Turning Chaos into Order

Preparedness, Concepts and Lessons Learned in Disaster Medicine

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(met een samenvatting in het Nederlands)

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Chapter 1
General introduction and outline of the thesis

J.J. Mark Haverkort

General introduction

The world has faced many major incidents and disasters, both natural and manmade, and the threat continues.[1] In recent years alone, natural disasters have injured numerous people and overwhelmed many healthcare systems. Recent examples are the 2015 Nepal and 2010 Haiti earthquakes. In 2011, an earthquake in Japan triggered a powerful tsunami, causing nuclear accidents and taking its toll on human life. The 2014 Ebola virus disease outbreak in Western Africa has called for a global response. The manmade-category disasters are caused mostly by industrial and transport accidents; mass gathering stampedes; and accidents with chemical, biological, radiological, and nuclear materials. The threat of terrorism, a manmade disaster, has increased globally over the last few years. Major cities in Europe and the United States of America have suffered from multiple and Mass Casualty Incidents (MCIs) and the threats remain.[2-6] Typically, MCIs lead to an imbalance between available medical resources and medical capacity. "Preparedness" is needed to combat this imbalance. Disaster Medicine covers the principles of preparedness through medical management, planning, development, training, and education for these events.[7] The goal of Disaster Medicine is "to reduce or eliminate avoidable loss of life and health, and physical and psychological suffering, in situations where available resources are insufficient in relation to the immediate need of medical care." [8]

The principles of Disaster Medicine can be traced back to the Middle Ages, although it has only become a distinct scientific discipline over the last 60 years.[9, 10] During the Middle Ages, knights were responsible for emergency care both in war and in peacetime, whereas public health came into existence to fight the Black Death epidemic, in order to create an organized response.[9] During the past 60 years, Disaster Medicine has become an acknowledged medical specialty. A trend has developed to advance the golden standards of Disaster Medicine from mere expert opinions to a standardized and evidence-based discipline.[11-13] Evaluation and sharing of events through a standardized method are of great importance as they can potentially improve future management of major incidents and disasters, allowing decision makers to broaden their knowledge and take informed decisions.[14-17]

In general, MCIs are subdivided into major incidents and disasters, both requiring adaptation and resilience from people and available resources to adequately respond to the situation. There is, however, a great dissimilarity in the handling of these situations. Major incidents are defined as situations in which the incident can be handled with available resources. However, an extensive rearrangement of the

resources is essential for a fully functional response. Disasters, on the other hand, are catastrophic events that unduly tax the emergency systems, hospitals, and infrastructure, thereby exceeding the capability of resources to such an extent that optimal trauma care can no longer be provided.[18, 19] This calls for a paradigm shift in the medical approach to these incidents. Instead of using resources for the greatest benefit of the individual patient, the limited resources are used for the greatest good of the greatest number of casualties.[20, 21]

Why do we need to prepare

As stated earlier, the worldwide risk of major incidents and disasters has been steadily growing. An increase in global threats, both natural and manmade, poses a risk to international healthcare systems.[22, 23] In parallel with these risks, hospitals have become increasingly vulnerable in their response to such incidents, owing to changes in the healthcare system.[24] This paradoxical development is considered to be the consequence of industrial and technical development over the years. At a rapid pace, technical abilities have led to the performance of new and advanced procedures with an increase in differentiation of the medical sector. This, combined with the ageing of the general population, has led to a rise in costs, which in turn has forced the healthcare sector to reconsider its cost effectiveness and to increase its efficiency. In doing so, hospital resources have become utilized to their fullest extent and hospitals hardly have any reserves at their disposal with which to respond to a sudden and unexpected surge of victims from MCIs.[25, 26] Hospital disaster plans describe the way resources and infrastructure should be reallocated in order to handle a MCI. These plans should describe key components of the response to a disaster and be regularly assessed and adapted based on new insights.

What to prepare for

Surge capacity is defined as the ability to accommodate an inflow of patients, which is a dynamic process.[27] Patient surge during MCIs will affect the quality of trauma care provided. The surge capacity, combined with the availability of the critical and limiting resources, such as ventilators, intensive care, and operating-theatre capacity, are critical factors in a hospital's disaster response.[26, 27] As a consequence of the developments in efficiency, hospitals need to prepare and plan ahead for situations causing a sudden increase in patient surge.

