Demand for Rapid and Accurate Regional Medical Response at Major Incidents

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“Simplicity is the key to disaster planning”

(Sten Lennquist)
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**ABSTRACT**

**Background:** A major incident is a situation where the available resources are inadequate in relation to the urgent need. As health care resources have become increasingly constrained, it is imperative that all resources be optimized from a regional and sometimes a national perspective in response to any major incident. The overall aim of this thesis is to improve understanding of the demand for rapid and accurate regional medical response at major incidents.

**Objective:** To systematically analyse specific decisions within regional medical response and identify factors that can influence patient outcome in major incidents.

**Methods:** This thesis was based on four studies. The same set of 11 measurable performance indicators for initial regional medical command and control was used in papers I, II and III. Paper I was a pilot study in an educational setting conducted during a simulation exercise. Paper II was an observational study to identify strong and weak areas within the initial regional medical response conducted during nine similar educational programs. Paper III retrospectively evaluated the performance of the initial regional medical response in major incidents occurring in two Swedish county councils. In paper IV, the Swedish national burn response plan was evaluated during two simulations in relation to patient outcome. Based on identified risks in simulation I, indicators for national response concerning burn care coordination were developed and used in the second simulation.

**Results:** Paper I demonstrated that despite good staff procedure skills, regional decisions about distribution of patients were insufficient and 11 simulated patients out of 30 critically injured were at risk for preventable death. In an educational setting, it is possible to combine measurable performance indicators and outcome indicators to examine the crucial decisions made in relation to patient outcome. In paper II, most of the regional decisions were made according to the objective but not always within the stipulated timeframe. The mean performance score was 14.05 ± 3 out of a possible score of 22.
There was a significant difference between indicator 7 and 8 (decision about strategic guidelines for response and first information to media) and the rest of the indicators \( (p < 0.05) \). In paper III, the 11 indicators were applied to 102 major incidents. Thirty-six incidents had to be excluded due to incomplete documentation. Regional decisions that should be made 1–10 minutes after alert had a significantly higher mean score than decisions 10–40 minutes after alert \( (p < 0.05) \). In paper IV, the results for patient outcome were: simulation I, 18.5\% \((n = 13)\) risk for preventable deaths and 15.5\% \((n = 11)\) risk for preventable complications; simulation II, 11.4\% \((n = 8)\) and 11.4\% \((n = 8)\), respectively. The last immediate (T1) patient was evacuated after 7 hours in simulation I, compared with 5 hours in simulation II. All burn cases transported to national burn centres in Sweden, Norway, Denmark and Finland had a favourable outcome in both simulations. A more timely and accurate response from regional management together with national coordination of burn care most likely had a positive impact on patient outcome in simulation II.

**Conclusions:** This thesis shows that measurable performance indicators for regional medical response enables a standardized evaluation were crucial decisions that can be related to patient outcome can be identified. Indicators can be applied to major incidents that directly or indirectly involve casualties provided there is sufficient documentation available and thereby could constitute measurable parts of a national follow-up of major incidents. Reproducible simulations of mass casualty events that combine process and outcome indicators can provide important results on the medical surge capability and may serve to support disaster planning.

**Key words:** Disaster, response, resources, casualties, distribution, simulation, quality, patient outcome
LIST OF PAPERS

This thesis is based on four papers referred to in the text as papers I, II, III and IV. The published papers have been reprinted with the permission of the copyright holders.

I Management of resources at major incidents and disasters in relation to patient outcome: a pilot study of an educational model.
Nilsson H, Rüter A.

II Quality control in disaster medicine training—initial regional medical command and control as an example.
Nilsson H, Vikström T, Rüter A.

III Performance Indicators for initial regional medical response to major incidents: – a possible quality control tool.
Nilsson H, Vikström T, Jonson C-O.
Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine Accepted December 4, 2012

IV Simulation-assisted burn disaster planning
Nilsson H, Jonson C-O, Vikström T, Bengtsson E, Thorfinn J, Huss F, Kildal M, Sjöberg F.
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PREFACE

My interest in disaster medicine began in the early 1990s when I was working as a nurse in the emergency department. I then moved to the intensive care unit and one day my chief Tomas asked me an important question: ‘I want you Heléne to sign up to work within this new project on trauma education and patient transports’. I replied that this did not fit in to my life right at that moment because my father had just recently passed away. But my chief responded that I now had to ‘board the train’, and be a part of this. That was the start of a very exciting and educational journey that resulted in a move from Sundsvall to Linkoping in 2001. When I finally stood in front of The Centre for Teaching and Research in Disaster Medicine and Traumatology (KMC), I knew that this was my big opportunity.

In my work as a nurse, I was often guided by the feeling of doing the best for each patient and each relative that I met. The journey to teaching and research in disaster medicine may seem long, but the importance of doing the right thing, at the right time, for the most people has guided me further on this pathway. I hope that this research can increase knowledge but also provide support to the medical staff who are standing in the heat of a major incident, forced to make rapid and accurate decisions to save as many lives as possible.
1. INTRODUCTION

Disasters and the numbers of people affected by them are increasing throughout the world [1]. The worldwide disaster report 2010 [2] showed that during the last decades, the risk of major incidents and disasters has increased significantly in parallel with increasing global population, urbanization and technology improvements.

In the past 15 years, several events have affected many Swedes; for example, the discotheque fire in Gothenburg, the ferry Estonia, the tsunami, and several major bus crashes. These are events that we often speak of as disasters because many people died and many people were severely injured. The effects of these events on the community and the people involved are still present in our society and have not been forgotten. Many lessons have been learned and many of the changes in the Swedish disaster preparedness system during this decade are due to the deficiencies that were revealed in the aftermath of these events [3–6].

A major incident is a situation where the available resources are inadequate in relation to the urgent need. It is something outside the normal routine that requires a shift from daily management style and thinking. As health care resources have become increasingly constrained, it is imperative that, in major incidents, all resources are optimized from a regional and sometimes a national perspective [7, 8].

In all casualty events, the medical staff’s main task is to quickly identify the most severely injured, treat life-threatening conditions and ensure that they are transported to the appropriate medical facility [9]. Decisions concerning the mobilization and organization of the health care resources are made at the strategic (regional) level of medical management, which in the Swedish health care system consists initially of a designated duty officer (DDO) [10, 11]. The task of the strategic management function is to optimize resource utilization and is therefore of utmost importance to the outcome of the operation [12].
Despite national regulations for disaster medicine preparedness in Sweden, there are still different opinions on what to expect of a DDO when notification of a potential major incident is received. A national summary of the number of major incidents or their scope does not exist today.

The measurable performance indicators used in this thesis are derived from the development of a new national doctrine in which the results were implemented as regulations for medical management in major incidents in 2005 [11]. These indicators have become an important tool for creating standards and comparing results. In addition, they have been used for many years for measuring the effectiveness of training for disaster management and command and control at different levels [13–16]. Although indicators as standards for prehospital medical command and control are fully accepted, the implementation of regional standards has been slow.

One way of addressing these problems is to continue the validation process to identify which specific decisions of the regional initial response are important in relation to patient outcome.

A systematic approach to the evaluation could possibly lead to better understanding of what parts of the regional medical response to major incidents need to be improved and whether performance indicators can be used as measurable standards for critical initial regional medical decisions. Furthermore, it would be beneficial if the indicators could be used by disaster planners as a quality control tool for post-incident follow-up.
2. THEORETICAL FRAMEWORK

2.1. Disaster medicine

The objectives of disaster medicine are to prevent, reduce and mitigate the effects of disasters on the health of the population affected, to restore health conditions to the pre-disaster situation and to protect or re-establish health services and facilities [17]. The literature within the field of disaster medicine states that the ultimate goal of the health care system is to reduce or eliminate the loss of life and health and subsequent physical and psychosocial suffering to the greatest extent possible [9, 18, 19].

Disaster medicine is also described as the science that analyses and teaches how the health care system should be performing in the most efficient way in situations with a lack of resources. Therefore, rigorous planning and preparedness are needed in addition to education and training on specific knowledge and skills [20].

Management of most of major incidents and disasters is based on knowledge of medical management in daily routines and emergencies, but the demands on health care are much higher in a situation in which there is a lack of resources. To achieve the overall goal, rapid allocation of resources, accurate priorities and the use of other simplified methods are needed within the framework of structured preparedness planning and a well-implemented medical incident command system [21].

2.1.1. Disaster

There is no generally accepted definition or conceptual interpretation of the term disaster and different definitions exist with many variations between countries and organizations [18, 22, 23]. The most common medical definition of a disaster is an event that results in casualties that overwhelm the health care system in which the event occurs [24].
Due to these multiple definitions, even the same word can mean different things to different experts and the word disaster connotes a subjective assessment that has a different meaning to different people.

New models and nomenclature have been reported describing disaster from more of a response point of view and the actual functional impact of the event, which can be useful for disaster planning, education and research [9, 22].

The Academy for Emergency Management and Disaster Medicine (EMDM Academy) have in consultation with an international consensus group of experts agreed on the following definition: a disaster is an event in which the medical need exceeds the response capabilities in the affected area, mainly due to a large number and/or severity of injured or ill victims. This imbalance can be due not only to a quantitative and/or a qualitative shortage of resources (personnel and materials) but also to organizational or operational shortcomings [25].

2.1.2. Major incident

A situation in which available resources are insufficient for the immediate need for medical care is commonly defined as a major incident. The term major incident describes the actual response to a sudden event, where the goal is to ensure an effective and efficient response that is proportionate to the circumstances. The definition is more related to the balance between immediate need and immediate access to resources rather than to specific numbers of casualties [9]. The use of the word major to trigger activation of special resources and plans in response to an event can also have subjective interpretations [26].

Even if the definition of a major incident varies between countries, the content is similar. The Health and Safety Executive, UK define a major incident as ‘a significant event which demands a response beyond the routine, resulting from uncontrolled developments in the course of the operation of any establishment or transient work activity’ [27].
Another definition of a major incident is ‘an emergency that requires the implementation of special arrangements by one or more of the emergency services and will generally include the involvement, either directly or indirectly, of large numbers of people’ [28].

In this thesis, the term major incident is used in the Swedish context as a generic term in health care, health protection, decease control and social services for different types of events including the risk or threat to society and psychosocial impact as a result of traumatic events (e.g. transportation accidents, spread of hazardous material, infrastructure disruptions, armed aggressions). A major incident is as an event that is so extensive or severe that the resources must be organized, managed and used in a particular way. Sometimes events that, taken in isolation, may not warrant classification as major incidents, may do so when considered together (e.g. several large traffic accidents at the same time) [11].

Although the terminology may differ, it is more important that the terminology used has a practical function in providing a base for decisions and performance in response to an alert [9]. The aim of declaring a major incident is to ensure important parts of the medical response system occur, such as notification of the event, activation of medical emergency/disaster response plans and coordination of medical operations [25].

In some countries, a major incident is declared by the first ambulance to arrive at the scene and in others at the regional (strategic) level [10, 29].

2.1.3. Research

Disaster medicine is a multidisciplinary science involving many different fields of medicine (e.g. prehospital care, emergency medicine, traumatology, surgery, anaesthesiology etc). In addition to several medical disciplines, disaster medicine must have a scientific basis with the use of experimental research methods [21].
Disaster medicine research has often been limited to anecdotal and descriptive reports and therefore specific disaster research is rare and often limited in scope; a quantitative approach has been asked for [24]. Another limitation is that data collection generally has to be retrospective due to the unexpected and sudden impact of an event [17, 24, 30, 31].

The possibility of establishing research methods for creating evidence-based best practice in disaster medicine has so far been limited [24, 31]. Randomized controlled experimental studies that can prove that a cause–effect relationship can be established between independent and dependent variables are rare. Experimental studies of a health intervention effect in disaster situations are considered impossible or unethical [24].

The lack of standardized data collection from empirical methodologies and definitions has been identified as one of the key problems in research [32, 33]. A further challenge in disaster medicine is to find evidence-based standardized data that are comparable and can be used for research purposes [25, 34]. Different guidelines and protocols for prospective data reporting from major incidents and disasters have been reported suggesting a more common structure that could improve preparedness, planning and response [35–38].

Several studies comparing different terrorist bombing events have used the Disastrous Incidents Systematic Analysis Through Components, Interactions and Results (DISAST-CIR) methodology [38]. This methodology of presenting data in a uniformly structured set in order to make comparisons is highly recommended [39].

In Sweden, the KAMEDO group has been using another uniform method for post hoc investigation visits to the sites of an event. These reports have been very useful for the improvement of the national disaster preparedness [40].

In order to establish a framework for assessing the effectiveness of medical response to a disaster, a template for uniform data reporting has recently been developed by a consensus group of experts. The template is based on several data elements, definitions and indicators that can be used for research studies with a focus on different response systems strategies, effects and outcome. However, the template has not yet been tested [25].
2.1.4. Disaster medical response system

This thesis addresses the initial phase of the medical response to major incidents in which the involvement of regional medical management is recognized as having the greatest impact on patient outcome but does not include the mitigation, preparedness or recovery functions although these activities do influence the implementation of an adequate response. The thesis focuses on the demand that a major incident involving physically injured or ill patients places on regional medical management from a health care perspective.

Notification of an event
The notification of an event is of utmost importance and the Emergency Dispatch Centre (EDC) plays an important role in the emergency system. The first medical decisions in an emergency are usually made by the operator at the EDC when they receive the first notification about an event, resulting in a predetermined emergency medical service (EMS) response and an alert to the nearest hospital according to defined criteria [41]. In other types of events, such as power failures, epidemics or incidents in other countries, initial recognition often occurs at a single hospital or other authority, and in such cases the magnitude and impact on health care may be unclear [42, 43].

Prehospital medical response
A coordinated and organized prehospital medical response to major incidents is necessary to adequately care for the injured. The ambulance service is often the first medical resource to arrive and has many important functions during major incidents.

