longer than five minutes had a better outcome (discharge rate 22% vs. 4%) if they received basic CPR before defibrillation. The exact duration of VF after which chest compressions before defibrillation is needed is unknown. Use of an advanced analysis of VF morphology to optimise the timing of defibrillation is currently actively studied.

Rapid defibrillation out of hospital

Since performance of defibrillation within the first few minutes of VF often leads to ROSC, much attention has been paid to the rapid defibrillation of OHCA victims. Efficacy of defibrillation by ambulance personnel is well established. Efficiently delegating defibrillation to professional responders without health care education, e.g. firefighters and police officers, after only minimal training is possible due to development of AEDs. Not all studies show additional benefit gained by the use of untraditional first responders, however, in these studies, the dispatching of and response by police have been partially suboptimal or the studies were not powered to detect a survival difference.

Also laypersons, e.g. flight attendants and casino personnel, working in locations with at least a moderate risk of a cardiac arrest among the customers or delayed access by EMS, have been trained in PAD programmes. In Las Vegas casinos, where security personnel are trained in the use of an AED, a survival rate of 53% to hospital discharge is reported among 90 patients having experienced witnessed collapse and VF as initial rhythm. In that study, the mean interval from collapse to first defibrillation was 4.4 minutes, and of the patients defibrillated during the three first minutes after collapse, even 74% survived to hospital discharge compared to 49% of those defibrillated after a longer interval. The Public Access Defibrillation Trial, conducted in USA and Canada in 2000 to 2003, was the first large scale randomised trial of PAD involving more than 19 000 volunteer responders from 993 community units, e.g. shopping malls and recreational facilities, randomised to CPR training with or without use of an AED. This study demonstrated that in public locations, implementing an organised emergency-response plan with training and equipping volunteers to provide early defibrillation
with an AED doubled the number of survivors to hospital discharge after OHCA. In another PAD study that involved 1 285 lay volunteers trained in the use of an AED, but not in traditional basic CPR, the discharge rate of patients with witnessed arrest tripled from the previous rate. Although not easy to evaluate, the cost-effectiveness ratio of PAD programmes seems to be reasonable across a range of public locations. Regarding the experience from Helsinki, the biggest costs in the PAD programme are due to training and administration, whereas the costs due to AEDs represent only 14–16% of the total costs.

The AEDs can be efficiently used even without prior training, as shown in the airports of Chicago, where highly visible defibrillators and clear instructions were deployed to public areas. In the case series, including 21 non-traumatic cardiac arrests, most of the survivors were defibrillated by a user who had no duty to act and no prior training in the use of an AED.

**Rapid defibrillation in hospital**

Similar to the out-of-hospital setting, a strong relationship between delay to defibrillation and outcome of patients in VF has also been demonstrated in hospitals. In-hospital rapid defibrillation programmes, in which members of nursing staff perform defibrillation with an AED before arrival of a physician or cardiac arrest team, have demonstrated their feasibility. At present, large studies evaluating the survival benefit of these programmes are not available. Studies with historical controls show an obvious increase in the discharge rate of patients with VF as the initial rhythm. Improvement of access to defibrillation inside hospitals is encouraged by recommendations and guidelines of many organisations, including Finnish national resuscitation guidelines. The reported actual use of AEDs and rapid defibrillation programmes in hospitals, however, appear to be scarce. In the data from NRCPR, only 1.4% of the patients in VF/VT were defibrillated using an AED. In a Finnish study usage of an AED occurred only once in the in-hospital resuscitation attempts in four secondary hospitals during a one-year period.

Recently a fully automated external cardioverter-defibrillator has become available for in-hospital use. This device monitors the cardiac rhythm continuously and is programmed to defibrillate life-threatening ventricular arrhythmias without human intervention. The study using simulated cardiac arrests showed significant decrease in defibrillation delay compared to normal response, i.e. defibrillation performed by a nurse, when usage of a fully automated external cardioverter-defibrillator occurred in the telemetry-monitored wards. Preliminary clinical experiences with this device have demonstrated high sensitivity and specificity of rhythm recognition without any restrictions of patient movement as well as high success rate of first defibrillation shock. The use of this device, however, is not widespread yet and requires identification of the patients at risk for a cardiac arrest.
2.4. Guidelines on cardiopulmonary resuscitation

Clinical practice guidelines are “systemically developed statements to assist practitioner and patient decisions about appropriate health care for specific clinical circumstances” \(^{20}\). They are developed to decrease inappropriate clinical variation, to cut costs as a result of rationalising health care, and to facilitate the usage of scientific evidence in clinical practice \(^{21}\). Despite wide scale dissemination, guidelines seem to have had limited effect on changing clinical practice \(^{212,213}\). Studies in countries such as the United States and the Netherlands suggest that at least 30% to 40% of patients do not receive care according to current scientific evidence, while 20% or more of the care provided is not needed or is potentially harmful to patients \(^{27}\). Guidelines on CPR are probably the most broadly disseminated and best-known clinical practice guidelines in health care.

Development of resuscitation guidelines

CPR, as known to today, is based on findings discovered in the middle of the 20th century. Elam and colleagues showed that arterial blood gases of a paralysed patient could be maintained at normal levels by mouth-to-mask or mouth-to-tube ventilation \(^{214}\). In the late 1950s, Safar and co-workers \(^{215-217}\) demonstrated the importance of an open airway during a resuscitation attempt and introduced opening of the airway by head tilt and chin lift. In 1947 Gurvich and Yuniev \(^{218}\) found that an electric discharge sent through the chest of a dog would be followed by a resumption of the cardiac function if applied no later than one and half minutes after the onset of induced VF. In 1956 Zoll and colleagues \(^{210}\) reported successful external defibrillation of four patients, of which the only long-term survivor was defibrillated after a considerably shorter delay than non-survivors.

On the base of these research findings, the National Academy of Sciences – National Research Council (NAS–NRC) Conference on CPR in 1966 recommended training of medical, allied health, and other professional personnel in the external chest compression technique according to the standards of AHA \(^{30}\). AHA, NAS–NRC, governmental agencies, professional medical societies, and private groups carried out the implementation of new techniques, through training programmes and materials, publications, recommendations, and evaluations \(^{177}\). After a National Conference on Standards for CPR and Emergency Cardiovascular Care, held in 1973, AHA and NAS–NRC published the second recommendations on CPR, including e.g. extension of CPR training programmes to general public, training on different levels of life support, and standardised performance testing \(^{126}\). Updated standards and guidelines were published by AHA in 1980 \(^{176}\), in 1986 \(^{177}\) and in 1992 \(^{178}\). Additionally, European Resuscitation Council (ERC) published guidelines for CPR in 1992 \(^{179,220}\) and updated these in 1998 \(^{180}\). To make the resuscitation practices uniform world wide, the first international guidelines on CPR, ‘Guidelines 2000’, were published in 2000 by AHA in collaboration with International Liaison Committee on Resuscitation (ILCOR) \(^{78}\). Based on these international guidelines, the
Finnish national resuscitation guidelines were published by the Finnish Medical Society Duodecim in 2002 as a part of the evidence-based CPG series, Current Care 134.

During the evolution of the guidelines on CPR, the majority of changes in recommendations have been relatively small. Tidal volume in ventilation has been reduced, rate of chest compressions has been increased, timing of defibrillation has been made earlier, and pharmacotherapy has been made more uncomplicated. The Guidelines 2000 are the first CPR guidelines in which the level of evidence was evaluated and indicated 78.

Adherence to the guidelines
Regardless of the fact that considerable efforts have been made in the development of resuscitation guidelines and that guidelines in other areas of medicine are poorly adhered to in the clinical practice 29,212, the literature concerning adherence to the resuscitation guidelines is limited. Some previous studies, however, show significant deviations from the guidelines in the practice by caregivers and organisations. The adherence to the resuscitation guidelines in rate and depth of chest compressions, compression interruptions, and ventilations have been studied using a data collection device connected to the defibrillator 221,222, observer 223, video recording 224, and voice and electrocardiogram recording by the AED 225. Table 4 summarises the results of these studies.

In the studies by Wik and colleagues, in a pre-hospital setting, and Abella and colleagues, in a hospital setting, both demonstrated using the same data collection device connected to a defibrillator that the depth of the chest compressions were commonly smaller and the rate of the compressions were higher 221 or lower 222 than recommended. Most interestingly these studies, as well as three others 223-225, showed extremely long periods of interruptions in chest compressions while spontaneous circulation was not present. In a study performed amongst first responders in Amsterdam, the Netherlands, chest compressions were actually performed only for about half of the duration of resuscitation attempts 225. About half of the interruptions were caused by the operation of an AED and the other half were caused by personnel for various reasons 225. As has become evident in the last few years, even short interruptions in chest compressions lead to a cease of coronary perfusion and, especially if occurring just before defibrillation, to a decreased chance of the return of spontaneous circulation 48,226,227. Chiang and colleagues 224 have introduced a simple method to improve guideline adherence during resuscitation. In their relatively small study the rate of chest compressions was higher and interruptions briefer when a tape of metronome bleeps at 100 per minute (for chest compressions) and a siren every 20 seconds (for intubation attempts) was played during resuscitation 224. Wik and Abella also reported ventilation rate, measured by impedance changes over the thorax. In the pre-hospital setting mean ventilation rate during the first five minutes of resuscitation was eight per minute and in hospital setting 21 per minute. It is worthwhile to notice that in the pre-hospital studies, first responders have been
Table 4. Summary of studies including data about adherence to the guidelines in real resuscitation situations.