Triage is used to prioritize the use of critical resources and to provide the right patients with the right care. In recent experiences with MCIs, triage generally resulted in a high incidence of over-triage of victims and there was limited or no

under-triage.[3, 19, 28, 29] Over-triage inappropriately assigns a high priority and the use of constrained resources to non-critically injured victims, thus impairing the management of the critically injured.[20] Generally, some over-triage is acceptable so as to reduce potentially life-threatening under-triage to zero.[20, 30] It is a misconception to assume that patient surge is limited by the ability of the ambulance services to transport casualties from the scene, because two-thirds of patients refer themselves to nearby hospitals during MCIs.[31]

The Dutch healthcare system has a unique solution to increase the resilience and preparedness of the healthcare system: a hospital dedicated to the handling of surge capacity from MCIs. This Major Incident Hospital (MIH) was established as a civil–military cooperation in 1991 and is located in a nuclear shelter in the University Medical Centre, Utrecht.[32] Its design and organization offer an available capacity and staffing to receive 200 patients from MCIs after a 30-min deployment time. The MIH has longstanding experience in optimizing preparedness for MCIs by designing new systems and instituting training and then evaluating their deployment.[33-36] The on-going development of systems, the design of new concepts, and the evaluation of their deployment are aspects that are studied in this thesis.

Rationale and outline of the thesis

This thesis focuses on preparedness for MCIs from a hospital point of view. The thesis is subdivided into two parts. Part 1, chapters 2-6, discusses new concepts and on-going developments to promote preparedness. Part 2, chapters 7-10, describes evaluations and lessons learned in preparedness and medical crisis management from different perspectives.

Part 1: Preparedness

Chapter 2 introduces the status of the current preparedness for an attack on the Utrecht Central Station, the busiest railway station in The Netherlands. General preparedness and the importance of adequate distribution of victims are discussed.

Chapter 3 describes the development of "dedicated mass casualty incident hospitals". This type of hospital is rare in the world of disaster preparedness. However, reserved standby capacity can provide a great deal of stability to a country's healthcare system in the event of major incidents or disasters. An overview is given of the facilities in three countries: The Netherlands, Italy, and Israel. The design of the hospitals is discussed in the light of the threats that each country faces.

Registration, tracking and tracing of patients is of great importance during a major incident. Computerized systems can greatly enhance the availability of information both internally and externally. **Chapter 4** describes the on-going development of the Patient Barcode Registration System, which is used to register, track and trace patients during MIH deployment.

Correct registration and medical-record keeping are challenging for staff during a major-incident response. At the scene, the chaos might undermine any system; however, in-hospital systems can be designed and put in place to optimize these efforts. A triage registration form was designed based on the experiences from the MIH. The form aims to improve the registration of the patient upon arrival in the ambulance bay and to offer assistance to the triage physician by guiding them through the process. **Chapter 5** describes the development of the form and its usability.

Chapter 6 discusses the lack of medical-record keeping during the acute phase of treatment in a high-surge situation. To enhance documentation, a pilot study with a specifically designed "disaster medical record" was performed. This pilot medical record was designed to follow the patient's course through the hospital system and to offer the right documentation to the care provider in a timely manner.

Part 2: Evaluations and Lessons Learned

One of the deployments of the MIH has been in a highly pathogenic and contagious infectious disease scenario. In 2014, the world witnessed the rapid spread of a highly contagious infectious disease in Western Africa. The Ebola virus disease, a viral haemorrhagic fever (VHF), was managed with effort contributed from all over the world. Spreading of the virus to other continents was a realistic scenario. **Chapter 7** presents the preparations for VHF patients made in the MIH. It discusses the challenges and presents novel working methods. The MIH has been deployed to treat an Ebola virus disease-infected soldier missioned to protect healthcare personnel. The main lessons learned are presented in the light of the preparations that were made.

In terms of preparedness, every single scenario should be rehearsed, and training should be as close to reality as possible. **Chapter 8** evaluates and compares two real evacuations of hospitals and care institutions to the MIH, further comparing them to an exercise that took place in a similar scenario.