The first task is to establish medical command and control, establish communication with the EDC and submit timely situation reports following a clear structure with a request for additional medical resources. These initial reports are of outmost importance and in most emergency systems they are sent to the EDC for relay to other designated parts of the incident command system, e.g. nearest hospital and the regional (strategic) level of medical command [19].
The second task is to liaise with the rescue services and police concerning safety issues and initial strategies, establish triage, treatment and stabilization at the scene, and evacuate casualties to definitive medical care [9].

To achieve controlled distribution of casualties in a major incident, evacuation is done according to a distribution key, which is sometime predetermined or delivered from the strategic level. This distribution key needs to be continuously updated to match the hospital’s capacity [9].

**Activation of disaster medical preparedness plan**

The first activation from a level of daily care to a higher level of medical response due to a major incident is the activation of the disaster medical preparedness plan. The response phase is the most critical and important part and cover all the processes that should be directed at reducing morbidity and mortality, which is the main objective of the medical part of a disaster plan [44].

Any event that can have a severe impact on routine health care should be compared with the activation threshold for the plan and the appropriate management level in order to optimize the medical resources and preserve the quality of care and the integrity of the health care system [45].

One important aspect of a comprehensive disaster plan is an all-hazard approach, that is, the same plan structure should be used in all types of incident (e.g. the same initial alert process, levels of alert and initial establishment of command and control). The plan provides a basic framework in response to various major incidents [20, 46].

**Hospital response**

The hospitals alert system in a major incident various between different incident command systems. However, general opinion is that at least the first receiving hospital must receive an immediate alert [9, 19, 46].
The key to a successful hospital response to a major incident is an emergency department that is able to effectively triage incoming patients and casualties, continue or start life-saving treatment and rapidly transfer patients to facilities for definitive care within the hospital [46]. If this key function is overcrowded already at the onset of response, the outcome will be suboptimal [47].

The decision makers at the regional level must have access to accurate information about hospital capacity so that early referrals can be sent to the appropriate place, appropriate requests for assistance can be made and whether a regional redistribution of patients is required [44].

**Coordination of disaster medical operations**

Coordination of disaster medical operations encompasses all medical and non-medical actions required to achieve the response objectives following activation of the response plan. To perform the necessary activities, health care services must be incorporated into an integrated medical management system composed of an operating structure including the division of tasks, roles, responsibilities and authorities [25, 48].

This also includes the coordination of diverse medical and non-medical operational assets. Rescue, decontamination, triage, stabilization, evacuation, and definitive treatment of casualties, performed by all the operational assets involved, also require multidisciplinary cooperation. It is essential that these assets function together effectively to work towards minimizing mortality and morbidity of the survivors [25].

### 2.1.5. Situational awareness

The term situational awareness means comprehension of the situation-specific factors that affect the performance of complex tasks to facilitate effective, real-time decisions during rapidly evolving events [49]. Situational awareness has been recognized as a critical foundation for successful decision making across a broad range of complex and dynamic systems such as aviation, air traffic control, power plant operations, command and control, and emergency services.
Situational awareness involves being aware of what is happening and understanding how information, events, and one's own actions will affect goals and objectives, both immediately and in the near future. Furthermore, there is a strong correlation between the accuracy, timeliness and reliability of the information available to the decision makers and the quality of decisions [50].

Information systems that support visualization of information during an event can contribute to more complete and accurate situational awareness [51, 52].

It is also important that disaster medicine is enriched through this multidisciplinary approach to crises management and takes advantage of the knowledge available in other research domains. This knowledge could be applied to the complex management of a major incident and improve our understanding of how to best support medical management at all levels.

2.1.6. Resource management

Dealing with major incidents places extraordinary demands on health care services. A major incident can rapidly change the situation from being resource rich to being depleted, which can affect the capability to establish medical care [21]. The term resource management is sometimes defined as efficient and effective deployment of an organization’s resources when and where they are needed [53].

Even though there are differences between countries in how emergency/disaster medical response systems are organized, this level of management is often referred to as strategic management, gold level or regional medical command and control. This level of command and control can make the overall decisions regarding mobilization and allocation of resources and distribution of casualties to minimize the consequences of the existing shortage [7, 10, 54–56].
Generally there are three management levels in a health care management system for major incidents and disasters: national, regional (strategic) and local. This is a hierarchical structure in which the relationship can be described as a higher level making demands and setting limits for those lower down. Furthermore, a higher level can increase the framework for resources and ensure that new resources are created and their use is optimized [10].

Several studies from major incidents and disasters have identified many shortcomings within command and control and resource management [55, 57–59]. Management elements that have been identified as problems areas are:

- delay in declaration of a major incident or disaster
- dispatch centre had no essential data (lack of structured reports)
- delay in scaling up medical response
- late, insufficient or uncontrolled distribution of casualties
- insufficient contact with medical commanders at the scene
- lack of notification of the event to hospitals
- scaling up or scaling down of hospital response
- different or inadequate methods for triage
- triage tags not used
- disagreement about medical treatment
- information (who, what, where, when, how)
- communication (technical and procedural)
- disaster plans and standard operational procedures not known
- no clear responsibilities
- international cooperation
- insufficient training
Regional medical response systems that can contribute to a more efficient and coordinated medical response have been established in many countries. This regional coordination has also shown a reduction in mortality [8, 60].

In several studies, the objective of medical response is described as the ability to meet the imbalance between needs and available resources in major incidents, emphasizing that sufficient resource management must be established immediately to avoid overwhelming the system and the risk of an unfavourable outcome [39, 59, 61].

2.1.7. Triage

Triage is described as a process whereby the injured are sorted and prioritized; ever since the Napoleon wars, different principles for prioritizing victims have been used. The main purpose of primary triage is to assign treatment and transportation priorities to multiple casualties [10].

Triage at the scene can be performed based on physiologic or anatomic data or a combination of these. Physiologic triage (primary and secondary) uses physiologic parameters; anatomic triage is based on the observed injuries and the severity of injury. Primary triage is used at the incident site for evacuation and transport to definitive care by using physiologic parameters such as motor response, respiratory and circulatory parameters (e.g. START triage, Triage Sieve, Care Flight, Sacco). Secondary triage is used in combination with primary triage and establishes the order in which the patients receive care at the hospital [9]. The result of triage at the scene must be communicated to the regional level in the early phase as the basis of a strategic overall medical approach and accurate distribution keys [10].

Major incident triage is a neglected field for scientific studies and how to determine the effectiveness of triage tools has been identified as an important research priority. One problem is that the systems and algorithms used are validated only for trauma patients and not for injuries in other types of events due to chemical, biological or infectious hazards [62].
There is no simple method for identifying those who are critically injured, which often creates the possibility of overtriage. Overtriage means the assignment of non-critically injured patients to immediate medical evacuation to hospital. Triage accuracy has been proved to be of great importance. In a study of terrorist bombings, a mean overtriage rate of 59% was found. This study also demonstrated that there was a linear relationship between the overtriage rate and critical mortality [63].

An analysis of the medical response to the bombings in London 2005 found that triage accuracy improved when the triage sieve was performed by trained, experienced EMS personnel compared with medically trained bystanders [54].

Prioritization is based on the severity of injury, treatment priority, and transportation ability. Because of prioritization, not all victims will receive the optimal care immediately, and deaths in certain groups might be inevitable; therefore, it is imperative to set medical and organizational priorities [64]. Such priorities can also be supported by a strategic/regional level of medical management [7, 8].

Major incident triage is dynamic and patients are repeatedly re-triaged along the evacuation chain and at the receiving hospital until definitive treatment is received. The triage process must be seen in a wide context and comprises the following elements:

1. Rapid evaluation of casualties
2. Assessment of the nature and severity of the injuries and their effects on vital functions
3. Categorization of casualties
4. Stabilization and conditioning for transport
5. Distribution and evacuation of casualties
6. Admission, if appropriate, to health care facilities for definitive care [25]
Many shortcomings in triage have been identified, most of which are due to the simultaneous use of several different triage tagging systems contributing to confusion; national standards have been called for in the United States, Australia and Norway [64].

In a major burn incident, correct triage is crucial for prioritizing transportation and selection criteria must be adopted to determine treatment priorities. Estimating the extent of burn injury by estimation of total body surface area (TBSA) is difficult at an incident site, making triage even more complicated [65, 66].

A study of the Volendam café fire in 2001 showed that the value of triage efforts involving mass burn casualties was limited and that rapid transportation of the injured patients to nearby hospital emergency departments still has priority because accurate assessment at the scene can be very difficult and can only be performed in hospital [65].

Priority tags have been used for many years within the EMS service and are included in the medical team’s equipment. Although triage and tagging are considered important in all training and education courses, there are only a few reports on their actual use in real incidents.

In a Swedish prospective study, the professional prehospital medical personnel were asked about the use of tags in their daily work and 68% replied that they had only used priority tags in training and exercises. Only 10% had used priority tags in a real incident and 21% had never used priority tags [67].

2.1.8. Distribution of casualties

There is a general perception that a short interval between the initial injury to definite medical treatment offers the best chance of survival [68]. Therefore, in order to optimize outcomes, one of the most important tasks of the medical management in major incidents is to establish an effective evacuation system to transport the injured from the scene to an appropriate health care facility [59].
Several case reports from major incidents and disasters show that injured survivors are usually rapidly evacuated within 1–3 hours after the incident [54, 55, 57–59, 66, 69]. Furthermore, a recurrent problem in several major incidents has been uncontrolled distribution resulting in individual receiving hospitals becoming overwhelmed and patients being transported to health facilities not capable of caring for the critically injured [21, 58, 70]. Therefore, the challenge in major incident management is to synchronize the medical response from all levels and after a rapid triage at the scene, decide on referrals and distribute casualties optimally between health care facilities [39]. Selection of the destination must be based on the best assumptions of the patient’s needs, the capabilities and capacity of individual hospitals and the resources available in the system [21, 59].

In a study on the tsunami in the Indian Ocean in 2004, Leiba et al. [71] found that establishment of first aid and triage and rapid evacuation to a secondary hospital was the best strategy concerning survival outcomes.

The Utstein template for acute medical response [25] describes several factors that must be considered regarding the distribution and optimal use of health care facilities:

- Number and flow of ill/injured survivors
- Injury types and severity
- Evaluation of the needs of the ill/injured
- Individual capacities and capabilities of the receiving health care facility
- Distance to health care facilities
- Evacuation capacity of the response system

In rural and sparsely populated areas, the challenge of coping with a major incident involving many casualties is even greater and a rapid response time, allocation of resources and accurate triage can have an impact on patient outcome [56]. The EMS and the nearest hospital can often offer limited resources and severely injured patients might need long-distance transportation to university hospitals. The nearest hospital must also be prepared for self-evacuated patients [58].
Different opinions exist on whether it is best to transport the most critically injured to the nearest hospital immediately or directly to the best-matched health care facility [72, 73]. Therefore, defining the main objective and strategies for medical management and distribution from an overall perspective is important to ensure that all patients receive optimal care [69].

Burn patients have usually been transported from the scene as quickly as possible first to a general hospital and then to a burn centre. In the Summerland fire in Douglas, Isle of Man for example, primary triage was not performed until after arrival at a hospital [74]. In both the Gothenburg fire and the Volendam café fire, however, several patients received treatment at the scene, because evacuation of casualties was protracted [3, 75].

Currently, the optimal method of handling burn casualties at the scene of a major incident depends on the location of the accident, the transportation possibilities and the number of casualties. Further research to identify the optimal strategy for emergency response in a mass casualty burn incident is warranted [76].

2.1.9. Time perspective

From a medical point of view, the most important issue in disaster management is to minimize mortality and morbidity (both physical and psychological) of the victims involved; good management is related to a favourable outcome [54, 77].

In the management of severe trauma, the time from injury to definitive care has been considered to be an important factor, yet the relationship between time and patient outcome remains unclear [78–81]. Several studies show conflicting results about the effect of short response times on patient outcome in cases of trauma [81–85]. Traditionally, a prehospital time interval greater than 60 minutes has been shown to be related to an increased risk of death and the term golden hour is commonly used to characterize the urgency for care of trauma patients [86]. In a recent study by Hoejenbos et al. [87], it was concluded that there is no such golden timeline, and that it is more important that a medical system is flexible and can adjust to each specific local situation.
In addition, several studies have indicated a direct correlation between the time interval from rescue to definitive care and survivor mortality. The time interval between impact of injury to definitive care is an important prognostic factor that can effect survivor outcome [48, 63, 88]. However, there is still a general perception that the response to a major incident is sensitive to time and rapid intervention from health care is required to improve outcome [45, 89, 90].

Major trauma transportation times are different in metropolitan and rural areas. In a comparison study on major trauma transportation in Western Australia, Fatovich et al. [91] found that there is more than double the risk of major trauma deaths in rural and remote areas and that time from the trauma to first prehospital care is very important.

A significant factor in rural areas is the accessibility to transport resources (e.g. ambulances and helicopters) to achieve rapid patient evacuation. Experience from the shootings in Oslo and Utøya Island in 2011 demonstrated the vital importance of an accurate triage and optimal use of ambulance helicopter resources [77]. However, the literature shows varying results with regard to post-trauma mortality and helicopter transport. Most studies demonstrate a significant improvement in trauma mortality when patients are transported directly by helicopter to level 1 care [92, 93].

Different quantitative models have been developed to identify benchmarks for prehospital response time to multiple casualty events in relation to trauma, but prospective studies of these models are needed to examine their validity and applicability [94, 95].