<table>
<thead>
<tr>
<th>Study</th>
<th>Patients</th>
<th>Providers</th>
<th>Methods</th>
<th>Main findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abella et al. 2005&lt;sup&gt;221&lt;/sup&gt;</td>
<td>67 IHCA</td>
<td>Hospital staff</td>
<td>Prospective data collection using defibrillator with data collection device</td>
<td>No-flow time 24%, 24% of compressions too slow, 36% of compressions too shallow, ventilation rate in 8% &lt; 10 min&lt;sup&gt;-1&lt;/sup&gt; and in 59% &gt; 20 min&lt;sup&gt;-1&lt;/sup&gt;</td>
</tr>
<tr>
<td>Wik et al. 2005&lt;sup&gt;222&lt;/sup&gt;</td>
<td>176 OHCA</td>
<td>Paramedics and nurse anaesthetists</td>
<td>Prospective data collection using defibrillator with data collection device</td>
<td>No-flow time 48%, mean chest compression rate 121 min&lt;sup&gt;-1&lt;/sup&gt;, 62% of compressions too shallow, mean ventilation rate 11 min&lt;sup&gt;-1&lt;/sup&gt;</td>
</tr>
<tr>
<td>Abella et al. 2005&lt;sup&gt;223&lt;/sup&gt;</td>
<td>97 IHCA</td>
<td>Hospital staff</td>
<td>Prospective data collection by observer</td>
<td>37% of chest compressions by rate &lt; 80 min&lt;sup&gt;-1&lt;/sup&gt; and 22% &lt; 70 min&lt;sup&gt;-1&lt;/sup&gt;, better outcome with higher compression rates</td>
</tr>
<tr>
<td>Van Alem et al. 2003&lt;sup&gt;225&lt;/sup&gt;</td>
<td>184 OHCA</td>
<td>First responders (police and fire)</td>
<td>Prospective ECG and voice recording by an AED</td>
<td>No-flow time 63% with shockable rhythm and 46% with non-shockable rhythm</td>
</tr>
<tr>
<td>Chiang et al. 2005&lt;sup&gt;224&lt;/sup&gt;</td>
<td>30 OHCA in emergency department</td>
<td>Hospital staff</td>
<td>Videotape analysis, intervention group resuscitated during audio prompts (metronome)</td>
<td>No-flow time 28% without and 21% with metronome</td>
</tr>
</tbody>
</table>

AED = automated external defibrillator  
IHCA = in-hospital cardiac arrest  
OHCA = out-of-hospital cardiac arrest
adequately and frequently trained in the use of an AED and the ambulance personnel in advanced cardiac life support \(^{222,225}\). Since it is well documented that basic skills in resuscitation deteriorate in a few months without regular retraining \(^{228-230}\), the performance in real life can deviate even further from the guidelines. The CPR providers in the Abella and Wik studies, have also been aware of data collection \(^{221,222}\) and this could have improved the performance.

In an observational study by Heames and colleagues \(^{211}\), only a quarter of physicians tend to place defibrillation electrodes within five centimetres from the recommended positions on the manikin, the apical electrode was generally placed too medial. The study was performed before publication of Guidelines 2000, which specify an even more lateral placement of the apical electrode compared with older guidelines \(^{78}\).

The Guidelines 2000 introduced amiodarone for primary antiarrhythmic and vasopressin for alternative vasopressor, both new drugs to the resuscitation algorithms \(^{78}\). The NRCPR data from 2000 to 2002 showed that lidocaine was used almost twice as often as amiodarone in the treatment of in-hospital VF/VT arrest and vasopressin accounted for only 3% of vasopressor use \(^{91}\). Johansson colleagues \(^{232}\) reviewed the administration interval of adrenaline in resuscitation situations from charts of 53 patients and found that in 68% of the cases the average between-dose interval was longer than recommended in the guidelines, 3–5 minutes, and 8% of the patients received no adrenaline.

An advisory statement of ILCOR recommends induced hypothermia after resuscitation from cardiac arrest due to VF, and possibly other rhythms as well \(^{233}\). Abella et al. \(^{234}\) have performed a survey about the use of this treatment by specialists in emergency medicine, cardiology, and intensive care medicine. The questionnaire study revealed that physicians had not broadly adopted the use of hypothermia, 87% of the respondents did not use it, mainly because they felt that there was not enough data to support the treatment \(^{234}\).

### 2.5. Resuscitation training

Many studies have clearly demonstrated that retention of resuscitation skills by laypersons and medical professionals is generally poor even shortly after training \(^{230,235-238}\). Additionally, resuscitation guidelines are updated frequently, which increase the need for retraining. In the last ten years, increasing attention has been paid to the disappointing results of training and training methods have been critised \(^{239,240}\). In 2003, ILCOR published an advisory statement on education in resuscitation, emphasizing e.g. concentration on life-saving core skills, facilitating instead of training, scenario-based teaching, and, training, for health care professionals, in crisis resource management and communication \(^{241}\).

To save resources and improve learning results, resuscitation training and retraining for both laypersons and health care professionals have been given using new
methods including for example peer-training\textsuperscript{242}, video self-instruction\textsuperscript{243}, computer programmes\textsuperscript{244,245}, and high-fidelity simulation\textsuperscript{246}. Effectiveness of any of these methods, however, has not been well established in resuscitation training. In other fields of medicine numerous interventions are used in practical implementation of guidelines\textsuperscript{29}. The evidence of their effectiveness is mostly mixed and is not necessarily applicable to implementation of resuscitation guidelines.
3. AIMS OF THE STUDY

The aim of the present thesis was to study improvement possibilities of the response to cardiac arrest in Finland through early defibrillation, early recognition of vital sign abnormalities prior to in-hospital cardiac arrest, and national resuscitation guidelines. The specific objectives are outlined as follows:

1) To describe the adherence of health care professionals and laypersons to the resuscitation guidelines, especially when positioning defibrillation electrodes (I–II).

2) To compare performance of laypersons and health care professionals as public access defibrillation instructors after similar eight hours instructor training (III).

3) To estimate the prevalence of abnormal vital signs prior to in-hospital cardiac arrest and to survey the current response strategies of Finnish hospitals to these (IV, VI).

4) To describe the current status of rapid defibrillation programmes in hospitals and health centres as well as changes of in-hospital resuscitation strategies after publication of national resuscitation guidelines in Finland (V–VI).
4. MATERIALS AND METHODS

The aims and designs of the six studies of the present thesis are briefly described in Table 5.

4.1. Finnish national resuscitation guidelines

The Finnish national guidelines on CPR were published in the series of clinical practice guidelines, Current Care. These evidence-based guidelines in various fields of medicine are published by the Finnish Medical Society Duodecim in collaboration with the national medical specialist societies, at the present (in 2005) there are a total of 53 guidelines in the series. The guidelines are published in the journal of the Finnish Medical Society Duodecim that is mailed to every member of the society, i.e. 80% of physicians in Finland. Additionally, the guidelines are available free of charge through the Internet portal of this society.

Table 5. Brief description of individual studies comprising the present thesis.

<table>
<thead>
<tr>
<th>Study</th>
<th>Study aim</th>
<th>Design</th>
<th>Setting or participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study I</td>
<td>To determine to what extent health care professionals adhere to the new guidelines when positioning the defibrillation leads</td>
<td>Observational study</td>
<td>136 physicians, nurses and EMTs from hospitals and EMS</td>
</tr>
<tr>
<td>Study II</td>
<td>To evaluate the pictures on the self-adhesive defibrillation electrodes in guiding laypersons to place the electrodes as recommended</td>
<td>Randomised controlled trial</td>
<td>150 laypersons placing six different electrodes</td>
</tr>
<tr>
<td>Study III</td>
<td>To compare effectiveness of health care professionals and trained laypersons as instructor in BLS using AED</td>
<td>Controlled trial, OSCE</td>
<td>Four health care providers and four trained laypersons training 38 lay volunteers</td>
</tr>
<tr>
<td>Study IV</td>
<td>To evaluate the effectiveness of observation practice in Finnish hospitals to detect abnormalities in vital signs prior to CA</td>
<td>Retrospective chart review</td>
<td>Patients with resuscitation attempt during 18 months in four hospitals</td>
</tr>
<tr>
<td>Study V</td>
<td>To describe the present status of resuscitation strategies and training in Finnish health centres</td>
<td>Cross-sectional mail survey</td>
<td>All public Finnish health centres</td>
</tr>
<tr>
<td>Study VI</td>
<td>To describe effects of national resuscitation guidelines to in-hospital resuscitation strategies in Finnish hospitals</td>
<td>Cross-sectional mail survey</td>
<td>All public Finnish hospitals</td>
</tr>
</tbody>
</table>

CA = cardiac arrest, EMT = emergency medical technician, EMS = emergency medical services, BLS = basic life support, AED = automated external defibrillator, OSCE = objective structured clinical examination
The national guidelines published in 2002 are based on international Guidelines 2000 and the main recommendations concerning the organisation of cardiac arrest management are as follows:

- Rapid defibrillation should be encouraged in institutional settings. Defibrillation, in case of VF/VT, should be performed within three minutes from the arrest and defibrillation should be included in duties and in resuscitation training of all nursing and medical staff. Defibrillation training should also be made available for staff other than medical or nursing, e.g. personnel in hospital reception and cafeterias.

- Amiodarone is the primary drug used for prolonged or recurrent VF or pulseless VT. Lidocaine can be used if amiodarone is unavailable.