Patient-centred care has been a topic of growing interest in medicine for years. However, during major incidents and trauma exercises, the focus is still on the operational response and patients' experiences are rarely reviewed. **Chapter 9** introduces a novel concept for evaluation. Mock patients were equipped with point-of-view cameras to gain insight into their experience during major incident exercises. To improve the healthcare sector's crisis and disaster preparedness, the Dutch government has funded a temporary support package project. The package provided the financial means to train key players in medical-crisis management. **Chapter 10** describes the effectiveness of such a package, which included the migration of trained personnel, and reflects on the suitability of such temporary measures for knowledge consolidation.

Chapter 11 summarizes the main conclusions and proposes recommendations for future research in Disaster Medicine.

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Chapter 2
Terrorist attack: setting the stage

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Submitted

Abstract

Preparation and planning are the key to successful response to major incidents and disasters. The region of Utrecht, in the Netherlands, organizes many activities through education, training and simulation in order to be prepared for incidents.

Analysis of recent incidents in Europe and the United states of America emphasize the need of distribution of casualties to centres where adequate care can be provided. Through the drafting of patient distribution plans and regional hospital disaster plans the Utrecht region has improved preparedness.

Moreover, the Netherlands is equipped with a unique facility which can provide an additional capacity of 200 beds to the Dutch healthcare system on a 30 minutes notice.

Introduction

In the light of the recent terrorist attacks on major European cities, the topic of preparedness has increasingly become a basis for discussion in The Netherlands. In this article, we give an overview of the preparations in the medical chain and the preparedness of the regional hospital system, as illustrated through the following scenario. "A suicide bombing has taken place at Utrecht Central railway station, during the rush hour; the first victims will arrive at your hospital within the next 5 minutes. What will happen next?"

Preparedness

Major incidents and disasters are situations in which the need for medical care exceeds the available medical capacity of a healthcare system. The difference between a major incident and a disaster lies in the organization of the response to the incident. A major incident can be successfully responded to through the reallocation of resources within the medical system. In the case of a disaster, however, the demand for medical care cannot be met by the existing system.

The main challenge during either of these events is firstly the redistribution of resources and staff to the right locations and, secondly, optimal utilization of these assets. This can be realized through efficient triage and the use of damage-control medicine. Preparation and planning, combined with a well-established command and control structure, are the key to successful upscaling and organization of the response. Regular education, training and simulation exercises form the basis from which to optimize these processes.

Every Dutch hospital has, by law, to be in possession of a hospital disaster plan describing the processes of up-scaling care and rearrangement of resources that are necessary in order to be prepared for a MCI response. As of 2005, training under these plans has to be performed on a yearly basis.

The control and the distribution of patient surge are critical for hospitals. The Advanced Trauma Life Support proposes and emphasizes the importance of "do no further harm". This proposition includes the distribution and concentration of victims to institutions that can provide the right care for that individual patient. Polytrauma, severe brain injury and burns are examples of injuries that demand specific care and capabilities from an institution. One of the risks during a MCI response is that all

patients are taken to a single centre that either lacks the knowledge to treat these specific injuries or is overwhelmed by the lack of patient distribution, leading to an overall dysfunctional response.

Past MCIs have provided the community with important lessons. The responses to and lessons learned from MCIs in Europe and the USA have been analysed in the literature.

Analysis of the Madrid, Boston, Paris, and Brussels attacks has confirmed that hospitals in close proximity continue to be overwhelmed with victims at an early stage.[1-4] Over-triage of patients, which is common because of the design of triage systems, further increases the patient surge. An effective response to these events is impossible without planning ahead and then implementing the plan as a robust, efficient, and well-rehearsed hospital disaster response. As a counterpart, the ambulance services are, by law, required to be equipped with a patient-distribution plan. The distribution plan serves two purposes: first, fast access to treatment that improves patient outcomes; secondly, adequate distribution that redirects patients away from hospitals that are in the proximity of the incident, and which would already be overwhelmed with self-referring patients.[6,7] As an adjunct to the individual hospital disaster plan, the region of Utrecht, the Netherlands, has drawn up a regional hospital disaster plan (R-HDP).[8] The R-HDP aims to coordinate the disaster plans of individual organizations (hospitals, ambulance dispatch, SOS alarm centres, involved government agencies, etc.) and the regional agreements between organizations. These plans are combined in order to achieve coordinated and efficient patient relief during major incidents and disasters.