This thesis is based on the hypothesis that all decisions in management that can influence the time from injury to definitive care should be made by trained personnel after careful evaluation. If management decisions, such as declaring a major incident, and decisions about resources and referrals are delayed, crucial time in the initial response phase might be wasted and the victims may be at risk of an unfavourable outcome [86, 96].
2.1.10. Surge capacity

A health care system needs surge capacity when the medical and health needs of the patients exceed existing resources. To enhance hospital preparedness, efforts must focus on how to improve the surge capacity [46]. Medical capacity is a term used to describe the number of persons that can be evaluated or treated within the health care system at any given time. Medical surge capacity is the maximum number of persons the health care system can evaluate and treat on sudden demand [97]. In remote areas, the threshold of surge capacity is different compared with a resource-rich metropolitan area [22]. Another key issue in surge capacity is the special need for expertise and specialist care for specific patient groups (e.g. burns, paediatrics, contaminated, neurological trauma) [44]. This has been defined by Hick et al.⁴⁴ as surge capability, i.e. the health care system’s ability to manage patients who require specialized evaluations or interventions.

There are three essentials components of surge capacity:

- staff (trained personnel)
- stuff (equipment and supplies)
- structure (physical space and management infrastructure such as an incident management command system with policies and procedures for escalation) [46]

Although disasters and mass casualty incidents are rare events, severe traffic accidents, fires, threats and interference with hospital infrastructure occur more often [7, 98]. Even a moderate-sized incident can affect the health care system to the extent that even a small expansion in capacity requires activation of the emergency or disaster plan [99]. Overcrowding of emergency departments, a constant lack of hospital beds and technical problems are a normal part of life in hospitals but can directly influence emergency/disaster preparedness by reducing surge capacity [100].
Simulation can be a useful tool in planning and identifying the typical and critical bottlenecks that may develop in a hospital during a multiple casualty events; e.g. in the imaging departments, availability of intensive care unit (ICU) beds, availability of immediate surgery, staff or material shortages, etc. Knowledge gained can support different strategies and decision making at all levels in hospital management [101]. Although valid methods for measuring preparedness are lacking, simulations in which the decisions can be related to patient outcome, not only for the incoming casualties but also for in-hospital patients and other routine arrivals to the emergency department can be part of a valuable surge benchmarking system [46]. The results can be used to minimize deviations from the guidelines, eliminate mistakes in management, and reach an acceptable threshold for every hospital [101]. In this thesis, the surge capability during a mass casualty burn event in a rural area was studied in two simulations in paper IV.

2.1.11. Quality control

Measuring quality of care within all fields of medicine is important. More than 30 years ago, Donabedan [102] proposed that the quality of health care could be measured by observing structures, processes and outcomes. Quality indicators are routinely used in several areas of the health care system and there is also an assumption that they provide a valid reflection of the outcome of care [103, 104]. The goal of developing quality improvement programs that rely on key performance indicators to continuously monitor a system’s overall performance and effectiveness has been identified [105–107].

Even if quality control is now included in almost all medical areas, there is still a need for further development and implementation in the field of disaster medicine [24, 25]. The National Board of Health and Welfare in Sweden has stated the importance of quality control and patient safety within health care in national regulations and guidelines [108]. The National Board have also urged the health care system to set standards for all areas of disaster preparedness, which could lead to more structured follow-up and quality control in the management of major incidents and disasters [11].
2.1.12. Process and outcome indicators

The literature often distinguishes between process indicators and outcome indicators. Process indicators measure the repeatable sequence of actions used to improve or produce good patient outcome, e.g. the output of activities or interventions [17, 105, 109]. Dunford [110] describes measurable performance indicators as tools that should be "specific, measurable, actions oriented, relevant and timely".

The mortality and morbidity rates are the most common outcome indicators used in medical management to measure the actual response to an intervention or the intended achievements. Although outcome measures of quality represent the desired end results of health care, validated process of care measures provide an important additional element to quality improvement efforts, as they indicate which provider actions should be changed to improve patient outcomes [111].

Several systems are available for scoring trauma severity in daily care. The most widely used systems for the purpose of predicting outcome after trauma are based on combined anatomic and physiologic parameters. Systems such as the Injury Severity Score (ISS) and the Trauma Injury Severity Score (TRISS) have been useful and have proved popular over time, but there is no ideal scoring system available [112].

There is no current evidence that victims from disasters and mass casualty events have a poorer outcome than daily trauma victims and only one study reports significantly poorer outcome for patients in a mass casualty event than individuals with the same type of injury mechanism [113].

In assessing medical response to disasters, it is important to distinguish between immediate deaths due to the impact of the hazard and the number of deaths that could have been prevented if optimal care had been delivered. The mortality rate of the immediate category of survivors has been suggested as a meaningful outcome indicator for the effectiveness of medical response and comparison of patient outcome from major incidents and disasters [54, 114].
Measurable performance indicators as standardized benchmarks for quality of management have been introduced in disaster medicine but have mainly been used as a method for standardized evaluations of performance in education, training and exercises to increase comparability [13, 16, 115]. The challenge is whether these indicators can be validated by demonstrating their relationship to a desirable patient outcome and thereby be associated with good results of disaster management and accepted as best practice [116].

2.1.13. Development of measurable indicators

As part of the development of a national doctrine for medical management at major incidents and disasters, the National Board of Health and Welfare conducted a concept and process modelling in 1999–2001. Important key processes in the management of major incidents evolved from this work and objectives and standards were established as measurable goals of medical management performance. The goals and standards were based on the overall goal of supporting the patient management process and were expressed as measurable performance indicators. The content of the modelling process and the method used for the development of the indicators have been described previously in two studies by Rüter et al. [14, 117].

To briefly summarize the process, all important management processes were identified and an ideal time frame was decided based on what are considered to be accepted standards in the management of severe trauma and best practice in the management of casualty incidents and disaster management [79, 118]. All processes identified were then linked and their relationships to one another established and described. Similarly, all processes involvingprehospital management and the initial regional medical management were linked sequentially (e.g. one process leading to or depending on another). All standards were based on the overall goal: to support the patient management process.
Since then, the measurable performance indicators extracted from this process have been used within national educational programs for evaluation of student performance and the effectiveness of disaster management training in combination with different simulation techniques [119, 120].

Previous studies have also shown that performance indicators can be useful as a method of evaluating command and control at different levels in full-scale exercises as well as staff skills procedures in management groups, and can create measurable and comparable results [13, 121]. Performance indicators for prehospital medical command and control have also been tested and used in a military setting [115].

In this thesis, measurable performance indicators for initial regional medical command and control derived from the national process and concept modelling have been used in three of these studies. This has been a part of a validation process to examine if these indicators have validity and reliability and whether they are useful as a tool for evaluation of medical response at real incidents. Based on this experience, a set of measurable indicators for national coordination of burn care was developed and used in study IV.

2.1.14. Staff procedure skills

In stressful situations such as the management of major incidents and disasters, the ability to work in a structured way is important. Medical management groups are initially formed by personnel (doctors, nurses, administrators) from different departments who are often on call at that particular time, but who are not always trained to work together. The purpose of staff is to add competencies, e.g. experts on public information and communication, psychological trauma support, hospital infrastructure and other administrative or medical support to increase the management capacity of the chief. Staff procedure skills can be described as the administrative ability of central staff to work as effectively as possible [10].

Good staff procedure skills in a management group during incidents and disasters are believed to be a prerequisite for good management of the situation.
To be able to evaluate staff procedure skills, a set of measurable goals that are known to all members is needed so that the staff are working more effectively. A systematic approach with performance indicators as standards has been used in the thesis for the evaluation of these skills and where areas for improvement within the medical management were identified [16]. Staff procedure skills have previously been measured during simulation exercises and an overall significant relationship has been identified between staff procedure skills and management skills in the evaluation of hospital management groups [122].

2.1.15. Education and training

Many difficulties or problems that have occurred in the management of major incidents and disasters can be traced to insufficient education and training and the low levels of skills of the staff involved [98, 123]. Routine knowledge and daily experience can be insufficient when professionals suddenly have to work in a disaster situation [123]. A recent study by Corrigan [124] showed that hospital staff feel that they are unprepared for dealing with a disaster and that additional education, and especially simulation exercises, are needed to increase the preparedness.

An appropriate level of education and training in the special principles and management practices for major incidents and disasters is imperative [125]. Several studies have demonstrated the effectiveness of management training [121, 126, 127]. Training programmes in disaster management that include exercises have been shown to significantly improve knowledge of professionals and by setting up standardized national training programmes, it is possible to enhance knowledge in a short period of time [119, 128].

Furthermore, lessons learned from six major bus crashes in Sweden have shown that the implementation of a standardized educational programme based on a national doctrine for medical command and control seems to be one of the reasons for the good outcome of these events [6]. However, there is little scientific evidence that a specific training intervention is effective in improving knowledge and skills, and what methods to use for evaluation of performance [129, 130].
In disaster medicine, education, training and improved planning are considered to be the most effective initial steps to increase preparedness and improve knowledge and skills, and they need to have a scientific base as in all other areas of medicine [131]. In a European survey on training objectives in disaster medicine, it was found that most countries wanted to emphasize the training of mass casualty incidents with regard to medical command, management, alerting procedures, assessment of immediate needs, casualty distribution and protection, and safety procedures [131].

Areas in disaster medicine that have been described as especially important in training are:

- Disaster planning and rehearsal
- Integration of local, regional and national resources into a disaster management system
- Hospital emergency management
- Communications and security
- Media relations
- Protection of health care delivery personnel and facilities
- Detection and decontamination of biological and chemical agents and radiation exposure
- Triage principles and implementation
- Logistics of medical evaluation, stabilization, disposition and treatment of victims
- Record keeping and post-event debriefing, critique and reporting
- Critical incident stress management
- Published research and experience in disaster management [125]

2.1.16. Simulation

Much of the research on teaching adults indicates that active participation is an important factor and that adults learn best when they are actively engaged, participate, play a role and experience. The combination of actively experiencing something, particularly if it is accompanied by intense emotions, may result in long-lasting learning [132].
This type of learning is best described as experiential learning (learning by doing) and is particularly suited to professional learning, where integration of theory and practice is pertinent and ongoing. Simulation offers the opportunity for practical experience in a controlled fashion, which can be reflected on at leisure [132].

The value of conducting simulation exercises is emphasized in virtually every textbook on disaster management [18–20]. One of the cornerstones in medical response to major incidents and disasters is decision making at all levels. Exercises and simulations have been shown to be an effective way of approximating different scenarios and enable emergency planners and responders to test procedures and decision making involving the various areas of disaster management, e.g. command and control, triage, medical management, coordination, surge capacity, etc. [120, 133, 134].

Disaster exercises can also be used as a proxy environment to evaluate and improve potential research instruments designed to study the application of medical management resources during major incidents and disasters [31].

Table-top exercises are the least formal and a discussion-based problem-solving method is often used. The actions tested are action intentions and not operational executions [135]. Table-top exercises are commonly used in emergency and disaster management training and have been shown to improve the development of emergency plans, enhance the dialogue among professionals and can be used to identify strong and weak points that need to be addressed [136–138].

The simulation models that can be used for table-top exercises include:

- Tables with symbols moved on maps
- Labels and tagged symbols placed on magnetic whiteboards
- Computer-simulated environments
Compared with a table-top exercise, a functional exercise is more complex for testing operational procedures and planning, a whole emergency plan or segments of a plan including, alerting, response, triage and treatment, hospital surge capability and cooperation (liaison). Functional exercises are usually executed in real time and may involve a single response agency or several agencies. Depending on the aim of the exercise, the design can be done using a simulation model or live in the field [135].

The most complex model is a full-scale exercise aimed to test all or a major proportion of the emergency response system and requires the statement of many exercises goals and a full staff of evaluators and controllers [135].

To set up an effective simulation exercise, the design is of utmost importance, e.g. set clear aims, goals and learning objectives and define all relevant input data:

- Available resources (staff, transport resources, material, competencies, numbers of hospitals, bed capacity, intensive care and surgical capacity, etc.)
- Geography, transportation times
- Scenario based on realism (number of casualties, types and percentage of injury categories)
- Pre-planned interventions
- Methods for recording data (evaluation templates) [9]

Although exercises can identify both strengths and vulnerabilities in preparedness, reliable metrics to gauge exercise performance and evaluation criteria are warranted [130, 139]. Furthermore, it has been suggested that more attention should be given to evaluating the effectiveness of disaster training activities in a scientifically rigorous manner, where the evaluation is based on performance improvement [126, 140].
A prerequisite for results from evaluations to be comparable is that the exercises/simulations are executed and evaluated in the same way, making it possible to obtain valid data. Several studies have demonstrated the possibility of applying both performance and outcome indicators in simulation exercises and full-scale exercises as a method of achieving a more standardized evaluation [13, 120, 141, 142].

### 2.1.17. Simulation system

The Emergo Train System (ETS) is a simulation tool that has been used to evaluate civil major incident doctrines, preparedness, triage, patient management, command and control and surge capacity. ETS allows modulation of known resources and competences to measure the effectiveness of alterations in medical organization and resources. The core of the system consists of a patient database with specific casualties and typical in-hospital patients together with specific staff and other different types of resources involved in emergency/disaster management; local prerequisites can be added to the system.

All ETS victims belong to a specific standardized injury category based on the Abbreviated Injury Scale (AIS) and the Injury Severity Score (ISS) [112]. Each victim has a defined medical need within a certain time frame and the time taken for each measure is calculated according to a defined standard. If a patient’s specific need (e.g. airway intervention, pleural drainage, surgery or ICU assessment) is not met within the stipulated time frame the patient is at risk for an unfavourable outcome. This risk is expressed by the system as a risk for preventable death or a risk for preventable complications. Thus, at the end of a simulation exercise, it is possible to calculate and summarize patient outcome and relate the result to the treatment given and to other decisions made.

The method allows modulation of known resources and competences to measure the effectiveness of alterations in medical organization and resources. ETS combines patient outcome with measurable performance indicators, which objectively quantifies the effectiveness of a medical intervention [143].
The different injury categories have been developed in a consensus process with national experts within the fields of traumatology and disaster medicine and in accordance with evidence-based best practise of trauma care. The specific burn categories have been developed in consensus and in collaboration with national burn experts in Australia and Sweden. Similar simulation systems exist as well as different computer-based simulation models [9, 131, 144, 145].