- Data collection and quality assurance of cardiac arrest management should be performed. A special form for data collection of resuscitation attempts, including sufficient data for uniform Utstein style reporting, should be used. A physician or nurse responsible for the co-ordination of resuscitation activities should collect the resuscitation forms and analyse the resuscitation performance annually using definitions of the Utstein reporting style for IHCAs and OHCAs.

- DNAR orders should be indicated clearly in the patient’s records and staff responsible for the patients care should be informed.

In order to facilitate the implementation of the guidelines, the Finnish Medical Society Duodecim also produced an educational video in Finnish about the use of an AED.

### 4.2. Studies on placement of defibrillation electrodes (I–II)

The practices of health care professionals in placement of defibrillation electrodes (I) and ability of laypersons to place defibrillation electrodes as recommended in guidance on pictorial instructions (II) were tested in observational studies with similar methods. The study involving health care professionals (I) took place 14 months after the publication of national guidelines on CPR.

#### Participants

A total of 136 health care professionals, whose duties included performing defibrillation in resuscitation situations, participated in Study I. Without prior notification the participants were recruited from three units of the university hospital, both from the wards and from the emergency rooms, from one primary hospital, and one health centre providing primary care as well as from two testing situations for
basic life support (BLS) providers of EMS. All personnel on duty on site at the moment of performing the study were recruited.

The laypersons for Study II were recruited from participants of Red Cross first aid courses and from military service men of The Finnish Defence Forces. The participants had to fulfill the following criteria: (a) voluntary participation, (b) age over 16, (c) no previous education in health care, (d) no training in the use of a defibrillator, and (e) no previous experience in using a defibrillator.

**Study protocol**

In the test situation, a single participant entered a room where a resuscitation training manikin (ResusciAnne®, Laerdal Medical Corporation, NY, USA) was lying on the floor. The participants were told about the life-saving nature of defibrillation and asked to rapidly attach the electrodes to the manikin. After which, the positions of the electrodes were measured. The distance from the superior edge of the sternal electrode to clavicle and from the medial edge to sternum was measured. The distance from the superior edge of the apical electrode to the axilla and from the centre of the apical electrode to the predetermined fixed point in the mid-axillary line were measured. All measurements were made with an accuracy of 0.5 centimetres. Correct placement was defined as both electrodes within five centimetres, equal to the average radius of an average self-adhesive defibrillation electrode, from the recommended position. Special attention was paid to ensure that the participants did not discuss the test performance with each other.

**Defibrillation electrodes**

In Study I, participants attached self-adhesive training electrodes (AED training pads, Laerdal Medical Corporation, NY, USA), with pictorial instructions of recommended placement hidden, on a manikin.

In Study II, included the electrodes of five commonly used AEDs. The most uncomplicated and suitable model for PAD was selected from each manufacturer. The included electrodes were:

1. Heartstart Pads (Philips Medical Systems, WA, USA) for HeartStart HS1 First Aid Defibrillator (Laerdal Medical Corporation, NY, USA)
2. Access CardioPads for Access AED (Access Cardiac Systems, MA, USA)
3. QUIK-PAK for Lifepak CR Plus (Medtronic, Inc, WA, USA)
4. Defibrillation/Pace Pads for Fred Easy (Schiller AG, Baar, Switzerland)
5. Defibrillation electrodes for FirstSave AED G3 (Cardiac Science, Inc, CA, USA)

The pictures of the electrodes are shown in Study II, Figure 1A-E. To test our hypothesis concerning the advantage of the lateral view picture to indicate the placement of the apical electrode, a pair of pictures representing the placement of the
sternal electrode in an anterior and the apical electrode in a lateral view was drawn (Study II, Figure 1F). The pictures were added onto training electrodes (AED training pads, Laerdal Medical Corporation, NY, USA). The electrodes given to the laypersons in the test situation were selected according to shuffle-randomized list.

4.3. Public access defibrillation instructor study (III)

Participants
Both the instructors and the study subjects were selected from among employees from several organizations, department stores and large companies with hundreds of employees, with plans to implement a PAD programme. Informed consent was obtained from all participants. No information about the Objective Structured Clinical Examination (OSCE) beyond the initial training was given. All subjects had prior BLS training but no experience with an AED.

Red Cross volunteer first aid personnel were used as a reference group. They had training sessions twice monthly after their basic first aid course, completed approximately two years ago, in addition to 20 h of training in first aid services at mass gatherings. The same instructor trained this group simultaneously with the study instructors group in BLS including defibrillation using an AED (AED-BLS).

Study protocol
The overview of the protocol of Study III is shown in Figure 1.

Training. The training was provided according to the AED-BLS programme, originally developed by European Resuscitation Council and thereafter adopted by the Finnish Resuscitation Council. The training programme has been shown to be effective in terms of achieving sufficient skills in rapid and safe defibrillation by laypersons. Eight instructors, including four laypersons and four health care professionals, were given a four-hour AED-BLS course by the same instructor, who was a nurse and trainer with 20 years experience in training at the Finnish Red Cross. They all received the 38-page booklet “CPR and defibrillation using an automated external defibrillator.” Two weeks later they were given a four-hour AED-BLS instructor course.

The newly trained instructors then trained a total of 38 lay volunteers (19 pairs) with no previous experience in the use of a defibrillator. Of the 19 pairs, nine were trained by health care providers and 10 by laypersons. As the training programme demands, all had previous training in BLS, (external chest compressions and ventilation). These skills were monitored during the training.

Lay volunteers were instructed to recognize the absence of consciousness, the absence of breathing, and the absence of signs of circulation. If all three were noted,
they were instructed to turn on an AED, attach it and follow the voice instructions. They were also trained to use a mouth-to-mask device (Laerdal Pocket Mask, Laerdal Medical Corporation, NY, USA) for ventilation. No specific instruction for external chest compressions and ventilation was provided.

The AED used was the AED Trainer (Laerdal Medical Corporation, NY, USA) with self-adhesive defibrillation pads with a cable and an AED-connector. It was used in two different scenario-based training modes. The first scenario was a patient in VF, and the second was a patient in asystole.

**Objective Structured Clinical Examination (OSCE).** The skills of the trained laypersons in AED-BLS were tested using Objective Structured Clinical Examination (OSCE). The OSCE, introduced by Harden and Gleeson \(^{250}\), has proven to be a valid and reliable method to test the practical skills of students \(^{248}\). In the OSCE, an identical task performed by all students in a fixed time is evaluated using a checklist.

The OSCE setting used in the study comprised two scenarios, and the test took place 2–3 weeks after the initial training. The subjects were tested in pairs, each pair alone. Just before the OSCE, they were informed that they would be evaluated during the performance. Each pair had two minutes to read the instructions at the examination
station before proceeding with their AED to the testing room, where they had five minutes at the station. The time was chosen to simulate an actual situation in Helsinki, where professional help arrives quickly. The manikin and two observers were present inside the room. All pairs participated in two scenarios; thus, the total number of performances evaluated was 38. In scenario 1, a lifeless person, a manikin, in simulated VF was lying on the floor when the pair entered the room. In scenario 2, the pair was informed that the manikin sitting in a chair was gasping for air, which an asystole as initial simulated rhythm.

The pair was asked to change roles between the stations: one was in charge of ventilation and the other of external chest compression and defibrillation.

The assessors, blinded to the identity of the trainers, were both anaesthesiologists and clinical teachers with 3–10 years experience. A third person in the room served as the eyewitness and recorded the time. A skills checklist was used to grade each pair (Study III, Appendix A). A total of 49 points was possible in each of the scenarios. The steps evaluated included recognition of unresponsiveness and possible cardiac arrest, calling for help, moving the patient to an open place, opening the airway, electrode pad positioning, the time from activation of the device to initial AED analysis, using the AED and delivering a shock safely when needed, using a ventilation device, delivering technically correct compressions and inflations with the correct frequency and sequence, and reporting the event to professionals arriving at the scene. As a reference, the lay members of the Red Cross first aid personnel were tested in a similar fashion in scenario 1.

4.4. Chart review (IV)

The charts of patients who suffered a cardiac arrest during an 18 months, December 2001 to May 2003, in four Finnish hospitals, a tertiary teaching hospital, a tertiary trauma centre and two secondary general hospitals, were reviewed. In the secondary hospitals and the tertiary trauma centre, the resuscitation attempts in the hospital are managed by an established resuscitation team, and a resuscitation officer continuously collects records of resuscitations. In these hospitals, the patients included in the study were identified from the resuscitation sheets. In the tertiary teaching hospital, no centralized collection of resuscitation sheets exists and the patients for the study were identified from the CPR related diagnoses entered in the hospital’s database.

The documented symptoms and vital signs, and any interventions undertaken during the eight hours prior to the cardiac arrest were analysed retrospectively. The number of observations during the 24 hours before the cardiac arrest was also recorded. The symptoms and vital signs were analysed against the MET trigger criteria used by Buist and co-workers 25, (Table 1).
4.5. Questionnaire studies (V–VI)

The resuscitation strategies in health centres (V) and hospitals (VI) were investigated in questionnaire studies. Both questionnaires comprised of a number of detailed questions concerning resuscitation strategies and training, especially rapid defibrillation by nurses using AEDs (Appendices 1 and 2). A survey questionnaire to the health centres was sent out in September 2001 and to hospitals in May 2004, two years after publication of Finnish national guidelines on CPR\textsuperscript{134}. A similar questionnaire study in the hospitals was performed before publication of the guidelines by Skrifvars and colleagues\textsuperscript{133} and served as comparison for study VI.