Major Incident Hospital (MIH)

The Netherlands is equipped with the MIH, a unique facility functioning as an insurance policy for the healthcare system. The MIH is positioned alongside the highway in Utrecht, a city located in the centre of the Netherlands. The MIH was founded as a civil–military cooperation between the Ministry of Defence and the Ministry of Health, Welfare and Sports and is located in and maintained by the University Medical Centre of Utrecht. As of 1991, the MIH is equipped with 200 fully prepared, standby patient beds in order to function as a buffer capacity for the Dutch healthcare system.[9] In the event of an acute peak in patient surge due to an incident, the MIH can be deployed within 30 minutes to receive up to 200 patients. The characteristics and statistics of the MIH are depicted in Figure 1. The combination of a University level-1 trauma centre, a military hospital, and the National Poison Information Centre offers

Table 1. Characteristics of the Major Incident Hospital

General	
Surface	8000m^2
Established in	1991
Total capacity	200 beds*
Time needed to deploy	30 minutes
Capacity	
Triage	10 beds
Intensive care	12 beds
Medium Care	50 beds
Low Care	134 beds
Operation theatres	3
Recovery	5 beds
Medical treatment capacity	
T1	16 / hour
T2	24 / hour
T3	60 / hour
Deployment criteria	
T1/T2	Minimum 5 patients
T1/T2/T3	Minimum 15 patients
Results	
Number of deployments	43
Number of patients admitted	787

* Can be extended up to 300 patients after 24 hours.

the right infrastructure and level of knowledge needed to respond to every type of incident. The MIH caters for non-traumatic scenarios as well; it has been deployed to receive patients from evacuated care institutions and can provide care for patients with highly pathogenic and contagious infectious diseases in the isolation unit.[10-12]

Owing to their capability to receive large groups of patients within a short time, other regional hospitals can continue providing care to regular patients, while the MIH caters for the patient surge from a large-scale incident. The aim of the MIH is to handle the acute phase of chaos, triage, stabilization and resuscitation. After the acute phase, patients are referred to regular hospitals throughout the Netherlands with the necessary medical and surgical expertise. These hospitals then proceed with the definitive care.

The MIH offers unique opportunities for patient distribution in the Netherlands, given the small size of the country. By dealing with the MCI patient surge either entirely or in part, it is possible to concentrate patients in a single centre, rather than distributing them throughout a number of hospitals. This concentration guarantees the adequate registration of patients, as well as ensuring continuity of care in surrounding institutions. Patient transport will benefit from a quick and efficient transport system. The emergency services will benefit from a single destination for patient relief and the logistical advantages it provides. Given that all emergency services will have the same destination, the authorities can close transport lanes on highways to other traffic, to further improve the speed and logistics of patient transport. The organizational benefits extend to the agencies involved, to the press and to the general public. A clear overview of the situation and of patients' locations can be provided. In a later phase, after the initial chaos, patients can be transferred to the regular healthcare system in an orderly and organized way and accompanied by complete medical documentation. This guarantees that the patient will be transferred to the right location for their respective care and social needs.

Scenario

The scenario posed the question of what would happen in the Utrecht region's healthcare system in the case of a terrorist attack at Utrecht Central railway station, during the rush hour. Based on the statistics from the Madrid and Brussels events, approximately 150 persons will be wounded in the attack, aside from those patients who have died at the scene. Considering the severity of injuries from previous major incidents caused by terrorist bombings, patient triage will result in 15 T1 (10%), 30 T2 (20%), and 95 T3 (70%) patients.[2, 13-15]

The safety region will respond by activating the national ambulance support plan, in order to mobilize extra capacity from throughout the nation. The medical officer in command of the scene will act according to the regional patient-distribution plans and the R-HDP. The hospitals in close proximity to the scene will be alerted and up-scaled to cater for the large surge of self-referring patients. These self-referring patients sometimes even arrive prior to the alerting of the hospitals and overwhelm the available resources.[6, 7] Typically, only 36% of patients are transferred by ambulance following a major incident or disaster.[6]