In this thesis, the decision-making performance of the initial regional medical command and control and staff procedure skills were measured during ETS simulation exercises in paper I. In paper IV, a simulation was designed using the ETS to measure the surge capability of the Swedish health care system in case of a mass casualty burn incident in a rural area. In both studies, the results were related to patient outcome.

2.1.18. Burn planning

An event resulting in many severe burn injuries could be a reality within any community and requires extreme efforts from the entire health care system. A situation where capacity needs exceed that of the available specialized burn centres may become a reality very quickly and warrants a planned response [75].

Burn centres play a key role in the preparation and response to a major incident. It is likely that more than one burn centre will be affected by any one incident. Burns units must make plans for rapid expansion of facilities through local and regional measures or via liaison with other units [146].

The need for planning for mass casualty burn events has been highlighted and the International Society for Burn Injuries (ISBI) has published guidelines for the management of multiple or mass burns casualties recommending that each country should have a disaster planning system that addresses its own particular needs [147].
In a comparison of events that have occurred in the last 20 years, Barillo and Wolf [148] suggest that the ability to handle an event involving 25–50 cases of burn injury may be an adequate number to prepare and plan for, and that such a plan should always be tested and critically evaluated.

Although single patients with severe burns are routinely transferred directly to burn centres, this strategy may have to be rapidly changed in a mass casualty incident when distribution to various local and regional hospitals is needed [66].

The challenge for the receiving units, at least initially, will be to stabilize and treat life-threatening injuries until secondary transport to a burn centre is possible. This primary distribution will perhaps ease some of the initial load for the burn centre but will quickly escalate in a secondary distribution phase when transport to a specialized burn care centre is necessary [149].

Many lessons have been learned from the Gothenburg discothèque fire in 1998 when 63 young people died and 200 were injured in one of the worst fire disasters in Sweden in modern times. The discothèque was located in a metropolitan area with several large hospitals within a short distance and the shortcomings in communication between command at the scene and the hospitals were compensated by the fact that patients were rapidly evacuated to different hospitals within 2 hours after the accident [3].

Experience from other burn disasters has shown that the availability of national specialized intensive care resources can quickly become saturated for a long period of time [3, 75]. Therefore, the need for additional use of burn beds in Europe would probably arise in the longer term. National planning in case of such needs is called for.
Based on the content of a new health care law, the Swedish National Board of Health and Welfare centralized all advanced burn care into two national burn centres in 2010 (in Linköping and Uppsala). One of the assignments was to also establish a national burn disaster management plan. In this thesis, the Swedish national burn response plan, including national coordination of burn care, was evaluated in two simulations in paper IV.
3. AIMS

The overall aim of this thesis is to improve understanding of the demand for a rapid and accurate regional medical response at major incidents. The research focuses for this thesis are:

- To identify specific important decisions of regional medical management.
- Compile and analyse strong areas, weaknesses or deficiencies in the initial regional medical response.
- Identify major incidents in selected regions and identify criteria and regionally developed objectives.
- To identify which developed objectives can also be applied nationally.
- To identify factors that influence patient time to definitive treatment and what decisions need to be quality assured.

Table 1 lists the specific aims for the four papers in this thesis.
<table>
<thead>
<tr>
<th>Paper</th>
<th>Title of the paper</th>
<th>Aim of the paper</th>
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<tbody>
<tr>
<td>I</td>
<td>Management of resources at major incidents and disasters in relation to patient outcome: a pilot study of an educational model</td>
<td>To relate the decisions made regarding resources to patient outcome in simulation exercises</td>
</tr>
<tr>
<td>II</td>
<td>Quality control in disaster medicine training—initial regional medical command and control as an example</td>
<td>To identify what decisions in the initial regional medical command and control need to be improved. The hypothesis was that measurable performance indicators can create comparable results and identify weak and strong areas of performance in regional medical management education and training</td>
</tr>
<tr>
<td>III</td>
<td>Performance Indicators for initial regional medical response to major incidents: – a possible quality control tool</td>
<td>To identify the occurrence of major incidents and the weak and strong parts of regional medical management</td>
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<tr>
<td>IV</td>
<td>Simulation-assisted burn disaster planning</td>
<td>To evaluate the Swedish medical system’s response to a mass casualty burn incident in a rural area with a focus on national coordination of burn care. To determine the robustness of the outcome and the reproducibility of simulations</td>
</tr>
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4. MATERIALS AND METHODS

This chapter describes the materials and methods used in the four papers in this thesis. An overview of the study setting in the different papers is presented followed by a presentation of the measurable performance indicators used in the four papers. Papers I and IV analysed if decisions made in management regarding resources could be related to patient outcome in a simulated environment. Papers II and III analysed strong and weak areas of the initial regional medical management at major incidents in an educational setting and in real events.

4.1. Study context

This section provides a description of the overall study context of the four papers in this thesis. A brief description of the Swedish emergency preparedness system for health care is given.

4.1.1. Swedish emergency preparedness system

In Sweden, emergency and crises management is mandatory based on an Act (2006:544) concerning municipalities and county councils. To ensure that emergency management takes interdependence into account, the planning and resource allocation for peacetime emergency preparedness is built on a system whereby the various stakeholders take joint responsibility. This means that despite different legislations, the responsibility for emergency and disaster preparedness is shared by the emergency authorities, e.g. rescue, police and health care, all with a mutual responsibility to plan and prepare for emergencies and disasters. The Swedish structure for civil emergency planning is coordinated by the Swedish Civil Contingencies Agency (MSB) [150].
The National Board of Health and Welfare (NBHW) is a government agency in Sweden under the Ministry of Health and Social Affairs. NBHW works within the fields of health and social care, environmental health, communicable disease prevention and epidemiology. One of their duties is the coordination and monitoring of the emergency preparedness in health and medical services within the county councils and the municipalities.

In Sweden, responsibility for providing health care is decentralized to the county councils and municipal governments. County councils are political entities whose representatives are elected by the electorate every 4 years. Every county council must provide residents with good quality medical care, and promote good health for the entire population. Sweden has 20 county councils (two of which are referred to as regions) and 290 municipalities. One municipality, the island of Gotland, has the same responsibilities for health care as the county councils [151].

Health care, social care, disease control and environmental health are ultimately regulated by laws and statutes. Based on legislation, the NBHW draws up regulations and general advice to regulate and guide those responsible for health and social care and their staff in their work on raising quality and increasing security and efficiency. The regulations are binding, and the general advice contains recommendations on how the laws and statutes can, or should, be applied [152].

In a national regulation for disaster medicine preparedness, the NBHW has chosen to define the situations that require a specific setup of incident medical management for health care for major incidents (swe= allvarlig händelse). Major incident is used as a generic term in health care, health protection, decease control and social services for different types of events including the risk or threat e. g. transportation accidents, spread of hazardous material, infrastructure disruptions, armed aggression and the psychosocial impact on society as a result of traumatic events [153].
In the regulation for disaster medicine preparedness [153], it is stated that within every county council’s health care system there must be an official with the authority to establish immediate regional medical command and thereby have control over all available medical resources within the region. In practice, the EDC can 24 hours a day on specific alarm criteria alert a DDO at the regional level who is empowered to take immediate action, depending on the type and magnitude of the incident.

Only the DDO is authorized to declare the situation a major incident for the county council’s regional medical organization and thereby activate the regional preparedness plan at the appropriate level [7, 10, 11]. Each county council determines if an event needs to be declared as a major incident and to what extent the regional medical preparedness plan needs to be activated, depending on their own capacity and the resources available at that time.

A delay in declaring a major incident may affect the medical response so the standard is to do it once too often rather than not do it when it is needed [26]. According to the Swedish national disaster preparedness doctrine, this decision is made at the regional level by the DDO after an alert from EDC or the medical incident command at the scene. The decision can also be made as a result of a specific situation occurring within the health care system, such as interference with the hospital infrastructure.

The notification of an event is of utmost importance and the EDC plays an important role in the emergency system. The first medical decisions are usually made by the operator at the EDC who receives the first call about an event [41]. Each county council has their own agreements on when the EDC must alert the DDO (Figure 1).
4.1.2. The County Councils of Södermanland and Östergötland

In paper III, 130 major incidents that occurred in the County Councils of Södermanland and Östergötland from 2006 to 2009 were studied. The two county councils are located in Sweden’s largest metropolitan areas after Stockholm, Gothenburg and Malmö, with approximately 699 000 inhabitants living in urban and rural areas. Within the region, there are five emergency hospitals. The University Hospital in Linköping is the largest and it provides highly specialized medical health care including a national burn centre.

The two county councils are similar in terms of regional medical management for major incidents and have fully implemented the national medical incident command and control system. All personnel acting as the county council’s DDOs are nurses with special education and training in disaster management and preparedness.
They all have good knowledge of the local and regional health care organization, and in their daily profession they work within hospital emergency management or regional health care disaster preparedness. Furthermore, they have a clear regional mandate to take immediate medical decisions over all medical resources within the county [154, 155].

During the study period for this thesis, the measurable indicators for prehospital command and control were implemented as standard operating procedures in both county councils, but no measurable indicators or predetermined goals for regional medical response were implemented in the disaster plans.

4.2. Materials and methods for papers I–IV

The thesis is based on four studies. The first study was a pilot study in an educational setting conducted during a simulation exercise. The second study was an observational study to identify strong and weak areas within the initial regional medical command and control conducted during nine similar educational programs. Study III evaluated retrospectively the performance of initial regional medical response in major incidents that occurred in two Swedish county councils. The fourth study evaluated the Swedish national burn response plan against fixed outcome indicators. The templates for the performance indicators in this thesis are presented in section 4.3.

4.2.1. Paper I. Management of resources at major incidents and disasters in relation to patient outcome: a pilot study of an educational model

Paper I was a pilot study conducted during a simulation exercise that was a part of a national educational program in disaster management. The aim of the study was to show the possibility to relate decisions made regarding resources to patient outcome in simulation exercises. Participants from different regions in Sweden were assigned to different management groups (hospitals and regional). This was the final exercise of the course and they all had previous experience from two prior exercises.
Each group worked in a separate staff room and could communicate with the other groups and counterplay by telephone. All interventions were standardized in objective and time according to a predefined template. Simulation was run in real time and the participants were alerted one by one.

The scenario was a large fire at a football arena with substantial structural collapse, fire and 100 casualties. All available resources in a fictitious geographic area were defined according to a disaster preparedness plan. Resources were visualized using ETS on large whiteboards making it possible for the counterplay to have control over logistics, resources and patient flow. Counterplay was made by professionals from the EDC, rescue services, police departments, ambulance services, media and national authorities all sitting in the same room. All had previous long experience of simulation exercises and the ETS.

Evaluation of the exercise was made using a set of 11 measurable performance indicators for initial regional medical command and control and staff procedure skills. The results of each indicator were scored 0, 1 or 2 according to the performance; 0 = objective was not met at all, 1 = objective met but not within the stipulated time frame, 1 = objective was partially met within the time frame, 2 = objective completely met within the stipulated time frame.

In the ETS, each victim had specified needs that had to be met within a specified time frame to avoid the risk of an unfavourable outcome. At the end of the exercise, the outcome was measured as the risk for preventable death. A total score of performance indicators was calculated together with the results of patient outcome (n = preventable deaths).

4.2.2. Paper II. Quality control in disaster medicine training—initial regional medical command and control as an example

Paper II was a prospective observational study in which 18 regional management groups were evaluated during 18 simulation exercises for regional and hospital medical command and control at major incidents. The set up of the simulation exercises was the same as in study I and the participants were observed during the simulation exercise by closed-circuit television.
The evaluations of all simulation exercises were done by the same three observers, who were all trained and experienced teachers within the course faculty. The participants were evaluated according to the performance of the management group.

Management performance was evaluated using a set of 11 measurable performance indicators for initial regional medical command and control. The results of each indicator were scored 0, 1 or 2 according to the performance: 0 = objective was not met at all, 1 = objective met but not within the stipulated time frame, 1 = objective was partially met within the time frame; 2 = objective completely met within the stipulated time frame. The total possible score was 22 and a score of 11 points was considered to be an acceptable result. The average score from all simulation exercises was calculated as well as the average score for each performance indicator. Two-way analysis of variance with one observation per cell and the post hoc Tukey test were used to compare means within and between groups. A p value <0.05 was considered significant.

4.2.3. Paper III. Performance indicators for initial regional medical response to major incidents – a possible quality control tool

Paper III was a retrospective observational study of 130 major incidents that occurred in two county councils in Sweden between 2006 and 2009. Both county councils had fully implemented the national doctrine and the DDOs had a clear regional mandate to take immediate regional medical decisions.

All available documentation from the regional command and control for 130 incidents, all declared as major incidents, were studied with regard to the type of incident, staff resources required for regional management, and how long the regional management body remained active. All incidents studied were classified into nine categories.

A set of 11 previously developed measurable performance indicators for assessing initial regional medical command and control were systematically applied. Each indicator was given a score of 0, 1 or 2 points; 0 = objective was not met at all, 1 = objective met but not within the stipulated time frame, 2 = objective completely met within stipulated time frame.
The average score for each indicator was calculated. The same statistical method as in paper II was used. Two-way analysis of variance with one observation per cell and the post hoc Tukey test for pairwise comparisons were used. A p value <0.05 was considered significant.

4.2.4. Paper IV. Simulation-assisted burn disaster planning

In paper IV, data were collected from two simulations of a mass casualty incident with burns in a rural area in the northeast of Sweden. The aim was to evaluate the Swedish national burn response plan in a simulation of a mass casualty incident against fixed outcome indicators expressed as risk for preventable deaths and risk for preventable complications and, by a repeat simulation, determine the robustness of the outcome and the reproducibility of the simulation. Special focus was directed to national coordination of burn care, which included response time, patient surge, and intensive care capabilities, and to identify gaps and deficiencies in trauma management in relation to patient outcome.

The two simulations were based on a large inventory of emergency resources available in this area as well as regional hospitals, university hospitals and burn centres in Sweden and abroad on a specific day and at a specific time (December 16, 2010, at 11 pm).