The questionnaire (Appendix 1) was sent to the chief physician of every health centre in Finland (N=279), followed by a reminder, if necessary. The receivers were asked to either answer the questionnaire themselves or to forward the questionnaire to the person in charge of resuscitation training and equipment in the health centre.

The questionnaire (Appendix 2) was also sent to the chief anaesthesiologist in all public hospitals that provide anaesthetic services in Finland. Of the separate units of University hospitals, those with anaesthetic services were included and analysed as individual hospitals. Total of 55 forms were sent out. The responders were asked to either answer the questionnaire themselves or to forward it to the physician in charge of the local in-hospital CPR organization. The data collection form included detailed questions about current in-hospital resuscitation strategies. If necessary, up to three reminders were sent, after which the heads of the department of anaesthesiology were contacted by email or telephone.

4.6. Statistical methods

In calculation of confidence intervals (CI) for proportions, modified Wald method was used (IV, I, II). The comparisons of categorical data between two groups were performed using Fisher’s exact test (V, I, II, III) and Chi-square (I, II), as appropriate. In comparisons of continuous data between two groups, unpaired and paired $t$-test was used, as appropriate (III), and in a case of multiple comparisons, one-way ANOVA with Bonferroni’s post hoc test (I) or Kruskal-Wallis test with Dunn’s multiple comparison when appropriate (II). All analyses were made using GraphPad Prism 3.0 for Mac (GraphPad Software, San Diego, CA) and a two-tailed $P$ value of less than 0.05 was considered statistically significant.

For a study comparing pictorial instructions of the electrodes (III), the sample size of 25 participants per group was calculated to give a power of 0.95 with a significance level of 0.05, with assumptions that, based on results of a previous study (II), 25% of the manufactured electrodes and estimated 70% of the electrodes with a lateral view picture for the apical electrode are placed correctly.
5. RESULTS

5.1. Placement of defibrillation electrodes (I–II)

Errors in placement
Two hundred eighty-six laypersons and health care professionals participated in Studies I and II. Of these, 29% placed both electrodes within 5 cm from the recommended positions. They placed, on average, the apical electrode further from the recommended position in the horizontal plane than in the vertical plane (mean 7.3 cm vs. 2.9 cm, \(P < 0.001\)). All erroneous placements of the apical electrode were too anterior. They generally placed the sternal electrode more accurately in the horizontal plane (mean 1.9 cm) and in the vertical plane (mean 2.2 cm), compared with the apical electrode in the horizontal plane (\(P < 0.001\) for both).

Placement by health care professionals
The 136 participants in Study I included 81 nurses, 34 emergency medical technicians, and 21 physicians. Of the participants, 74 were recruited from a university hospital, 34 from EMS, and 28 from primary care settings. Of the physicians participating, 10 were senior house officers in anaesthesia and intensive care medicine. Only 31 participants had read the national resuscitation guidelines (Study I, Figure 1). Of the health care professionals, 25% (95% CI 19–33) placed both defibrillation electrodes within 5 cm from the recommended positions (Figure 2).

Placement by laypersons guided by pictorial instructions
The median age of the 150 participants of Study II was 29 (range 16–72) and they consisted of 84 males and 66 females. The participants attaching various electrodes did not differ significantly by age (\(P = 0.6190\)) or gender (\(P = 0.3217\)). Of the participants, 32% (95% CI 23–40) placed both electrodes within 5 cm from the recommended positions (Figure 2).

The proportion of correct placements varied significantly between the electrodes with different pictorial instructions (Figure 2, \(P = 0.0016\)). The pair of study electrodes with a lateral view picture on the apical electrode was most often placed as recommended compared to the five commercial electrodes (\(P < 0.05\) compared with any other).
Figure 2. Proportion of correct placement of defibrillation electrodes. Both by laypersons, guided by pictures on different electrodes, and by health care professionals (combined from I–II). Data are proportions, with 95% confidence intervals. EMT = emergency medical technician.

5.2. Training of public access defibrillation (III)

The mean score of trained laypersons in both OSCE scenarios was 35 (range 21–44, standard deviation [SD] 6) out of checklist maximum 49. No difference was found between the performance of subjects trained by a layperson and those trained by a health care professional (Study III, Figure 1). A significantly better performance occurred in scenario 1, patient on the floor and initial rhythm VF, than in scenario 2, patient in chair and initial rhythm asystole (Study III, Figure 2). The mean score of regularly training first aid personnel was significantly higher than that of newly trained study groups (Study III, Figure 2).

5.3. Abnormal vital signs before cardiac arrest (IV, VI)

Patient and event characteristics

The total number of patients in Study IV was 110, 64 males and 46 females, and the mean age was 68 (SD 16, range 8 to 97) with a mean length of stay before cardiac arrest of 4.4 days (SD 4.3, range 1 to 21). Thirty-three patients (30%, 95% CI 22 to 39) presented with a shockable rhythm. Thirty-nine patients (35%, 95% CI 27 to 45) achieved ROSC. The number of resuscitation attempts in the tertiary teaching
hospital was 15, in the tertiary trauma centre 17, and in the two secondary general hospitals 20 and 58. Of the cardiac arrests, 54 (49%, 95% CI 40 to 58) occurred in the ICU, the cardia care unit, the operating room, or in the emergency department and 56 (51%, 95% CI 42 to 60) on the wards.

**Observations prior to cardiac arrest on wards**

The frequency of documented observations in the 24 hours prior to cardiac arrest on the wards varied considerably among patients and parameters (Table 6). Only records of heart rate and blood pressure occurred more than once during these 24 hours (mean 1.6 and 1.4 times per 24 hours, respectively).

**Table 6.** Number of documented observations per ward patient (N=56) during 24 hours prior to cardiac arrest (Study IV).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Median (25th, 75th percentiles)</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart rate</td>
<td>1 (0, 3)</td>
<td>0–10</td>
</tr>
<tr>
<td>Blood pressure</td>
<td>1 (1, 2)</td>
<td>0–6</td>
</tr>
<tr>
<td>Respiratory rate</td>
<td>0 (0, 0)</td>
<td>0–3</td>
</tr>
<tr>
<td>Level of consciousness</td>
<td>0 (0, 2)</td>
<td>0–2</td>
</tr>
<tr>
<td>Oxygen saturation</td>
<td>0 (0, 2)</td>
<td>0–6</td>
</tr>
<tr>
<td>Diuresis</td>
<td>0 (0, 0)</td>
<td>0–4</td>
</tr>
<tr>
<td>Temperature</td>
<td>0 (0, 0)</td>
<td>0–3</td>
</tr>
<tr>
<td>Pain</td>
<td>0 (0, 1)</td>
<td>0–3</td>
</tr>
</tbody>
</table>

**Table 7.** Composition of resuscitation teams or medical emergency teams (N=29) in Finnish hospitals (additional data from Study VI).

<table>
<thead>
<tr>
<th>Team member</th>
<th>Hospitals (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physician</td>
<td></td>
</tr>
<tr>
<td>Anaesthesiologist</td>
<td>25</td>
</tr>
<tr>
<td>Specialist in internal medicine</td>
<td>7</td>
</tr>
<tr>
<td>Physician on duty, speciality varies</td>
<td>6</td>
</tr>
<tr>
<td>Specialist in surgery</td>
<td>3</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
</tr>
<tr>
<td>Nurse*</td>
<td></td>
</tr>
<tr>
<td>Intensive care unit</td>
<td>17</td>
</tr>
<tr>
<td>Emergency department</td>
<td>11</td>
</tr>
<tr>
<td>Other</td>
<td>9</td>
</tr>
</tbody>
</table>

Total number of team members is higher than number of teams since many physicians or nurses may be appointed in same hospital or the composition of teams may vary depending the time of day. *Clinical area where nurse member of the team works.
Vital signs prior to cardiac arrest

Of the 54 patients suffering a cardiac arrest in monitored areas, 12 (22%, 95% CI 13 to 35) fulfilled at least one of the MET criteria and interventions were always made without delay. Of the 56 patients suffering cardiac arrest on a ward, 30 (54%, 95% CI 41 to 66) fulfilled at least one of the MET criteria. The frequency and delay of interventions made for the patients with abnormal vital sign on the wards are shown in the flow chart (Study IV, Figure 1). The proportion of patients whose vital signs observations fulfilled at least one MET criteria varied significantly between hospitals (Figure 3).

The mean delay from the first documented abnormal vital sign to the cardiac arrest was 3.8 hours (SD 2.8, range 0.5 to 8.0). The most common MET criteria displayed were respiratory distress (17 cases), SpO₂ < 90% on oxygen (10 cases), and decreased level of consciousness (10 cases). The frequency of observations of ward patients who did not fulfil MET criteria is shown in the flow chart (Study IV, Figure 1).

Medical emergency teams in Finnish hospitals

Of the 52 hospitals that responded to the survey in Study VI, 29 (56%) had a resuscitation team or a MET. In most of these hospitals (25/29) the team was also called to emergencies other than cardiac arrests. Only three hospitals, however, had
determined criteria e.g. values of vital signs for calling the team. The members of the teams are shown in Table 7.

5.4. Rapid defibrillation programmes (V–VI)

The response rates from the hospitals and the health centres on the questionnaires were 95% (N=52) and 51% (N=141), respectively. Most respondents from hospitals reported that nurses generally perform defibrillation before the arrival of the physician on the general wards, as well as in monitored areas such as the cardiac care unit (Figure 4). In the health centres these rapid defibrillation programmes were much less common (Figure 4). Those having an appointed person in charge on resuscitation preparedness, 59% of the responding health centres, nurses were more often likely to perform the first defibrillation before physician arrived (36% vs. 13%, \( P < 0.01 \)).