Simultaneously, in accordance with the patient-distribution plan, a request will be made to deploy the MIH. The accident and emergency department will receive the request and inform the trauma surgeon on duty. The trauma surgeon

will then, after consultation with a member of the board of directors, decide whether deployment will take place. Within 5 minutes, a decision is made and communicated back to the officer who has requested the deployment. In this scenario, the MIH will be deployed and up-scaled to the maximum scenario and resources, and an automated phone alerting system will be activated to recruit from a pool of 1200 staff, including support staff from the Dutch Red Cross. The MIH is equipped to receive 16 T1 and 24 T2 patients per hour. Upon arrival in the ambulance bay, patients are triaged and registered with the Patient Barcode Registration System. Primary survey, resuscitation and stabilization of vital functions take place in accordance with Advanced Trauma Life Support protocols. Further care is provided according to damage-control principles within the MIH's own intensive care unit, operation theatres and wards.[9, 16] The process to refer patients to regular care insitutions is initialized within two days. Patients are referred to medical centres based on social grounds and medical needs. The intention is to downscale and close the MIH within five days, after which the process of evaluation to learn from the experience and to improve for future deployments will begin.

Every scenario will lead to points for improvement. The sharing of lessons learned, and their solutions, will lead to the optimization of preparedness and care. An adequate level of education, training and simulation is the key to success in preparedness. Initiatives such as large, regional major-incident exercises take place frequently in the Utrecht region, with the participation of the whole medical chain. The Medical Response to Major Incidents (MRMI) course was introduced in 2010. This course merges the principles of the separate Major Incident Medical Management and Support (MIMMS) and Hospital Major Incident Management and Support (HMIMS) courses.[18] The course features simulations using the MacSim card system, which is based on patients from the London and Madrid bombings.[17] During these simulations, the functioning of the complete medical chain is rehearsed, giving the emergency services and the hospital organization valuable insights into each other's processes and critical needs.

In conclusion, a range of activities involving education, training, and simulation take place so as to prepare the Utrecht region for major incidents. An important step has been initiated through the introduction of patient distribution and regional hospital disaster plans. Furthermore, the Netherlands is equipped with a unique facility that is equipped with 200 stand-by, fully prepared, reserve beds for the healthcare system.

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Chapter 3
Dedicated mass-casualty incident hospitals: an overview

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Submitted

Abstract

Introduction: Hospitals worldwide are preparing for mass casualty incidents (MCIs). The Major Incident Hospital in the Netherlands was constructed 25 years ago as a dedicated hospital for situations wherein a sudden increase in medical surge capacity is mandated to handle a MCI. Over the years, more initiatives of dedicated MCIs have arisen. Herein, we compared the MCI facilities from three countries considering the reasons for construction and the functionality.

Methods: Three dedicated mass casualty hospitals and one hospital with a largely fortified structure were compared. The centres were located in the Netherlands, Italy, and Israel. Between August 2015 and January 2016, structured interviews were conducted with representatives of the hospitals' medical operations. The interviews focussed on general information regarding the need for MCI preparedness and scenarios that require preparation, reasons for construction, hospital missions and the experiences gained including training.

Results: All dedicated MCI hospitals had a common policy wherein they sought to create normal work circumstances for the medical staff by using similar equipment and resources as in normal hospitals. The MCI hospitals' designs differed substantially, as determined by the threats faced by the country. In Europe, these hospitals are designed as a solution to surge capacity and function as buffer hospitals offering readily available, short term, additional medical capacity to the local healthcare system. Israel faces constant threat from long-term conflicts; during the 2006 war, several hospitals suffered direct missile impacts. Therefore, Israeli MCI hospitals are designed to be fortified structures offering shelter against both conventional and non-conventional warfare and intended as a long-term solution during siege situations.

Conclusion: Several dedicated MCI hospitals are presently being constructed. During construction, the local circumstances should be taken into account to determine the functionality for both short-term solutions for surge capacity and as fortified structures to withstand under-siege situations.