Results of the inventory were transferred into the ETS. The burn injuries used in the simulations were connected to specific burn categories making evaluation of primary, secondary and tertiary levels of care possible. Issues regarding psychosocial crisis management, fatality management and public information as well as other aspects of surge capacity such as shortages of specific materials were excluded as a prerequisite.

A standardized injury scenario comprising injuries from the ETS victim bank (n = 400) was used based on the characteristics of a rapid indoor fire in a three-storey building, with all exits blocked and people jumping out in panic.

Injury profiles were: injuries with an ISS ≥25 (e.g. burns/inhalation injuries (n = 35) and other trauma (n = 35)); ISS 12–23 (n = 25); ISS 7–11 (n = 150); non-injured, ISS 0 (n = 95); non-survivable, ISS 75 (n = 60) (Table 2).
Each simulation was conducted during a 1-day workshop and was led by a moderator. The simulation was divided into five phases: alarm phase (real time), after 1.5, 5, 10 and 24 h. Between each phase, time was paused and management issues were discussed before restarting a new phase. During the pause, the simulation clock was moved forward and all the resources and patients were moved according to the new time and into their new location on the white boards.

During the phases, casualties were processed through triage, medical treatment at the scene, loading and transportation to a designated medical facility based on the decisions made by the participants. The discussions and decisions made were documented by a secretary. After each simulation, the collected data were summarized and a calculation of patient outcome was made.

At the time of simulation I, the participants were guided by the intentions of the national burn response plan. A number of risks during the response were identified, discussed and documented in simulation I. Before simulation II, a set of measurable performance indicators for national coordination of burn care was developed based on the previous results of identified risks. In simulation II, the new performance indicators were tested as a suggested standard response procedure for national coordination of burn care. A learning effect was anticipated and hypothesized for the second simulation. (Table 3).

Example of an ETS-patient and photos from different simulation exercises are presented in appendix 1 and 2.
Table 2: Injury profiles

<table>
<thead>
<tr>
<th>Injury type</th>
<th>No. (n = 400)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severe brain contusion</td>
<td>5</td>
</tr>
<tr>
<td>Intracranial lesion requiring surgery</td>
<td>5</td>
</tr>
<tr>
<td>Airway obstruction (e.g. maxillofacial trauma)</td>
<td>3</td>
</tr>
<tr>
<td>Burn injury on the face + pulmonary injury</td>
<td>5</td>
</tr>
<tr>
<td>Thoracic trauma (haemothorax, pneumothorax)</td>
<td>3</td>
</tr>
<tr>
<td>Pulmonary contusion</td>
<td>4</td>
</tr>
<tr>
<td>Femoral fracture</td>
<td>7</td>
</tr>
<tr>
<td>Burn injury 20–30% TBSA</td>
<td>13</td>
</tr>
<tr>
<td>Burn injury 50–60% TBSA</td>
<td>10</td>
</tr>
<tr>
<td>Blunt abdominal trauma/major pelvic disruption with clinical signs of shock</td>
<td>13</td>
</tr>
<tr>
<td>Concussion</td>
<td>5</td>
</tr>
<tr>
<td>Neck trauma, suspected spinal injury</td>
<td>4</td>
</tr>
<tr>
<td>Vascular injury, open fractures/joint injury</td>
<td>4</td>
</tr>
<tr>
<td>Fracture requiring surgery</td>
<td>8</td>
</tr>
<tr>
<td>Thoracic/lumbar injury</td>
<td>4</td>
</tr>
<tr>
<td>Minor injuries</td>
<td>75</td>
</tr>
<tr>
<td>Severe psychological shock</td>
<td>75</td>
</tr>
<tr>
<td>No visible injury</td>
<td>95</td>
</tr>
<tr>
<td>Severe burn injury 90% of TBSA, unsavable</td>
<td>2</td>
</tr>
<tr>
<td>Dead at the scene</td>
<td>60</td>
</tr>
</tbody>
</table>
Table 3: Identified risks within national coordination of burn care during simulation I and the performance indicators tested in simulation II

<table>
<thead>
<tr>
<th>Simulation I: identified risk</th>
<th>Simulation I: comments</th>
<th>Simulation II: performance indicator (PI) set for national coordination of burn care (standard within x minutes from alert)</th>
<th>Simulation II: PI achieved: YES/NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burn response plan not known by all actors within emergency system. Other incident alerts concerning daily burn care may arise</td>
<td>Need for a standard</td>
<td>1. Assess and evaluate content of alarm (1 min)</td>
<td>YES</td>
</tr>
<tr>
<td>Major incident declared in region of burn centre important. Management without jurisdiction. If not done, delay in response and resource allocation</td>
<td>Need for a standard. Use same standard as regional level</td>
<td>2. Declaration of major incident for regional health care within own region (1 min)</td>
<td>YES</td>
</tr>
<tr>
<td>Initial management overwhelmed. The need for early staff support is important. If not done, delay in management’s ability</td>
<td>Need for a standard. Use same standard as regional level</td>
<td>3. Decision on level of alert for staff (3 min)</td>
<td>YES</td>
</tr>
<tr>
<td>Contact with burn expert important. Burn expert occupied. Risk in a delayed inventory, burn expert activation. Inventory can take time</td>
<td>Need for a standard. A predefined distribution key to burn centres must be preset in plan to save time</td>
<td>4. Establish contact with burn centre within own region (local level) (3 min)</td>
<td>YES</td>
</tr>
<tr>
<td>Contact with the other national burn centres important. Burn expert could be occupied. Risk in a delayed inventory, burn expert activation</td>
<td>Need for a standard. Alert via the ordinary DDO at regional level is important</td>
<td>5. Establish contact with burn centres in other regions (regional level) (5 min)</td>
<td>YES</td>
</tr>
<tr>
<td>Regional management in affected region might be overwhelmed. Telephone lines occupied</td>
<td>Need for a standard</td>
<td>6. Establish contact with affected region (delivery of first distribution key for burns) (15 min)</td>
<td>YES</td>
</tr>
<tr>
<td>Inventory might take time. Delay in contact between regions and other burn centres in Scandinavia</td>
<td>Need for a standard</td>
<td>7. Decide on inventory; ensure the base information for a more definitive distribution key of burns (20 min)</td>
<td>YES</td>
</tr>
<tr>
<td>Simulation I: identified risk</td>
<td>Simulation I: comments</td>
<td>Simulation II: performance indicator (PI) set for national coordination of burn care (standard within x minutes from alert)</td>
<td>Simulation II: PI achieved:</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-------------------------</td>
<td>-----------------------------------------------------------------</td>
<td>---------------------------</td>
</tr>
<tr>
<td>Difficult to set goals. Burn mass casualty incident might also involve trauma injuries. Coordination of all other specialized ICU beds might be needed but is not included in the coordination of burn care. Difficulties with triage at the scene. Might not be possible to transport a burn expert to the scene especially over long distances to rural areas</td>
<td>Need for a standard. Strategies for triage and primary assessment at the scene, at the receiving hospital and secondary transport for burn centre referrals need to be predefined in the plan</td>
<td>8. Formulate general guidelines for national burn response and coordination (30 min)</td>
<td>YES</td>
</tr>
<tr>
<td>Need for a standard.</td>
<td>9. Create basis for first bulletin in own region (internal + external)</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>HEMS important especially in the rural areas. No coordination exists but needs to be established in cooperation. Many national actors involved and other countries. Lack of knowledge about the specific needs of HEMS for helipad, refueling, medical staffing, etc. Large risk for increase in time patient at the scene and delay in patient distribution</td>
<td>Need for a standard. Many issues need to be further addressed before organization is described in the plan</td>
<td>10. Assess whether national coordination of ambulance transport resources (EMS + HEMS) needs to be established (40 min)</td>
<td>YES</td>
</tr>
<tr>
<td>Need for a standard</td>
<td>11. Ensure that there is adequate information for decision on referrals (deliver definitive key for distribution of burn injuries and notify all the receiving burn centres) (40 min)</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>Contacting and notifying all receiving units might take some time. Delay in contact between regions, cross-border hospitals and burn centres in Scandinavia due to different standards of response. Risk for delay in patient distribution</td>
<td>Need for a standard</td>
<td>12. Identify the need for cooperation with other national authorities and international networks based on the burn assignment (40 min)</td>
<td>YES</td>
</tr>
<tr>
<td>Need for a standard</td>
<td>13. Create base information to depict the national situation (60 min)</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>Parallel alerts to different authorities at national level. Other national authorities at the level of a national crisis respond according to other plans</td>
<td>Need for a standard</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The role of the NBHW is not clear. What can be expected from the national level of health care and other authorities and vice versa? Delay in providing correct medical information</td>
<td>Need for a standard</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4.3. Templates for the performance indicators

Templates for the performance indicators used in this thesis are presented for study I in Tables 4 and 5, for studies II and III in Table 4 and for study IV in Table 6.

Table 4: Performance indicators for initial regional command and control

<table>
<thead>
<tr>
<th>Performance indicator</th>
<th>Standard (within x min from alert)</th>
<th>Score (2-1-0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Declaring major incident</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2. Deciding on level of preparedness for staff</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>3. Deciding on sending additional resources to scene</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4. Deciding on receiving hospitals</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>5. Establishing contact with incident officers at the scene</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>6. Deciding on preliminary referrals</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>7. First information to media</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>8. Formulate general guidelines for response</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>9. Ensuring that there is adequate information for deciding on referrals</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>10. Estimate if the resources in own organization are adequate</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>11. Notify decision for referrals to receiving hospitals</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>Approval level &gt;11</td>
</tr>
</tbody>
</table>
Table 5: Performance indicators for staff procedure skills

<table>
<thead>
<tr>
<th>Performance indicator</th>
<th>Time/points</th>
<th>Score (2-1-0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Assigning functions to staff members</td>
<td>Directly on arrival</td>
<td></td>
</tr>
<tr>
<td>2. Positioning in room in accordance to above</td>
<td>Directly</td>
<td></td>
</tr>
<tr>
<td>3. Designated telephone numbers</td>
<td>Directly</td>
<td></td>
</tr>
<tr>
<td>4. Introduction of arriving staff member</td>
<td>Max 1 min</td>
<td></td>
</tr>
<tr>
<td>5. Utilization of equipment (only if equipment is available)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whiteboard</td>
<td>Not</td>
<td>0</td>
</tr>
<tr>
<td>Flip-chart</td>
<td>Not</td>
<td>0</td>
</tr>
<tr>
<td>Fax</td>
<td>Not</td>
<td>0</td>
</tr>
<tr>
<td>Computer</td>
<td>Not</td>
<td>0</td>
</tr>
<tr>
<td>Other (specify)</td>
<td>Not</td>
<td>0</td>
</tr>
<tr>
<td>Average:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Staff briefing</td>
<td>Max 8 min</td>
<td></td>
</tr>
<tr>
<td>7. Content of staff briefing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reports from staff members</td>
<td>Not</td>
<td>0</td>
</tr>
<tr>
<td>Summarizing</td>
<td>Not</td>
<td>0</td>
</tr>
<tr>
<td>New assignments</td>
<td>Not</td>
<td>0</td>
</tr>
<tr>
<td>Next staff briefing</td>
<td>Not</td>
<td>0</td>
</tr>
<tr>
<td>Average:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Telephone discipline</td>
<td>(during staff briefing)</td>
<td></td>
</tr>
<tr>
<td>9. Content of staff schedule</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Staff briefings</td>
<td>Not</td>
<td>0</td>
</tr>
<tr>
<td>Media contacts</td>
<td>Not</td>
<td>0</td>
</tr>
<tr>
<td>Meals</td>
<td>Not</td>
<td>0</td>
</tr>
<tr>
<td>Staff relief</td>
<td>Not</td>
<td>0</td>
</tr>
<tr>
<td>Average:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Summary (oral to staff members)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Summary (written to report)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>Approval level &gt;11</td>
</tr>
</tbody>
</table>
Table 6: Performance indicators for national coordination of burn care

<table>
<thead>
<tr>
<th>Performance indicator (standard within x minutes from alert)</th>
<th>Within x minutes from alert</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Assess and evaluate content of alarm</td>
<td>1</td>
</tr>
<tr>
<td>2. Declaration of major incident for regional health care within own region</td>
<td>1</td>
</tr>
<tr>
<td>3. Decision on level of alert for staff</td>
<td>3</td>
</tr>
<tr>
<td>4. Establish contact with burn centre within own region (local level)</td>
<td>3</td>
</tr>
<tr>
<td>5. Establish contact with burn centre in other region</td>
<td>5</td>
</tr>
<tr>
<td>6. Establish contact with affected region Deliver preliminary referrals for burns</td>
<td>15</td>
</tr>
<tr>
<td>7. Decide on inventory; ensure the base information for a more definitive distribution of burns</td>
<td>20</td>
</tr>
<tr>
<td>8. Formulate general guidelines for national burn response and coordination</td>
<td>30</td>
</tr>
<tr>
<td>9. Create basis for first bulletin in own region (internal + external)</td>
<td>30</td>
</tr>
<tr>
<td>10. Assess whether national coordination of ambulance transport resources (EMS + HEMS) needs to be established</td>
<td>40</td>
</tr>
<tr>
<td>11. Ensure that there is adequate information for decision on referrals (deliver definitive key for distribution of burn injuries and notify all burn centres involved)</td>
<td>40</td>
</tr>
<tr>
<td>12. Identify the need for cooperation with other national authorities and international networks based on the burn assessment</td>
<td>40</td>
</tr>
<tr>
<td>13. Create base information for depiction of the national situation</td>
<td>60</td>
</tr>
</tbody>
</table>
5. RESULTS

The complete results of all studies can be found in papers I–IV appended in the second part of the thesis.

5.1. Paper I. Management of resources at major incidents and disasters in relation to patient outcome: a pilot study of an educational model

The first paper was a pilot study collecting data from one standardized simulation exercise during a national education and training course in regional and hospital medical response to major incidents.