![Bar graph showing defibrillation rates](image)

**Figure 4.** Rapid defibrillation programs in health centres and hospital areas of different type (proportion of units where nurses are likely to perform the first defibrillation without the presence of a physician; Studies V–VI).

CCU = cardiac care unit
ICU = intensive care unit
ED = emergency department
The hospitals commonly had AEDs on general wards and manual defibrillators in monitored areas (Study VI, Table 2). Seventy-nine percent of the hospitals had obtained AEDs after the publication of the national resuscitation guidelines. Forty-six percent of the hospitals had a defibrillator placed on every ward. Of the health centres, 44% used manual defibrillators, 26% used AEDs and 30% used both.

Training in defibrillation was given to staff members other than health care professionals in 15% of the hospitals and in 4% of the health centres. Of the hospitals 33% used a standardized four-hour course in CPR and defibrillation, adapted by the Finnish Resuscitation Council from the European Resuscitation Council, and 25% of the hospitals used the defibrillation training video by the Finnish Medical Society Duodecim.

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**Figure 6.** Proportions of Finnish hospitals adhering to certain recommendations in Finnish national resuscitation guidelines in 2004 (Study VI) compared with data collected with similar methods in 2000, indexed by reported use of national guidelines for cardiopulmonary resuscitation (NGCPR).
5.5. Changes in in-hospital resuscitation organisation (VI)

Of the respondents, 41 (79%) reported use of the national resuscitation guidelines or their own instructions, based on the national guidelines, in the hospital. Eleven hospitals (21%) used other guidelines or had no formal guidelines. Figure 5 summarises the changes in resuscitation strategies in hospitals after publication of international Guidelines 2000 \(^{30}\) and Finnish national resuscitation guidelines \(^{134}\).

Many hospitals (44%) reported using exclusively amiodarone, and a few (4%) only lidocaine for prolonged or persistent VF or pulseless VT, and use of both drugs occurred in 44% of the hospitals. A beta-blocking agent was used in one hospital, but the rest of the hospitals had no formal guidelines on the use of antiarrhythmic drugs in resuscitation.

A special form for data collection of resuscitation attempts was used in 69% of the hospitals. Collection and routine review of the forms occurred in 46% of the hospitals. A total of 43% performed data collection of IHCAs, and 22% used definitions provided in the Utstein Guidelines for IHCA \(^{247}\).

A unified style for the documentation of “do not attempt resuscitation” orders were used in 22 (48%) out of 52 hospitals. There were various ways of indicating a DNAR order: the letter combination “DNR” (14 hospitals), a symbol (6 hospitals), or written as the sentence “not for resuscitation” (2 hospitals). Of the hospitals, 19% had orders concerning decision-making of DNAR orders. Withholding resuscitation without a previous DNAR order was usually based on a decision by the physician in charge in most hospitals (94%) and in some hospitals also based on a decision made by a nurse (12%).

The hospitals with national guidelines based resuscitation strategies more often had rapid defibrillation programmes on general wards (29/41 vs. 6/11), performed data collection as recommended (10/41 vs. 1/11), and had uniform style for indication of DNAR status (20/41 vs. 5/11), but less commonly used amiodarone (35/41 vs. 11/11).
6. DISCUSSION

6.1. Placement of defibrillation electrodes (I–II)

Only one quarter of health care professionals with duty to perform defibrillation placed the self-adhesive electrodes within five centimetres from recommended positions (I). This proportion is similar to that found by Heames and co-workers regarding physicians, 22% of apical electrodes and 65% of sternal electrodes placed correctly. In their study, as well as the Study I a majority of participants placed the apical electrode clearly more anteriorly than recommended.

Of the laypersons that placed defibrillation electrodes by guidance of pictorial instructions on the electrodes, 32% placed electrodes correctly (II). The most common error was again, similar to the professionals of Study I, too anteriorly placed apical electrode. The study showed significant variation in the quality of the instructions on the electrodes and also found that electrodes with a lateral view picture, designed for the study, showing the placement of the apical electrode were most often placed correctly. All participants were laypersons with no previous experience or training in the use of a defibrillator. Since defibrillators have been used in some PAD programmes by random laypersons, the quality of pictorial instructions is critical if correct placement of electrodes is to be achieved. A good quality of pictorial instructions could also lead to better adherence to the resuscitation guidelines by health care professionals. A small study has shown that most nurses without training in the use of an AED placed electrodes incorrectly if guided only by pictures on the electrodes.

The most common error in the placement of the electrodes in both studies leads to a decreased distance between electrodes. When the electrodes are placed too closely, the current flow through non-cardiac tissue is enhanced and the current is shunted from the heart. The clinical impact of this phenomenon on VF patients, however, is not confirmed in clinical trials. On the other hand, the effect of electrode placement on success of cardioversion of atrial fibrillation has been demonstrated suggesting that the position of the electrodes during defibrillation of VF is of also important. The importance of a short delay to defibrillation, not exceeding a few minutes, has been definitely demonstrated. Thus, the exact positioning of the electrodes may have a lower priority than prompt action and courage of untrained responders to use a defibrillator.

The adherence to the guidelines when positioning the defibrillation electrodes could possibly be improved by emphasizing the issue in defibrillation training and by updating the pictures on electrodes and educational material to be in accordance with the current guidelines.
6.2. Training in public access defibrillation (III)

The current study (III) found no differences in the performance between laypersons trained by health care providers and those trained by layperson instructors, and thus, suggests that a layperson can be trained in eight hours to be a competent PAD instructor. In this study, the four-hour AED-BLS training programme of which feasibility and effectiveness in PAD training have been documented earlier, was used. The Finnish Red Cross volunteer first aid personnel who were trained similarly in defibrillation, performed significantly better in a simulated cardiac arrest situation. This can be due to better BLS and process skills achieved by regular first aid training, and a higher degree of motivation.

A defibrillation within the first minutes is the only effective treatment for VF, the most common cause of sudden cardiac death. The effectiveness has been proven for PAD programmes in public locations with at least a moderate incidence of witnessed cardiac arrests. The data on public use of AEDs by random untrained bystanders is limited and currently, in most PAD programmes, the defibrillation is the responsibility of predetermined and trained layperson. Although most laypersons can use an AED correctly in simulated cardiac arrest without previous training, a short, 2–5 hours, training significantly decreases a delay from arrival to the patient to first defibrillation shock. Skills needed to correct and speed use of an AED seem to deteriorate relatively fast after training and retraining is needed to maintain an adequate level of skills. Recently AHA has particularly emphasised the importance of training rescuers, as well as the developing and practicing of structured response plans. Estimates of training costs vary regarding to the cost-and-benefit analysis. The biggest costs in a community-based pilot study in Helsinki were related to training and administration. Costs of training could possibly be decreased if a layperson associated with a PAD location could act as an instructor and give training to other individuals.

Teaching methods for PAD require further research, since the current training programmes do not seem to be sufficient to ensure rapid defibrillation. In the PAD trial, with rescuers trained to respond to a SCA, resuscitation was attempted in only half of the witnessed SCA victims, and the on-site AED was used in only about one third of SCA victims. The cost-effectiveness of a PAD programme is highly sensitive to the probability that the deployed AED is actually used in a cardiac arrest that occurs at the site of deployment. The proposal for the development of abbreviated instructions without chest compressions and ventilations, or at least ventilation instruction, may make it possible to increase the number of qualified AED operators in the community. In the study by Capucci and co-workers survival to hospital discharge was tripled by PAD programmes with training, lasting four hours, including no specific instructions for chest compressions and ventilation. The usability of the AEDs greatly affects the need for training. The differences in user interfaces, e.g. pictorial instructions for electrode placement and voice prompts,
of the currently available AEDs cause variation in success and time to shock delivery by untrained rescuers.253

6.3. Abnormal vital signs before cardiac arrest (IV, VI)

The chart review (IV) showed that of patients who suffered cardiac arrest and whose resuscitation was attempted in the four hospitals during one and a half years, 54% had abnormal vital signs, documented approximately almost four hours before the arrest. The prevalence of these warning signs in this study was somewhat lower than in most earlier studies, up to 84%16-23. The recorded observational intervals of the patients, however, were quite long since the only parameters measured at least once a day, on average, were heart rate and blood pressure. For example, respiratory rate was measured in only one patient, and there were no observations documented in seven patients. Thus, the actual prevalence of abnormalities in vital signs prior to cardiac arrest is probably higher.

In a study by Franklin and Mathew19, 66% of patients that suffered cardiac arrest on general medical wards had documented deterioration of vital signs within six hours of the cardiac arrest. They analysed the responses of nurses and physicians to the deterioration and frequently found a failure of the nurse to notify a physician, a failure of the physician to obtain or interpret an arterial blood gas measurement, and a failure of the ICU triage physician to stabilise the patient’s condition before transferring the patient to the ICU. Comparable reasons for suboptimal care prior to ICU admission have been found in a confidential inquiry by McQuillan and co-workers99, i.e. failure of organisation, lack of knowledge, failure to appreciate clinical urgency, lack of supervision, and failure to seek advice. Also the current study showed delayed or absent response to the recorded abnormal vital signs. Because of the study design, the reasons for suboptimal care could not be assessed. There appears, however, to be a need for improvement in detection and management of patient at risk of a cardiac arrest on the wards.