The total scores for the measurable performance indicators for initial strategic management and staff procedure skills are shown in Table 7. Despite good staff procedure skills, the decisions about sending additional resources to the scene, deciding on receiving hospitals and referrals were delayed. This resulted in a lack of personnel resources and medical competencies that could perform life-saving interventions at the scene. Evacuation of the injured was delayed due to late and inadequate referrals given from the regional management. Despite available hospital resources, no patients were sent to any hospitals in a neighbouring region, except for three cases of burn injuries who were transported by helicopter to a burn centre.

As a result of inadequate medical response and insufficient distribution of patients, 11 of 30 critically injured patients were at risk for preventable death (Table 7).

This pilot study demonstrates that, in an educational setting, it is possible to combine measurable performance indicators and outcome indicators to examine the crucial decisions made in relation to patient outcome.
Table 7: Number of casualties referred to other regions, reason for preventable deaths and score for performance indicators for initial strategic management and staff procedure skills in a pilot exercise in a scenario with 100 casualties

| Number of casualties referred to other regions | 3 |
| Preventable deaths (total number)             | 11 |
| Inadequate management of airway and/or breathing at the scene | 5 |
| Failure to operate within time frame           | 2 |
| Late admission to ICU                          | 4 |
| Score for staff procedure skills               | 19.25 points (max 22) |
| Score for initial strategic management         | 16 points (max 22) |

5.2. Paper II. Quality control in disaster medicine training—initial regional medical command and control as an example

In paper II, data were collected from 18 regional management groups in 18 standardized simulation exercises. Eleven measurable performance indicators for initial regional medical command and control were used as a template for evaluation.

The total score for the 11 indicators for each group ranged from 8 to 18 out of 22, with a mean (±SD) of 14.05 (±3). The average score for each performance indicator ranged from 0.31 and 1.89 out of 2. Most of the decisions were made according to the objective but not always within the postulated time frame (Table 8).

There was a significant difference between the mean score for indicators 7 and 8 and the rest of indicators 1–6 and 9–11 (p < 0.05) (Figure 2).
This study shows that the decision about strategic guidelines (alignment) and decisions about how to manage the information (media) are the two performance indicators that are most difficult to attain.

Table 8: Results of 11 performance indicators for initial regional medical command and control and the average score out of 2, for each indicator in 18 simulation exercises

<table>
<thead>
<tr>
<th>Performance indicator</th>
<th>Standard (within x min. from alert)</th>
<th>Average score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Declaring major incident</td>
<td>1</td>
<td>1.89</td>
</tr>
<tr>
<td>2. Deciding on level of preparedness for staff</td>
<td>3</td>
<td>1.84</td>
</tr>
<tr>
<td>3. Deciding on sending additional resources to scene</td>
<td>3</td>
<td>1.31</td>
</tr>
<tr>
<td>4. Deciding on receiving hospitals</td>
<td>5</td>
<td>1.84</td>
</tr>
<tr>
<td>5. Establishing contact with incident officers at scene</td>
<td>10</td>
<td>1.21</td>
</tr>
<tr>
<td>6. Deciding on preliminary referrals</td>
<td>10</td>
<td>1.31</td>
</tr>
<tr>
<td>7. First information to media</td>
<td>15</td>
<td>0.89</td>
</tr>
<tr>
<td>8. Formulate general guidelines for response</td>
<td>15</td>
<td>0.31</td>
</tr>
<tr>
<td>9. Ensuring that there is adequate information for deciding on referrals</td>
<td>20</td>
<td>1.00</td>
</tr>
<tr>
<td>10. Estimate if the resources in own organization are adequate</td>
<td>30</td>
<td>1.26</td>
</tr>
<tr>
<td>11. Notify decision for referrals to receiving hospitals</td>
<td>40</td>
<td>1.15</td>
</tr>
<tr>
<td>Total average score (out of 22)</td>
<td></td>
<td>14.05</td>
</tr>
</tbody>
</table>
5.3. Paper III. Performance indicators for initial regional medical response to major incidents: a possible quality control tool

Paper III was a retrospective study of major incidents that occurred in two Swedish county councils from 2006 to 2009.

5.3.1. Descriptive results

A total of 130 incidents, declared as major incidents, were included and classified as follows: accidents \((n = 48)\), fires \((n = 23)\), threats \((n = 37)\), interference with hospital infrastructure \((n = 15)\), chemical, biological, radiological, nuclear, and explosive (CBRNE) events \((n = 2)\), infectious events \((n = 2)\), weather alert \((n = 1)\), support to other region \((n = 1)\), incident abroad \((n = 1)\).
Approximately 1229 casualties (range 3–135/incident) were directly involved in incidents classified as accidents, fires or threats. In 35 major incidents (27%), casualties were distributed to more than one hospital and in 15 major incidents (11.5 %) one or more hospitals activated their hospital disaster plan.

Regional medical command and control was established by the DDO alone in 50 major incidents (38%); and in 36 major incidents (28%), a specific regional medical officer (physician) was alerted. In 34 major incidents (26%), one or more staff positions were called as support and a more comprehensive regional medical management group was established in 10 major incidents (7%) (Figure 3).

In 98 major incidents (75%), the regional medical command and control was active for 4 hours or less (median time 60 minutes) (Figure 4).

![Bar chart](image)

**Figure 3:** Extent of regional medical command and control in 130 major incidents.
Figure 4: Time regional medical command and control were active in 130 major incidents (MI). Median value = 60 minutes.

5.3.2. Performance indicators

The 11 measurable performance indicators used to assess the initial regional medical command and control were applied in 102 major incidents (78%) in the following categories: accidents, fires, threats and CBRNE events.

The indicators were not applicable as a set for 28 incidents (21.5%) due to different characteristics and time frames. These incidents involved interference with hospital infrastructure requiring regional support (power failure, IT disturbance, phone interruptions), an incident occurring in another region (evacuation of in-hospital patients), an incident abroad with regional impact (evacuation of Swedes from Lebanon), weather alerts (storms), and infectious events (suspected water contamination, mass vaccination during the H1N1 flu pandemic).

Thirty-six incidents were indicators could have been applied were excluded because of incomplete documentation. The category distribution of the exclusions did not differ from the major incidents studied; they were all casualty incidents to which the indicators could have been applied (Figure 5).
Performance indicators \((n=726)\) were collected from 66 major incidents involving accidents, fires, threats and CBRNE events. The objective was met completely or partially in 446 indicators (64%) and in 280 indicators (38%), the objective was not met at all. The mean score for each performance indicator ranged from 0.03 to 1.63 out of a maximum score of 2 (Table 9).

Comparison shows that performance indicators measuring decisions in the early phase of an incident (1–10 min after alert) had a significantly higher mean score than indicators measuring decisions in the secondary phase (e.g. 10–40 min after alert) \((p < 0.05)\). Performance indicator 8 (formulate general guidelines for response) and indicator 10 (decide if resources in own organization are adequate) differed significantly from indicators 1, 2, 3, 4, 5, 6, 7, 9, and 11 \((p < 0.05)\). There was no significant difference between indicator 3 (decision on additional resources to the scene) and indicator 11 (notify decision for referral to receiving hospital) (Figure 6).
**Figure 5: Study case flow.**

Major Incidents (MI) occurred in two county councils in Sweden 2006-2009
\( (n=130) \)

- MI where indicators were not applicable \( (n=28) \)*
- MI with insufficient documentation \( (n=36) \)
- MI where indicators were applicable \( (n=102) \)
- MI with sufficient documentation \( (n=66) \)

*Interruptions in hospital infrastructure, infectious events, incidents abroad, regional support asked from other region, weather alerts*
Table 9: Mean scores (0–2) of 11 performance indicators for initial regional medical command and control in 66 major incidents

<table>
<thead>
<tr>
<th>Performance indicator (standard within x minutes from alert)</th>
<th>Mean score (0–2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Declaration of major incident (1 min)</td>
<td>1.48</td>
</tr>
<tr>
<td>2. Decision on level of alert for staff (3 min)</td>
<td>1.41</td>
</tr>
<tr>
<td>3. Decision on sending additional resources to scene (3 min)</td>
<td>1.32</td>
</tr>
<tr>
<td>4. Decision on receiving hospitals (5 min)</td>
<td>1.63</td>
</tr>
<tr>
<td>5. Establishing contact with incident officers at scene (10 min)</td>
<td>1.53</td>
</tr>
<tr>
<td>6. Decision on preliminary referrals (10 min)</td>
<td>0.86</td>
</tr>
<tr>
<td>7. First information to media (15 min)</td>
<td>0.75</td>
</tr>
<tr>
<td>8. Formulate general guidelines for response (15 min)</td>
<td>0.18</td>
</tr>
<tr>
<td>9. Ensuring that there is adequate information for decision on referrals (20 min)</td>
<td>0.93</td>
</tr>
<tr>
<td>10. Assessment if resources in own organization are adequate (30 min)</td>
<td>0.03</td>
</tr>
<tr>
<td>11. Notify decision on referrals to receiving hospitals (40 min)</td>
<td>0.97</td>
</tr>
</tbody>
</table>
Figure 6: Comparison of scores from 11 different performance indicators in 66 major incidents.

Figure 6—Comparison of scores from 11 different performance indicators in 66 MI. The mean values of the 11 indicators are on the baseline. The numbers of each performance indicator are circled. Numbers that lie below the same horizontal line are not significantly different from each other. For example: Scores from Indicators 8 and 10 differ significantly from the rest of the indicators (1, 2, 3, 4, 5, 6, 7, 9, and 11).
5.4. Paper IV. Simulation-assisted burn disaster planning

Paper IV evaluated the Swedish medical system’s response to a mass casualty burn incident in a rural area with a focus on national coordination of burn care. Data were collected from two table-top simulations of a mass casualty incident with burns during two workshops.

The two regional hospitals at Mora and Falun (100 km and 184 km from the scene) received the largest number of injured ($n = 44$) and was the same in both simulations. However, there was a difference within the group with less burn/inhalation injuries in the second simulation. The delivery of the first distribution key for burns was made after 30 min in simulation II compared with 90 min in simulation I.

In simulation I, the university hospitals in Uppsala and Linköping (i.e. the two hospitals with national burn centres) received both trauma and burn/inhalation injuries, which resulted in reduced surgical and intensive care capacity and affected the burn care capacity. In simulation II, the two hospitals received only severe burn/inhalation injuries.

Ten different regional hospitals in Sweden and cross-border hospitals in Norway received casualties. Burn intensive care beds in Linköping, Uppsala, Oslo, Bergen, Helsinki and Copenhagen were used within the first 24 hours (Figure 7).

Of 400 casualties, 14.7% ($n = 59$) were transported by ambulance to a regional hospital and 6.5% ($n = 26$) were transported long distance by HEMS to university hospitals and burn centres. The last injured patient triaged as immediate (T1) was evacuated after 7 hours in simulation I and after 5 hours in simulation II. The need for secondary transportations by HEMS to university hospitals within the first 24 hours was reduced from 13 to 4 in simulation II (Table 10).

The overall result was that timely and accurate response from the regional medical command together with more timely response from a national coordination function most likely had a positive impact on patient outcome in simulation II.
Figure 7: Distribution of casualties after 24 hours.

Table 10: Number of injured and transportation mode during the first 12 hours in simulations I and II

<table>
<thead>
<tr>
<th></th>
<th>Number of immediate (T1) cases</th>
<th>Number of delayed (T2) cases</th>
<th>Number of minor (T3) cases</th>
<th>Total number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sim I</td>
<td>39</td>
<td>20</td>
<td>21</td>
<td>59</td>
</tr>
<tr>
<td>Sim II</td>
<td>39</td>
<td>21</td>
<td>–</td>
<td>59</td>
</tr>
<tr>
<td>EMS primary</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HEMS primary (direct)</td>
<td>19</td>
<td>7</td>
<td>1</td>
<td>26</td>
</tr>
<tr>
<td>EMS secondary (hospital to higher level of care)</td>
<td>2</td>
<td>–</td>
<td>–</td>
<td>2</td>
</tr>
<tr>
<td>HEMS secondary (hospital to higher level of care)</td>
<td>13</td>
<td>–</td>
<td>–</td>
<td>13</td>
</tr>
<tr>
<td>BUS</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>216</td>
</tr>
<tr>
<td>Self-evacuation (taxi, private vehicle)</td>
<td>0</td>
<td>11</td>
<td>11</td>
<td>37</td>
</tr>
<tr>
<td>Time of last evacuation (time from alert)</td>
<td>+7 h</td>
<td>+5 h</td>
<td>+8 h</td>
<td>+4 h</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>+2.5 h</td>
</tr>
</tbody>
</table>
5.4.1. Patient outcome

All burns transported to burn centres in Sweden (Uppsala/Linköping) had a favourable outcome in both simulations. Patients with extensive burn injuries (TBSA >50%; \( n = 9 \)) who were transported to burn centres in Norway, Denmark and Finland also survived. The results for patient outcome are presented in Table 11.

Table 11: Patient outcome in simulations I and II

<table>
<thead>
<tr>
<th>Type of injury</th>
<th>Sim I ((n))</th>
<th>Sim II ((n))</th>
<th>Cause</th>
<th>Measured outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burn injury 20–30% TBSA</td>
<td>4</td>
<td>3</td>
<td>Did not reach ICU within 4 h</td>
<td>Risk for preventable death</td>
</tr>
<tr>
<td>Inhalation injury</td>
<td>1</td>
<td>–</td>
<td>Did not reach ICU within 4 h</td>
<td>Risk for preventable death</td>
</tr>
<tr>
<td>Burn injury face/inhalation injury</td>
<td>3</td>
<td>–</td>
<td>Did not reach burn ICU within 12 h</td>
<td>Risk for preventable death</td>
</tr>
<tr>
<td>Severe brain contusion</td>
<td>1</td>
<td>1</td>
<td>Did not reach ICU within 4 h</td>
<td>Risk for preventable death</td>
</tr>
<tr>
<td>Intracranial haemorrhage (Glasgow Coma Score 7–9)</td>
<td>4</td>
<td>4</td>
<td>No intubation within 1 h</td>
<td>Risk for preventable death</td>
</tr>
<tr>
<td>Major fracture</td>
<td>11</td>
<td>3</td>
<td>Did not reach operating room within 4–6 h</td>
<td>Risk for preventable complication</td>
</tr>
<tr>
<td>Pneumothorax</td>
<td>–</td>
<td>3</td>
<td>Did not reach ICU within 4 h</td>
<td>Risk for preventable complication</td>
</tr>
<tr>
<td>Pulmonary contusion</td>
<td>–</td>
<td>2</td>
<td>Did not reach ICU within 4 h</td>
<td>Risk for preventable complication</td>
</tr>
<tr>
<td>Total preventable deaths/preventable complications</td>
<td>13/11</td>
<td>8/8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
6. DISCUSSION

This chapter discusses the main findings and methodological considerations from the four studies in this thesis, followed by a more general discussion. Conclusions are stated and future research work is suggested for further improvements in this area.

6.1. Discussion of findings from paper I

Papers I and IV focused on how patient outcome can be related to decisions made by management, executed in a simulated environment. In paper I, the performance indicators for regional management and staff procedure skills were used for evaluation of management and the ETS simulation tool was used for resources, logistics, patient flow and calculation of times and patient outcome. The simulation exercise was set up according to a standardized scenario of a football arena on fire with 100 casualties.

The results from the study showed that 11% of victims had a risk for preventable death. This may reflect that, in the chosen scenario and given the resources at hand, it is inevitable that some of the casualties die. Or, could there be other reasons?

The score for strategic management decisions, 16 out of a possible 22, shows that many of the important initial decisions were made, but not always according to the stipulated time frame of the indicators. Although the high score for staff procedure skills indicated that the staff worked in a structured and well-organized way, some of the patients had a risk for unfavourable outcome.

As a result of the simulation, it was possible to detect that five patients out of 11 had a risk for preventable death because their airway was not supported adequately. This implies that not enough adequately trained staff were sent to the scene to perform life-saving measures.
The other six patients did not reach hospital within the time frame and this could be related to the fact that not enough ambulances were allocated in the early phase, wrong decisions were made about distribution of patients and not enough hospitals were alerted. These types of shortcomings in resource management have also been reported in several studies from real major incidents [57, 59, 98, 123].

In order to evaluate the outcome of the medical response to a major incident, the processes involved must be assessed [104]. To be able to do this, there is a need for standardization and for sets of goals reflecting what is to be considered as good and less good performance [105].

The performance indicators worked well to detect some of these important initial decisions but the indicators chosen do not yet have a qualitative aspect and there is a possibility that wrong decisions were not detected. However, a simulation exercise is a controlled environment in which all input variables are usually known to the instructors, which makes evaluation with performance indicators easy and less subjective.

The most important indicator in the evaluation is patient outcome, and it is influenced by all activities in an organization and should be measured together with other indicators [104, 105]. Standards (benchmarks) for evaluation methods that examine and describe the relationship between performance in disaster response and patient outcome are yet to be described.

Our results show that simulation exercises with a built-in standardized evaluation methodology can produce comparable results and that timely strategic (regional) management decisions are influence patient outcome. By using performance indicators, it may be possible to identify the crucial decisions that may be related to patient outcome. However, only comparison of results from many exercises can determine if results of the outcome is robust and what parts need to be improved.
6.2. Discussion of findings from paper II

Papers II and III focused on 11 measurable performance indicators for initial regional medical command and control. In paper II, the indicators were used prospectively for evaluation of strategic management groups in an educational setting. In this study, areas of the initial regional medical response that need improvement were identified.

Disaster medicine training and education is an area that enables us to use, test and also validate different methods and best practices in a safe environment [31]. In previous studies by Rüter et al., measurable performance indicators were introduced as a method for evaluation and a measure of quality control [14]. In paper II, the simulation exercises had the same standardized setup as in the pilot study. The same methodology for evaluation of performance was used.

Indicator 8 (formulate general guidelines for response) had the lowest score. Formulating general guidelines for response involves the first overall decision that helps the management to set the right focus towards the most important task in the early phase of an event. This decision is perhaps the most important decision and the one that will probably have an impact on the whole process and may influence patient outcome. One explanation for the low score for this indicator could be that the participants perceived the decision too difficult to make due to the stressful situation and therefore did not prioritize the decision, or did not consider it important at all.

The purpose of early contact with the media is to ensure that the correct medical information is given to avoid rumours and speculation. If a short bulletin is issued by strategic management at an early stage, this is one way of starting up good public information management [18]. The performance indicator with the second lowest score was indicator 7 (first information to media). A reason for this could be that the participants did not prioritize the task or they more or less forgot to do it within the time frame of 15 minutes. Another possibility may be that the time frame for the indicator (15 min) is too short and therefore was difficult to achieve.
The results from these performance indicators also demonstrate that the teaching and the simulation exercises must emphasize these two specific learning objectives. Thus, the scoring of the performance indicators also serves as a quality control tool for the actual educational program.

The method provided quantitative and comparable results and ensured objective judgement of management performance. The importance of each indicator in relation to the overall result or the equal value of each indicator could be topics for discussion. As part of a continued validation process, further correlation studies are needed as well as prospective studies from real incidents.

6.3. Discussion of findings from paper III

Papers II and III focused on 11 measurable performance indicators for initial regional medical command and control. In paper III, the indicators were used retrospectively on regional documentation from real events. In the final systematic review of 66 major incidents, all performance indicators could be applied and used to assess the regional medical response. Initial actions taken (often by the DDO and a regional medical officer–physician) within the first 10 minutes, such as declaring a major incident, alerting receiving hospitals and establishing contact with medical command at the scene, were often done correctly and on time.

Several studies on incidents involving casualties show that effective casualty distribution plays a vital role in disaster management, especially if the incident occurs in a rural area where resources are limited [54, 56, 77, 156]. The results shows that decisions made after 10 minutes, usually concerning the distribution of casualties, were often somewhat delayed. The reason for this could be that the DDO had to wait for reports and additional information from the medical incident command at the scene.
Our study of the regional documentation files revealed that the prehospital reports were sometimes not sent at all, or not according to standard operating procedures (e.g. first report within 3 minutes and a second verifying report within 10 minutes of arrival at the scene) resulting in the DDO being forced to obtain the information via the EDC instead. This unnecessary procedure could be one of the factors affecting the ability to make decisions at the right time.

Another weakness observed in regional medical management was the absence of formulating guidelines for response, or in other words, taking a set of objectives and designing a strategic plan to mitigate any consequences of the incident. These findings are consistent with the results from paper II where such strategic decision making was also shown to be difficult.

The regional command and control alerted a neighbouring county on one occasion only. The reason could be that the major incidents were not of sufficient magnitude or there was no other reason to request resources from another region. It may also be that this decision was considered, but was not documented in the log file. However, there may also be a fundamental barrier such that neighbouring counties are only alerted when resources begin to run out. In a minor incident, it is probably enough to distribute casualties to the hospitals within one county, but in a major incident involving a large number of casualties, early contact with neighbouring counties can be crucial, particularly when higher levels of trauma care are required [59]. The significantly low mean score for indicator 11 suggests that the importance of an early alert and establishment of cooperation between county councils needs to be stressed even more in education and training.

The study demonstrates that a DDO has to deal with several types of major incidents, all with different characteristics and time lines. Many of the incidents studied were handled by DDO alone and this emphasizes the essential need of medical competence and disaster medicine management training.

The performance indicators used in this study were found to be not fully applicable to major incidents due to interference with hospital infrastructure.
Even though an individual indicator (e.g. declare major incident) could be applied, most of the other indicators would have to be adjusted with regard to other types of incidents, objectives and time standards.

This study was also limited to major incidents that were fully documented and 36 of the cases studied had to be excluded. Therefore, we cannot rule out the risk of selection bias. However, the category distribution of the exclusions did not differ from the rest; these major incidents were all casualty incidents to which the indicators could have been applied.

Our study has some limitations due to its retrospective design and the lack of coherent incident documentation. In the future, the implementation of digital support systems that can provide real-time data, capture information and share it along the chain of medical command might increase efficiency, ensure a more timely hospital and regional response and facilitate follow-up at all levels. Measurable performance indicators for regional medical command and control can be applied to incidents that directly or indirectly involve casualties provided there is sufficient documentation available. Further prospective studies are needed to examine if the time taken for regional decisions about distribution of casualties correlates with patient time at the scene, time to definitive care and patient outcome. If implementation of indicators becomes mandatory in regional medical response plans, improved resource allocation and causality distribution, especially in the early phase of a major incident, may lead to quality improvements. Modification of the present indicators or additional indicators applicable to other types of incidents such as interference with hospital infrastructure might be needed.

6.4. Discussion of findings from paper IV

Papers I and IV focused on how patient outcome can be related to decisions made in management, executed in a simulated environment. Paper IV evaluated the Swedish medical system’s response to a mass casualty burn incident in a rural area with a focus on national coordination of burn care. Data were collected from two table-top simulations of a mass casualty incident with burns.
The main findings in paper IV was that better national coordination of burn care and more timely distribution of burns cases based on the experience from the first simulation and possibly also a learning effect, led to a better patient outcome in a second simulated mass casualty burn incident. The differences in results between the two simulations were small but detectable and the reproducibility of simulation was satisfactory.

We found that timely and accurate response from the regional medical command together with more timely response from a national coordination function most likely had a positive impact on the result for patient outcome in simulation II. In addition, the results indicate that a more precise distribution of casualties on short distances to regional hospitals and long distances with HEMS to university hospitals and burn centres can be advantageous. Thus, by timely and specific referrals, the on-scene time was also reduced. This line of reasoning can be supported by studies from real incidents where the efficient management at every stage of the response probably contributed to a low critical mortality [54, 77].

The reasons for the altered outcome in simulation II can have many explanations. First, despite the long transport distances, a more rapid mobilization of resources from both the Swedish and Norwegian side of border made it possible to start transportation to the nearest regional hospitals by ambulances after 45 minutes. Second, the early mobilization of ambulance helicopters from Norway with both anaesthesia physicians and nurses probably contributed to these results due to the possibility of performing life-saving airway interventions after 1 hour. Third, measurable performance indicators used in simulation II were found to be applicable and could probably have stimulated the participants to perform a more timely and effective management in simulation II.

Achieving rapid patient evacuation based on transport resource accessibility (e.g. ambulances and helicopters) can be a significant issue in rural areas. In Sweden, there are seven HEMS resources available, compared with 12 HEMS in Norway where they also include physicians. Experience from the shootings in Oslo and Utøya Island in 2011 demonstrated the vital importance of optimized use of ambulance helicopter resources [77].
The results with regard to post-trauma mortality and helicopter transport vary in the literature, but most studies report a significant improvement in trauma mortality when patients are transported directly by helicopter to level 1 care [92, 93].

During these simulations, the extent of air transportation and coordination of helicopters was shown to be a bottleneck and was identified as a significant risk factor for an unfavourable outcome. The absence of a predefined organization and coordination routines concerning air transport in a mass casualty event such as described in our study must be addressed further at national level. Unfortunately, it was not possible to fully test the function during these simulations.

Further experimental simulations are needed with defined interventions to ascertain outcome and examine whether preventable deaths and complications can be reduced. The experience from the present simulations using a simulation system that combines both process and outcome indicators can create important results that may serve to support disaster planning.

6.5. Methodological considerations

A major concern when conducting research in an area that is one’s own professional working field is the potential conflict between the dual roles of a teacher/developer and a researcher. The studies in this thesis have been conducted in parallel with my work on the education and development of new educational systems in addition to supporting county councils with the implementation of a national approach to medical command and control at major incidents on all levels. This has likely influenced some of the interpretations of the research findings in these studies. However, the combination of teaching, development and implementation based on knowledge and research gives a multi-perspective approach, which sometimes can be an advantage.
One limitation of the performance indicators is that they do not have qualitative aspects and therefore the instrument can be perceived as blunt because of the measurement scale of 2-1-0. However, if the evaluator has knowledge of the subject matter, and all input variables are known, such as in a controlled simulation exercise, the prospective scoring of indicators is more objective, reducing individual differences between observers’ interpretations.

Another concern with the indicators is that they are not weighted against each other and decisions about alerts and distribution are undoubtedly of greater importance to the outcome than information to the media. Another limitation may be that these indicators are based on the Swedish management doctrine and might have to be adjusted to fit into another incident management system, and although they have been used in international educational settings, this can affect the external validity.

As part of the validation process, the indicators were used on real events in paper III. Due to its retrospective design and the lack of coherent incident documentation, the study was limited to major incidents that were fully documented and therefore, as already discussed, we cannot rule out the risk of selection bias.

The data in papers I, II and IV were collected from simulation exercises. Simulation bias may have affected parameter estimation and therefore the main outcomes in a simulation model. However, in this thesis, all the simulation exercises were standardized in an effort to reduce the bias as far as possible and to control all interventions made. Despite the use of a robust simulation system, it cannot be excluded that some bias occurred that might have influenced the results.

The simulation system used has fixed outcome measures that only measure a risk for preventable death or complication; they are not definitive measures of mortality or morbidity. However, the results of patient outcome can be of indicative value and further experimental simulations are needed with defined interventions to ascertain outcome.
6.6. General discussion

The lessons learned from mass-casualty events are that proper triage, appropriate resuscitation, and timely evacuation and distribution to more than one hospital decrease morbidity and mortality in trauma patients and facilitate appropriate utilization of the available resources [54, 77]. Another important truism is that the ultimate goal is to optimize care for the greatest number of patients. This means matching patients with facilities that have the appropriate resources available in sufficient quantities to provide the necessary care [59].