About half of the hospitals that responded to the survey (VI) had a cardiac arrest team or a MET. Almost all teams were also called to emergencies other than cardiac arrest, but only three hospitals had predetermined calling criteria for the team. In the study by DeVita and co-workers27 the implementation of the calling criteria for MET seemed to increase the call volume of the team and decrease the incidence of cardiac arrests. Other studies have compared a cardiac arrest team and MET24-28,121,134. The results of these studies are mixed, as most before-and-after or cohort comparison studies have found a significant decrease in hospital mortality and cardiac arrest rate, while the largest and the only randomised study found no difference in the outcome. There is strong evidence, however, that most patients at risk can be identified hours before cardiac arrest or unplanned ICU admission by simple physiological measurements. Also the benefit of early management of conditions like acute myocardial infarction or sepsis is obvious. Another approach to improve the
detection and treatment of deteriorating patients is through education of nurses and physicians responsible for patients on the wards\textsuperscript{109}. Effects of this education on the outcome of the patients have not been evaluated.

The high prevalence of documented abnormalities in vital signs many hours prior to cardiac arrest underlines the totally different nature of OHCAs and a great majority of IHCA\textsuperscript{s}. Most OHCAs are SCAs caused by malignant arrhythmia\textsuperscript{132} whereas IHCA is, especially in wards, caused by more complex and gradual deterioration of vital functions\textsuperscript{16,23}, also shown in Study IV. Thus, the optimal strategies in treatment of cardiac arrest may be different. Recognition of warning signs enables initiation of intensive treatment before cardiac arrest occurs. On the other hand, treatment of patient in cardiac arrest should be targeted to the underlying cause, which in the case of VF or VT is defibrillation, but may be more complex in most cases of IHCA. Currently, the aetiology of IHCA\textsuperscript{s} is poorly described.

6.4. Rapid defibrillation programmes (V–VI)

The health centre survey (V) showed that before the publication of the Finnish national resuscitation guidelines, nurses were likely to perform defibrillation before a physician arrived to the patient only in a minority of Finnish health centres. AEDs were not in common use and training in resuscitation was described mostly as insufficient. At the time of study (V), the rapid defibrillation programmes were even more infrequent in the Finnish hospitals\textsuperscript{133}. The current questionnaire study (VI) in hospitals showed, however, a marked increase in the proportion of the hospitals with rapid defibrillation programmes from 15\% to 67\%. Likewise, our unpublished data from the questionnaire study in 2004 also show an increase in rapid defibrillation programmes in health centres (24\% to 42\%). The change had taken place soon after the publication of the national guidelines recommending this strategy. Active marketing by defibrillator manufactures, decreased prices of the AEDs, other guidelines, and many other factors may also have had a great influence, however, in the initiation of rapid defibrillation programmes, too.

The rapid defibrillation programmes in the hospitals were common compared with earlier studies by others. In 2002, only 33\% of NRCPR hospitals reported some form of AED technology in any part of the facility, and regarding the registry data, only 1.4\% of the patients with VF/VT as initial rhythm were defibrillated using an AED\textsuperscript{19}. The availability of a defibrillator of any type has been reported to be small, for example of the hospitals in Rome in 2000 and 2001 most had less than one defibrillator per floor and not even all cardiac arrest teams had one of their own\textsuperscript{258}. A nation-wide postal survey from UK showed that only 42\% of hospitals had AEDs available and of these hospitals, only 38\% allowed advanced life support certified nurses in to use them without supervision\textsuperscript{259}. 

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There is no prior literature on the occurrence of rapid defibrillation programmes in primary care settings and thus comparison cannot be made. Generally the proportion of health centres allowing nurses to defibrillate without the presence of a physician, 24%, in our country is considered to be low. Increasing the use of AEDs by non-physician personnel could be an important improvement in resuscitation preparedness in the health centres.

Regardless of an increased number of the rapid defibrillation programmes in the hospitals, the actual performance in resuscitation situations cannot be accurately known. Reports have been published on successful implementation of the rapid defibrillation programmes. There are, on the other hand, some reports of the reluctance of nurses towards defibrillation, which have resulted in a prolonged delay to defibrillation in spite of the presence of AEDs on the wards. Successful implementation of changes in the clinical practices requires a comprehensive approach and the use of multimodal interventions. In the case of defibrillation by nurses, a change in nursing philosophy must also occur, and defibrillation should become an expected rather than an extended nursing role.

Limited data are available in the literature and data on cost-benefit ratio of this concept are still lacking despite the advocacy, already for many years, for hospitals to use an AED in first-responder rapid defibrillation. There is no doubt that defibrillation within a few minutes is a highly effective treatment of VF or pulseless VT. Most patients suffering a cardiac arrest in hospital, however, have asystole or PEA as an initial rhythm and thus, do not benefit from a rapid defibrillation programme. Also long-term survival after IHCA is considerably worse than after an OHCA treated with rapid defibrillation. Despite the recommendations to use an AED by first-responders in hospitals, the use of AEDs in hospitals is controversial. An AED can be operated efficiently after minimal training even by laypersons, which makes it possible to extend defibrillation to all hospital staff and thus shorten the delay to defibrillation. The use of an AED leads to, however, long interruptions of chest compressions because of voice prompts and rhythm analysis, which can worsen the outcome of the patient, especially when the interruptions occur immediately before and after defibrillation attempts. In Study VI, AEDs were the most commonly used defibrillators on general wards whereas the use of manual defibrillators was more common in ICUs and cardiac care units. Of the health centres, 56% had at least one AED.

6.5. Role of national guidelines (I, VI)

The hospital questionnaire study (VI) demonstrated important changes in resuscitation strategies of the hospitals in a whole nation after publication of the national guidelines. Changes not only occurred in the hospitals that reported using national guidelines but also in the hospitals that were not using the national guidelines, and in many areas of resuscitation organisations, i.e., use of guidelines,
rapid defibrillation, pharmacotherapy, DNAR policy, as well as data collection, and quality assurance. Mostly the changes were more common in the hospitals that reported using national guidelines. There are some issues that can explain the good acceptance of the national resuscitation guidelines. The fact that the national guidelines were published in a guidelines programme, operated by the respected physicians’ society Duodecim, instead of as a separate single guideline may be an important reason for adoption without large implementation interventions. The Current Care guidelines are available free of charge through the Internet and through the local intranets of most hospitals. In addition, it can be speculated that the role of the appointed nurse or physician in charge of resuscitation organization in the hospitals has been important in implementing the guidelines into practice.

It can further be speculated that the observed changes in the Finnish hospitals could also be the result of many other reasons, for example the marketing of user-friendly AEDs for in-hospital use in the recent years has probably promoted an interest in rapid defibrillation programmes. Even hospitals not using the national guidelines launched rapid defibrillation programmes in general wards and all of them used amiodarone.

Good adherence to the guidelines by the hospitals is an interesting finding because studies in various clinical areas show that CPG only have a limited effect on practices in health care, especially if applied without a clearly targeted implementation 26. In a literature based evaluation of quality of care in the United States roughly 70% of patients received acute care as recommended or nearly as recommended, while 30% received acute care which in most cases could be contraindicated 268.

In the observational study on defibrillation electrode placement by health care professionals (I), a low level of adherence to the guidelines was found. Placement of the electrodes, in the majority of cases, was as recommended in the preceding European Resuscitation Council guidelines, that is, the apical electrode more forward to mid/anterior axillary line 269. This change in recommended practice is not necessarily implied clearly enough in the guidelines. Of the 136 mainly non-physician professionals, only 31 had read the guidelines whereas as many as 49 were not even aware of the guidelines. Studies are needed to find the most efficient methods to implement the resuscitation guidelines.

6.6. Limitations

The data collection methods in studies on defibrillation electrode placement (Studies I, II) may have some limitations, since the anatomy of resuscitation training manikin does not fully correspond to the anatomy of a real patient. In the study protocol, the data collector was not blinded to the purpose and hypothesis of the study.
The limited number of instructors was Study III major limitation. Also the OSCE setting has limitations, since interrater agreement was not tested and performance was not video recorded for certifying the actions taken. The clinical impact of many tasks included in the checklist is unknown, and thus the OSCE score achieved may not correspond to the real ability of responders to alter the outcome of the patient. The OSCE score, however, corresponds to the adherence to the current evidence-based guidelines.

The fairly rigid and structured design of studies I–III may also fail to address some issues of complex resuscitation situations in real life, e.g. the performance in electrode placement was not influenced by emotional pressure. Studies addressing the performance of rescuers in a real life are difficult to perform, however. Using mock scenarios enables comparisons between groups in well-controlled circumstances.

In the retrospective chart review (Study IV), some patients who sustained an IHCA may have been omitted and the notes in the patient charts are probably not complete. The four hospitals in the study may not be representative of all Finnish hospitals and the total number of patients in the study is small.

The questionnaires in studies V–VI were designed to minimize the risk of misinterpretation. Some of the questions, however, may have been misunderstood, particularly if the respondent was not familiar with CPR. For instance, not all physicians working in the primary health care may know the difference between a manual defibrillator and an AED. The questionnaires were not piloted or tested prior to these studies. Secondly, the response rate of the study in health centres (V) yielded only 51%, and thus responses may not be representative of all Finnish health centres situations. The response rate, however, does not question the main finding of infrequent implementation of rapid defibrillation programmes. Most importantly, the effect of nationally published resuscitation guidelines among other possible influences on the resuscitation strategies in hospitals cannot be unquestionably defined.
7. SUMMARY AND CONCLUSIONS

The present study addressed different aspects of possibilities for improvement of the response to cardiac arrest at different levels of health care with special reference to the organisation of rapid defibrillation programmes, recognition of pre-arrest signs, and adherence to the national resuscitation guidelines. The specific conclusions are:

1) The majority of the health care professionals, 75%, place defibrillation electrodes incorrectly, mostly too close to each other. The current picture designs on the electrodes seem to be suboptimal in showing the recommended position of the apical electrode. It is suggested that by showing a lateral view instructional picture on the electrode, successful placement of the apical electrode can be improved. In resuscitation training more emphasis is needed on the correct placement of the defibrillation electrodes.

2) A similar eight-hour instructor training programme in the use of an automated external defibrillator seems to be as effective at training laypersons as it is at training health care professionals. Using laypersons as instructors may enable more widespread implementation of public access defibrillation programmes.

3) Significant physiological deterioration is common before a cardiac arrest on the wards: in Finnish hospitals, 54% of these patients had abnormal vital signs documented on average 3.8 hour before the arrest. During this period, the interventions were commonly either insufficient or performed too late. Currently, in Finland, a medical emergency team with defined calling criteria only exists in three hospitals. These deficiencies should be addressed by appropriate education in identifying patients at risk for cardiac arrest and by implementing more effective interventions for such patients. A more widespread introduction of the medical emergency team practice could effectively support the achievement of this goal.

4) Before publication, in 2002, of the Finnish national resuscitation guidelines nursing staff performed defibrillation without the presence of a physician only in 24% and an automated external defibrillator was available in 56% of the health centres. After a previous questionnaire study, performed in 2000, most of the hospitals had launched a rapid defibrillation programme. In 2004 nurses were likely to perform the defibrillation on general wards without the presence of a physician in 67% of the hospitals. In addition to the increase in rapid defibrillation programmes, many other resuscitation strategies, including drug treatment, “do not attempt resuscitation” policy as well as data collection and quality assurance, were changed in many hospitals to conform to the guidelines. The results encourage publishing resuscitation guidelines in well-recognised national series of clinical practice guidelines.
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Jouni Nurmi
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APPENDICES

Appendix 1. Questionnaire to the health centres (translated).

Name of health centre
Name and contact information of respondent

Background information
Bed capacity (n)
Population for services are provided (n)
Number of patients in 2000 (n)
Physician available 24 h/day (yes / no)
Physicians on duty out of office hours (n, speciality)
Anaesthesia services (24h / office hours / no)
Appointed person in charge of resuscitation preparedness (profession and speciality / no)

BLS skills and training
Every member of the staff is competent in BLS (yes / no)
Physicians are competent in BLS (yes / no)
Nurses are competent in BLS (yes / no)
Non-medical personnel is competent in BLS (yes / no)
BLS skills are assessed (yes, who are assessed? / no)
Health centre has written BLS instructions (yes / no)
BLS training is provided to the personnel (yes / no)
BLS training is provided by physician (yes / no)
BLS training is provided by the person appointed to be in charge of resuscitation preparedness (yes / no)
BLS training is provided by an appointed persons (yes / no)
BLS training is given on regular bases (yes / no)

ALS training
Defibrillation training is provided for the physicians (yes, for all / yes, but not for all / no)
Defibrillation training of physicians is regular (yes / no)
Defibrillation training of physicians is supervised (yes / no)
Training in intubation is provided to physicians (yes / no)
Comprehensive ALS training including tactics of resuscitation, rhythm recognizing, and resuscitation drugs is provided for physicians (yes / no) 
Defibrillation training is provided for registered nurses (yes, for all / yes, but not for all / no) 
Defibrillation training is provided for enrolled nurses (yes / no) 
Defibrillation training is provided for cleaners (yes / no) 
Intubation training is provided for nurses (yes / no) 
Comprehensive ALS training including tactics of resuscitation, rhythm recognizing, and resuscitation drugs is provided for nurses (yes / no)

Training equipment of the health centre
BLS training manikin (yes / no) 
ALS training manikin for intubation training, rhythm simulation, cannulation and defibrillation (yes / no) 
Paediatric BLS manikin (yes / no) 
Paediatric ALS manikin (yes / no) 

Supervision of competence
ALS skills of physicians (yes / no) 
BLS skills of physicians (yes / no) 
BLS skills of nurses (yes / no) 
ALS skills of nurses (yes / no)

Organisation of resuscitation training
In your opinion, is the resuscitation training in your health centre sufficient and is it given systematically? (yes / no) 
If the resuscitation training in the health centre is insufficient, please specify potential reasons 
In your opinion, is resuscitation training sufficient but without coordination? (yes / no) 
Written instructions for resuscitation training exist (yes / no) 
Appointed person in charge of BLS training in health centre (yes / no) 
Appointed person in charge of ALS training in health centre (yes / no) 
Every ward has its own appointed persons in charge of training (yes / no) 
Does the health centre participate in resuscitation training of ambulance staff or local fire brigade? (yes / no)

Recognition of cardiac arrest, alarming, and BLS
Every ward has instructions for recognition of cardiac arrest and starting BLS (yes / no) 
Same instructions are used on every ward (yes / no) 
Ward staff is alarmed in cardiac arrest situation by shouting (yes / no) 
Ward staff is alarmed using emergency alarming system (yes / no)
Ward staff is alarmed using telephone (yes / no)
Physician is alarmed using paging device (yes / no)
Physician is alarmed using general in-centre broadcast (yes / no)
Physician is alarmed using mobile phone (yes / no)
Health centre has resuscitation team (yes / no)
Resuscitation team has an own phone number for calls (yes / no)
The phone number of resuscitation team varies, e.g. regarding of the time of day (yes / no)
On the wards, resuscitation is provided at the site where the patient has collapsed (yes / no)
On the wards, patient is moved for resuscitation, for example, to a resuscitation room (yes / no)

Defibrillation
Defibrillator is placed on every ward (yes / no)
Defibrillators are in shared use between wards (yes / no)
Emergency department has a defibrillator (yes / no)
Operating department has a defibrillator (yes / no)
Defibrillators are also placed to (tick all that apply: department of radiology, cafeteria, restaurant, somewhere else)
All defibrillators are manual (yes / no)
All defibrillators are automated (yes / no)
Both manual and automated defibrillators are used (yes / no)
On the ward, a nurse usually perform defibrillation before physician arrive (yes / no)
On the ward, defibrillation is usually performed by physician (yes / no)

Advanced life support
Approximate number of cardiac arrests per year (n)
ALS is provided independently by ward nurses and physician (yes / no)
ALS is provided by a resuscitation team (yes / no)
ALS response is organised in some other way (yes, please specify / no)
Resuscitation team is located in the emergency department (yes / no)
Resuscitation team is located in the other department or unit (yes, please specify / no)
Physicians in resuscitation team (n, specialities)
Nurses in resuscitation team (n, specialities)
Resuscitation team carries own equipment (yes / no)
Resuscitation team uses equipment of the ward (yes / no)

Instructions and guidelines
Written instructions for ALS (yes / no)
Resuscitation management is not necessary based on guidelines or instructions (yes / no)
Guidelines by European Resuscitation Council from 1998 are generally used (yes / no)
Guidelines by American Heart Association from 1992 are generally used (yes / no)
Guidelines published in Finnish pocket guide for acute care (Meilahden akuuttihoito-opas, Duodecim, 1997) are generally used (yes / no)
Health centre has produced its own guidelines or instructions for resuscitation (yes / no)
Other guidelines or instructions are used in health centre (yes, please specify / no)
Are ambulance personnel used for resuscitation (yes, if already present / yes, ambulance is called for cardiac arrests / no)

Data collection and ethical issues

Special form is used in documentation of resuscitation (yes / no)
“Do not attempt resuscitation” policy (yes / no)
In cases where DNAR decision is not documented, resuscitation attempt can be withheld based on decision taken by a nurse (yes / sometimes / no)
In cases where DNAR decision is not documented, resuscitation attempt can be withheld based on decision taken by a physician (yes / sometimes / no)
Uniform style of indicating DNAR decision in patient charts (yes / no)
DNAR is documented in patient notes (yes / no)
DNAR decision requires discussion with patient or relatives by physician (yes / usually / no)
DNAR decision requires discussion with patient or relatives by nurse (yes / usually / no)
Other DNAR policy (yes, please specify / no)
Instruction for termination of unsuccessful resuscitation attempt (yes / no)
Termination of unsuccessful resuscitation attempt is decided on case-to-case base (yes / no)
Data collection on resuscitation attempts is performed (yes / no)
Data of all resuscitation attempts are collected based on Utstein template (yes / no)
Data of all resuscitation attempts are collected using an own data collection model (yes / no)
Resuscitation forms are reviewed after resuscitation attempt (yes / no)
Debriefing is organised for personnel participated in resuscitation attempt (yes / no)
Is purchase of automated external defibrillators considered (yes, AEDs have been purchased / yes, decision to purchase has been made / yes, decision to not purchase has been made / no)
Resuscitation training has been improved (yes, please specify / no)
Improvement of resuscitation training has been planned (yes, please specify / no)
Appendix 2. Questionnaire to the hospitals (translated).