The basic tenet for preparedness has been that a major incident always begins at the local level. However, local hospital preparedness has diminished markedly in the past 30 years because of restructuring of the health care system with a concentration of specialized care and differentiation between acute and planned health care [157]. The need for rapid regional medical response at major incidents from an overall health care perspective is therefore of great importance. The DDO is an important link between daily health care and regional disaster preparedness and has to deal with various types of alerts and major incidents with different characteristics and time lines. This level of strategic medical management supporting the medical command on scene is of outmost importance and this emphasizes the essential need of medical competence and disaster medicine training as well as individual skills.

The ability to measure regional medical response and to predict the likely performance at future events is critical. It is also key to answering the fundamental questions that the public and policymakers alike have about the health care system: how much confidence can we have that it will function as planned when the next large-scale incident or disaster occurs?

Although major incidents differ in type, size, scope and circumstances, there are certain medical and organizational principles that are common to all. In these studies, we found that areas in need of improvement are the same in simulation exercises as in real events. These similarities and common features can allow for the further development of a consistent national medical approach to major incidents.
Accumulation of data, reported in a similar standardized fashion, would enable experimental research that could improve our understanding regarding the optimal medical response to various events [38].

In Sweden, the number of major incidents per year is unknown. In order to implement an effective quality control of response to major incidents, specific standards for regional medical response need to be set and agreed from a national perspective. This will probably also enhance follow-up and comparison of major incidents in the future.

6.6.1. Performance indicators

This thesis has focused on measurable performance indicators that are derived from a national concept and modelling process [14]. The thesis demonstrates that areas in initial regional medical response in need of improvement can be identified with performance standards. It shows that performance can be assessed in relation to outcome and that such evaluation can identify critical points of success and failure.

Although all indicators from this modelling process (prehospital, hospital and regional) have been used successfully for many years in evaluation of students, simulation exercises and full-scale exercises, not all have gained full acceptance. The prehospital indicators have been implemented as standard routines for EMS response in 17 county councils and the establishment of on-scene medical command and control is the same throughout Sweden. But the chain is no stronger than its weakest link and despite national regulations, the medical regional response time and actions taken are different in different county councils. This raises concerns about the management of major incidents with multiple casualties and this could create an unfavourable delay in patient distribution when many county councils are involved.

Lessons learned from past events are evident and based on this knowledge, a standardized and quality assured regional medical response to major incidents is called for [39, 54, 66, 77]. Research can contribute with numbers, facts and conclusions but it is important that policy makers also set the bar.
The quality control of regional medical response at major incidents must be an ongoing process to ensure effectiveness and to continuously detect deficiencies, leading to quality improvements. In this study, the regional indicators have been further analysed and we believed that they have construct validity and assess what they are intended to assess. Moreover, they have reliability and can be used in a reproducible way. Based on that assumption, the indicators can be used for quality control as standard benchmarks in major incidents including casualties and threats where there is a risk for escalation of the event.

The selection of appropriate indicators of effectiveness that are of key importance is warranted [24]. It is a challenge to show what truly reflects the effectiveness of one or other set of indicators. The indicators used in this thesis evaluate the effectiveness of medical command and control, but more research is necessary where patients from real incidents are included to ascertain the effects related to outcome. Further development with a qualitative approach might also further strengthen the indicators. It is to be hoped that this thesis will contribute to the validation process of indicators for regional medical response and that these indicators, in combination with the prehospital indicators already in use, can be valuable tools for disaster planners.

6.6.2. Documentation

Insufficient documentation is a well-known problem in disaster management; it is a challenge in a stressful situation to ensure accurate record keeping [66, 77]. A prerequisite for evaluation and research is the retrieval of data and the lack of documentation leads to limited external validity of the reports [24].

One of the findings in this study was insufficient documentation of the log files of regional management. Regardless of the reason, this needs to be addressed urgently for the future. Perhaps a digital information system that could provide timely and accurate information for management and at the same time record all data would ensure and improve the medical response to major incidents. Such a system may also be useful for quality control and follow-up where data could be compared nationally.
If national standards for medical response become implemented, it would be easy to also incorporate performance indicators into digital information systems. Such systems could facilitate situational awareness for all management levels involved (prehospital, hospital and regional) and create more coherent documentation of the event.

6.6.3. Planning

In this thesis, most of the major incidents that were examined were casualty incidents and none was of sufficient magnitude to be considered as a mass casualty incident. Nevertheless, if a mass casualty incident occurs, rapid regional and national response is imperative due to the limited national specialist intensive care resources. As the need for specialized burn beds has declined in Sweden during the last 20 years, the access to specialized burn care is becoming increasingly limited. This has implications for disaster planning. Even a moderate incident with severe burns would probably use all available national burn beds, especially in a small country such as Sweden. National coordination of burn care is needed, but even when we have developed a response plan, many issues still have to be resolved.

One of the issues that raised concerns was that the requirement for air transportation and coordination of helicopters was a bottleneck and was identified as a significant risk factor for an unfavourable patient outcome. The absence of a predefined organization and coordinated routines concerning air transport in a mass casualty event such as this must be addressed further at a national level. It was not possible to test this fully during these simulations.

Although the burn response plan tested was limited in scope to coordination of burn care, it provides general principles for national coordination of specialized care that can be adapted to other types of major incidents. To maximize resource utilization, all types of specialized trauma care could be coordinated through a national logistic coordination function that can manage information on resource availability and match patients in need of care to available resources. Such a function can provide good support to the county council involved in the challenging task of timely patient distribution during a mass casualty incident.
6.6.4. Education

All county councils have according to the Swedish Health care law the responsibility to prepare for major incidents so that they can be handled in the best possible way, eliminating or reducing loss of life and health, as well as limiting physiological suffering as much as possible. This requires planning and preparedness. None of these activities is possible without education and training supported by simulation techniques and interactive models so that the decisions made can be evaluated and related to potential patient outcome.

More training is required on the initial regional response for different types of major incidents, and how to support situational awareness, determine goals and medical response strategies. Research using both quantitative and qualitative methods is needed to enhance knowledge from education, training, simulation and real events. This will provide a step forward towards more evidence-based best practice in medical response to major incidents.

6.7. Conclusions

The conclusions of the four papers of this thesis can be summarized as follows:

- Measurable performance indicators for initial regional response to major incidents enables standardized evaluation where it is possible to find crucial decisions that can be related to patient outcome.
- If implementation of measurable indicators for regional medical response becomes mandatory, processes concerning resource allocation and casualty distribution may be quality assured.
- Measurable performance indicators can serve as a quality control tool to identify areas that have to be improved in disaster management education and training.
• Measurable performance indicators for initial regional medical command and control can be used as a quality control tool for major incidents that directly or indirectly involve casualties, provided there is sufficient documentation available.
• Measurable performance indicators could constitute measurable parts of a national follow-up of major incidents.
• Digital information system that could provide timely and accurate information and at the same time record all data would ensure and improve the medical response to major incidents and facilitate follow-up at all levels.
• National coordination of burn care and timely distribution of cases involving burns led to a better patient outcome in a simulated mass casualty burn incident.
• Reproducible simulations of mass casualty incidents that combine process and outcome indicators can provide important results on medical surge capability and may serve to support disaster planning.
• Modification of the present and additional indicators might be needed to assess hospital-related incidents.

6.8. Future research

This thesis has contributed to knowledge on the demand for rapid and accurate regional medical response at major incidents. Future prospective studies may demonstrate the true capability to make accurate and timely decisions within regional management in relation to patient outcome. This would lead to improvement in disaster medicine response. Further experimental simulations are needed with defined interventions to ascertain outcome and examine whether preventable deaths and complications can be reduced.
The study in paper III was conducted using data from major incidents occurring in Sweden from 2006 to 2009. Efforts to improve the regional medical response in these county councils have increased markedly in the last 5 years and quality indicators have now been implemented in the regional preparedness plans and have already been used as a quality control tool. It would therefore be of great value to collect new data to investigate changes over time and potential improvements.

The introduction of digital information and support systems for incident management in the future could help to provide accurate documentation of times and activities throughout the chain of medical command and support follow-up of major incidents at all levels. It would be interesting to further examine the time perspective and if there is a correlation between the patient’s time at the scene and the distribution key.

Future studies will demonstrate if performance indicators for initial regional medical command and control and national coordination of burn care can constitute measurable parts in the national evaluation and follow-up of major incidents.

I was once taught that simplicity is the key to disaster planning and that sometimes it can be a great advantage to use simple methods. Furthermore, education and research in disaster medicine are strongly connected to each other and are inseparable.
SVENSK SAMMANFATTNING

Syftet med denna avhandling är att öka kunskapen om vilka regionala medicinska beslut som är viktiga att ta snabbt vid händelser med många skadade eller där det kan finnas en risk för att många kan komma att bli skadade. Exempel på sådana händelser kan vara stora trafikolyckor, bränder och bombhot men även störningar i sjukvårdens infrastruktur (elförsörjning och IT-system). De beslut som har tagits eller som borde ha tagits, behöver också kunna utvärderas och ställas i relation till hur det i slutänden gick för patienterna och på detta sätt öka möjligheten till kvalitetsförbättringar. För att detta ska vara möjligt behöver det finnas en fastställd standard för vad som anses vara bra eller mindre bra.


Studie I visade att vid en simuleringsoövning av en läkarbrand så riskerade 11 patienter att avlida. Trots goda kunskaper i stabsarbete var innehållet i den regionala sjukvårdsledningens beslut bristfälliga och togs inte inom den satta tidsramen. I studie II så identifierades i liknande övningar brister i strategiska inriktningsbeslut och i tidig informationshantering. Studie III visar att majoriteten av de händelser som påverkat sjukvårdens katastrofmedicinska beredskap i de studerade landstingen var olyckor, bränder, allvarligare hotsituationer och infrastrukturstörningar. Utvärderingen av den regionala sjukvårdsledningens dokumentation i 66 allvarliga händelser visar på att beslut som rör fördelningen av drabbade, strategiska inriktningar och behov av ett eventuellt stöd från andra landsting behöver förbättras. Studien visade också på att det fanns brister i ledningsdokumentationen.
I studie IV visar resultatet från två standardiserade simuleringar av en stor diskoteksbrand med 400 drabbade på ett gynnsamt resultat för samtliga svåra inhalations- och bränskadade som transporterades i tidigt skede till ett bränskadecentrum i Sverige, Norge, Danmark och Finland. Flertalet av de svenska ambulanshelikoptrarna användes för transporter under de första 24 timmarna. En nationell samordning av bränskadevård som etableras tidigt kan leda till en mer korrekt och effektivare fördelning av skadade och fungera som ett stort stöd till det landsting som drabbats. Simuleringarna identifierade även att fördelningen av allvarligt skadade mellan landsting kan komma att försenas eftersom inkommande larm om allvarlig händelse hanteras på olika sätt i olika landsting. Hur samordningen och samverkan mellan sjukvården och övriga aktörer på bästa sätt ska etableras och organiseras när det gäller helikoptertransporter i en masskadesituation behöver undersökas vidare.

Denna avhandling visar att mätbara kvalitetsindikatorer för initial regional sjukvårdsledning möjliggör en standardiserad utvärdering där det är möjligt att identifiera viktiga initiala regionala beslut som kan ha betydelse för patienten. Indikatorer kan användas i uppföljning av större händelser där det direkt eller indirekt finns drabbade eller skadade. Metoden kan även användas för att testa sjukvårdens förmåga att ta hand om andra typer av scenario som och kan ge värdefulla resultat att använda i katastrofplanering. Kombinerat med mätbara kvalitetsindikatorer kan dessa resultat användas för att utvärdera beslut under och efter en händelse och kan identifiera förbättringsområden inom landstingens beredskapsorganisationer. Vid skadehändelser behöver viktiga medicinska beslut tas tidigt så att rätt skadad individ får rätt vård och behandling, inom rätt tid. Eftersom sjukvårdens resurser oftast är mycket ansträngda behöver beslut vid större händelser tas från ett övergripande regionalt (landstings) perspektiv.

För att på bästa sätt kunna hantera händelser med många skadade eller där risken är stor att många kan komma att bli skadade behövs därför en snabb och kvalitetssäker medicinsk respons från den regionala ledningsnivån som är likartad i hela Sverige.
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Appendix 1: Example of ETS patient

<table>
<thead>
<tr>
<th>447</th>
<th>Female 31 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Healthy</td>
<td></td>
</tr>
<tr>
<td><strong>EMERGENCY DEPARTMENT</strong></td>
<td>Finding / Measure</td>
</tr>
<tr>
<td>Airway:</td>
<td>Snoring sounds / Intubation</td>
</tr>
<tr>
<td>Breathing:</td>
<td>Normal breathsounds</td>
</tr>
<tr>
<td>Circulation:</td>
<td>HR 121 BP 95/55 36.5 °C / IV fluid</td>
</tr>
<tr>
<td>Disability:</td>
<td>GCS 13</td>
</tr>
<tr>
<td>Exposure:</td>
<td>50% TBSA full thickness burn / TO OP</td>
</tr>
<tr>
<td>Time:</td>
<td>0/30</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>447</th>
<th>Female 31 years</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BURN UNIT</strong></td>
<td>Finding / Measure</td>
</tr>
<tr>
<td>Airway:</td>
<td>Clear / Re-exam endotracheal tube</td>
</tr>
<tr>
<td>Breathing:</td>
<td>Normal breathsounds</td>
</tr>
<tr>
<td>Circulation:</td>
<td>HR 80 BP 115/75 38.8 °C / Antibiotics, IV fluid</td>
</tr>
<tr>
<td>Disability:</td>
<td>GCS 13 / Analgesia</td>
</tr>
<tr>
<td>Exposure:</td>
<td>50% TBSA. Normal urine output. Need of skin transplantation. Severe pain</td>
</tr>
<tr>
<td>Time:</td>
<td>0/30</td>
</tr>
</tbody>
</table>
Appendix 2: Photo of ETS simulations