Hospital
Name and contact information of respondent

Background information
Type of hospital (primary local hospital / secondary central hospital / tertiary university hospital / unit of university hospital / other, specify)
Number of beds (n)
Type of monitored areas in hospital (tick all that apply: cardiac care unit / intensive care unit for medical and surgical patients / intensive care unit for medical patients / intensive care unit for surgical patients / high dependency monitoring ward / medical emergency ward / emergency room)
Presence of an anaesthesiology (always / during office hours / no)
Appointed person to be in charge of resuscitation preparedness (yes, specify profession and speciality / no)

Training
Resuscitation training is provided in coordinated and supervised fashion (yes / vary between units / no)
Assessment of competence in resuscitation skills (physicians and nurses / physicians / nurses / some other group, specify / no assessment of competence)
Resuscitation training provided in the last two years (tick all that apply: BLS training for nurses, BLS training for physicians, defibrillation training for all nurses / defibrillation training for some nurses, specify / defibrillation training for all physicians / defibrillation training for some physicians, specify / ALS training for nurses / ALS training for physicians / BLS and defibrillation practical training for nurses / BLS and defibrillation practical training for physicians / ALS practical training for nurses / ALS practical training for physicians)
In your opinion, resuscitation training for physicians is sufficient (yes / no, specify why / do not know)
In your opinion, resuscitation training for nurses is sufficient (yes / no, specify why / do not know)
Resuscitation training of physicians is regular (yes, specify interval / no / do not know)

Resuscitation practises
Orders for physicians in management of cardiac arrest (national resuscitation guidelines / guidelines by ILCOR from 2000 / Meilahden akuuttihoito-opas [acute care pocket guide published by Duodecim in Finnish] 2002 / Meilahden akuuttihoito-opas 1997 / guidelines by European Resuscitation Council from 1997 / guidelines by American Heart Association from 1992 / instructions produced in hospital, tick also guidelines if instructions are based on some / no orders for management of cardiac arrest, practices depend on physicians)
Antiarrhythmic drug for prolonged or recurrent ventricular fibrillation (lidocaine / amiodarone / beta-blocker / other, specify / varying practice)
Call of resuscitation team, or if that does not exist, of physician (paging device / mobile phone / general in-hospital broadcast / other, specify)

Resuscitation team
Hospital have a resuscitation team (yes / no -> go to question number 18)
Resuscitation team is called also to other emergencies than cardiac arrests (yes, based on subjective decision by nurse or physician / yes, based on predetermined objective criteria / no)

Members of resuscitation team (tick all that apply: consultant of anaesthesiology and intensive care / house officer of anaesthesiology and intensive care / consultant of internal medicine / house officer of internal medicine / consultant of surgery / house officer of surgery / physician on duty, speciality varies / other physician, specify / nurse from emergency department / nurse from intensive care unit / other nurse, specify / other member, specify)

Rapid defibrillation

Deployment of defibrillators (every ward have defibrillator / only wards treating cardiac patients have defibrillator / defibrillators are in shared use)

Defibrillators on general wards (manual defibrillators / automated external defibrillators / both)

In addition to wards, defibrillators are deployed also to (tick all that apply: department of radiology / lobbies / cafeteria / outpatient clinic / other, specify)

Defibrillation on general wards (by nurse using automated external defibrillator before arrival of physician or resuscitation team / by nurse using manual defibrillator before arrival of physician or resuscitation team / nurses do not defibrillate without presence of physician)

Defibrillation on wards treating monitored cardiac patients (by nurse using automated external defibrillator before arrival of physician or resuscitation team / by nurse using manual defibrillator before arrival of physician or resuscitation team / nurses do not defibrillate without presence of physician / no ward of that type in hospital)

Defibrillation in cardiac care unit (by nurse using automated external defibrillator before arrival of physician or resuscitation team / by nurse using manual defibrillator before arrival of physician or resuscitation team / nurses do not defibrillate without presence of physician / no cardiac care unit in hospital)

Defibrillation in intensive care unit (by nurse using automated external defibrillator before arrival of physician or resuscitation team / by nurse using manual defibrillator before arrival of physician or resuscitation team / nurses do not defibrillate without presence of physician / no intensive care unit in hospital)

Defibrillation in emergency department (by nurse using automated external defibrillator before arrival of physician or resuscitation team / by nurse using manual defibrillator before arrival of physician or resuscitation team / nurses do not defibrillate without presence of physician / no emergency department in hospital)

Defibrillation training for non-medical staff, for example personnel in lobbies and cafeterias (yes, specify / no)

CPR-D course concept by Finnish resuscitation council has been used in defibrillation training (yes / no / do not know)

Defibrillation training video by the Finnish Medical Society Duodecim has been used in defibrillation training (yes / no / do not know)

Resuscitation and training equipment purchased during last two years (tick all that apply: manual defibrillator / automated external defibrillator / automated external defibrillator trainer / manikin capable to defibrillation training / defibrillation training video by the Finnish Medical Society Duodecim / other, specify)

Data collection and quality assurance

Special form for note keeping in resuscitation situations (yes / no)

Centralised collection of resuscitation forms (yes / no)

Review of resuscitation forms (yes, specify by whom / no)

Statistics compiled for quality assurance (yes, using Utstein template / yes, using other template / no)
“Do not attempt resuscitation” orders

Uniform style for indicating DNAR order in patient charts (yes, specify / no)

In cases where DNAR decision is not documented, resuscitation attempt can be withheld based on decision taken by nurse (yes / sometimes / no)

In cases where DNAR decision is not documented, resuscitation attempt can be withheld based on decision taken by physician (yes / sometimes / no)

Written orders concerning decision making and documenting DNAR orders (yes / no)

Interventions used to implement the resuscitation guidelines in hospital

Estimate the extent of use and effectiveness of different methods in a scale of 1 to 5, 1=not used or no effect and 5=used to great extent or highly effective

Distribution of educational material

- Extent of use (1 / 2 / 3 / 4 / 5)
- Effectiveness (1 / 2 / 3 / 4 / 5)
- Personnel to whom the intervention was targeted (tick all that apply: physicians of resuscitation team / anaesthesiologists / other physicians / all nurses / some of the nurses, specify)

Educational meetings in small groups, under 20 participants

- Extent of use (1 / 2 / 3 / 4 / 5)
- Effectiveness (1 / 2 / 3 / 4 / 5)
- Personnel to whom the intervention was targeted (tick all that apply: physicians of resuscitation team / anaesthesiologists / other physicians / all nurses / some of the nurses, specify)

Educational meetings in large groups, more than 20 participants

- Extent of use (1 / 2 / 3 / 4 / 5)
- Effectiveness (1 / 2 / 3 / 4 / 5)
- Personnel to whom the intervention was targeted (tick all that apply: physicians of resuscitation team / anaesthesiologists / other physicians / all nurses / some of the nurses, specify)

Inclusion of participating providers in preparation of resuscitation orders of the hospital

- Extent of use (1 / 2 / 3 / 4 / 5)
- Effectiveness (1 / 2 / 3 / 4 / 5)

Meetings with providers in their own setting to give information about resuscitation guidelines. The information given may have included feedback on the actual performance.

- Extent of use (1 / 2 / 3 / 4 / 5)
- Effectiveness (1 / 2 / 3 / 4 / 5)

Search of opinion leaders of the group of profession or work team and focusing the education on them.

- Extent of use (1 / 2 / 3 / 4 / 5)
- Effectiveness (1 / 2 / 3 / 4 / 5)

Giving feedback about performance and adherence to guidelines in actual resuscitation situations.
- Extent of use (1 / 2 / 3 / 4 / 5)
- Effectiveness (1 / 2 / 3 / 4 / 5)

Reminders during resuscitation (for example, recommended drug dosage in drug ampoules, resuscitation form that guide the performance)
- Extent of use (1 / 2 / 3 / 4 / 5)
- Effectiveness (1 / 2 / 3 / 4 / 5)

Identifying obstacles to improve resuscitation performance by, for example, interviewing staff members.
- Extent of use (1 / 2 / 3 / 4 / 5)
- Effectiveness (1 / 2 / 3 / 4 / 5)

Mass media (includes for example posters, intranet, newsprint of the hospital)
- Extent of use (1 / 2 / 3 / 4 / 5)
- Effectiveness (1 / 2 / 3 / 4 / 5)

Other intervention
- Extent of use (1 / 2 / 3 / 4 / 5)
- Effectiveness (1 / 2 / 3 / 4 / 5)
- Description of the intervention

Attitudes towards Finnish national resuscitation guidelines

Scale ranging from strongly disagree (1) to strongly agree (7).

Resuscitation guidelines are useful as educational tools (1 / 2 / 3 / 4 / 5 / 6 / 7)
Guidelines are a convenient source of advice (1 / 2 / 3 / 4 / 5 / 6 / 7)
Guidelines can improve the quality of health care (1 / 2 / 3 / 4 / 5 / 6 / 7)
Guidelines are based on scientific evidence (1 / 2 / 3 / 4 / 5 / 6 / 7)
Guidelines are made by experts (1 / 2 / 3 / 4 / 5 / 6 / 7)
My occupational competence is insufficient for adopting the latest guidelines (1 / 2 / 3 / 4 / 5 / 6 / 7)
Most of our team members have disapproving attitudes toward guidelines (1 / 2 / 3 / 4 / 5 / 6 / 7)
Guidelines are not valued in our organisation (1 / 2 / 3 / 4 / 5 / 6 / 7)
To implement guidelines is too expensive for us (1 / 2 / 3 / 4 / 5 / 6 / 7)
Guidelines challenge the autonomy of care providers (1 / 2 / 3 / 4 / 5 / 6 / 7)
Guidelines oversimplify medical practise (1 / 2 / 3 / 4 / 5 / 6 / 7)
Guidelines are difficult to find if needed (1 / 2 / 3 / 4 / 5 / 6 / 7)
I use guidelines frequently in my work (1 / 2 / 3 / 4 / 5 / 6 / 7)
Use of guidelines is suitable only in primary care (1 / 2 / 3 / 4 / 5 / 6 / 7)
Guidelines are suitable to be used at a specialised level of care (1 / 2 / 3 / 4 / 5 / 6 / 7)