Introduction

Hospitals worldwide prepare for both natural and manmade major incidents and disasters. Over the last 15 years, terrorism has become a great threat to several countries of the world. Major cities in Europe and the United States have suffered multiple and mass casualty incidents (MCIs), and the increased threat is on-going.[1-6] Terrorism-driven MCIs present the challenge of uncommon trauma for western centres, where blunt trauma usually exceeds sharp trauma, requiring specific training. Further, by definition, MCIs lead to an imbalance between available medical resources and the required trauma care capacity.[7-9] Hospital handling of MCIs such as terrorist attacks, war-casualty situations, and other large incidents have been described previously, and all have a common denominator; chaos, a different type of trauma mechanism and the need for alternative resource allocation to provide the necessary care as well as the large numbers of casualties might compromise the quality of trauma care provided.[7, 8] Hospital disaster plans are developed to rearrange and redistribute hospital resources to provide the severely injured with the best possible level of care. Surge capacity, the ability to accommodate an inflow of casualties that exceeds the routine daily capacity of a hospital, is a fundamental issue in mass casualty care compromising the standard of trauma care. Besides the number of patients in need of treatment, arrival rate and use of available resources should be taken into account.[9] The lessons learned from the medical response in several terrorist attacks all include the difficulty in handling the patient surge combined with the level of over triage further increasing the surge.[2, 3, 6, 9] Moreover, an equal distribution of patients over the regional hospitals wherein patients go to the centres where they can receive appropriate care (i.e., neurosurgery or burns care) is often not successful owing to dysfunctional use of distribution plans or lack thereof.[2, 3, 10] The high rate of self-referral to the emergency departments in case of a MCI especially compromises the hospital's infrastructure and logistics.[11] In the Netherlands, a dedicated MCI hospital was constructed to function as buffer capacity to handle the surge in such instances. The construction and properties of this Major Incident Hospital (MIH) have been described previously by Marres et al.[12] In short, it is equipped with 200 beds and can be activated within 30 min to respond to high-surge situations. The MIH is supported by the UMC Utrecht, a level-one trauma centre equipped to provide full trauma care round-the-clock. After evaluating its deployments over 15 years, it was concluded that having a dedicated facility benefitting from improved infrastructure functions very well during high-surge incidents.[13] In recent times, the interest in dedicated MCI hospitals has risen, and various initiatives have started from both private and government backgrounds, one of the most prominent being in Israel,

where the continuous threat of MCIs forces hospitals to prepare for under-siege periods rather than isolated incidents. This study compares the MCI facilities from three countries considering the reasons for construction and functionality.

Methods

Several dedicated MCI hospitals currently exist: we focus on two such centres in the Netherlands and Israel, and a third initiative, in Italy, which is in the process of raising the requisite funding to start construction. Several hospitals in Israel are fortified to withstand the daily threat of missile attacks; one of these initiatives is included to illustrate this scenario. Medical operation representatives of these hospitals were interviewed regarding the design, scope, functionality and operations. The interviews were designed based on Lennquist's protocol, the current standardised protocol for reports from major accidents and disasters.[14] The categories in the protocol were used as guidelines for the interview questions. The first part of the interview aimed to acquire general information regarding the need for MCI preparedness and scenarios that it should be prepared for (i.e., risk areas for natural disasters or terrorist attacks). All interviews took place between August 2015 and January 2016.

Results

The results are presented based on the location of the hospitals. An overview of the results is depicted in Table 1.

The short-term "buffer" solution: Utrecht, the Netherlands

The main threats faced by the Netherlands are natural disasters (i.e., flooding due to dike failure) and mass-gathering events given the dense population of the country. Further, threat of terrorist attacks in Europe has greatly increased, as seen by the attacks in Madrid, London, Paris, and Brussels.[3, 4, 6] During the cold war, all newly constructed university medical centres in the Netherlands were obliged to construct fortified nuclear shelters inside their premises to enhance preparedness in case of escalation of the cold war conflict. Most of these shelters nowadays serve as housing for technical equipment or as storage facilities. However, one centre was developed to be a dedicated structure with extra emergency care facilities in case of a MCI. Situated in the centre of the Netherlands is the MIH, a fortified bunker on the ground floor of the University Medical Centre Utrecht (UMC Utrecht). The UMC Utrecht

is a level-one trauma centre and university hospital and is adjoined by the Central Military Hospital (CMH). The opportunity to construct the MIH resulted from the central location of the facilities combined with the already present civil-military medical cooperation. The location of the MIH itself was already founded during the construction of the UMC Utrecht, when the fortified nuclear structure was built in the basement of the new hospital. The structure was initially designed as an emergency hospital for the care of large numbers of military casualties. However, owing to the growing demand for civilian MCI preparedness, the MIH was initiated in 1991 under military-civilian cooperation.[12] During the 25-year existence of the MIH, it has thus far been deployed 43 times for a total of 787 patients.[13, 15] The MIH is the result of an opportunity to collaborate between the civilian and military medical branches, as both need guaranteed medical capacity, though for different motives. The military demands a guaranteed medical capacity, with the highest possible level of care available, for soldiers who are deployed in conflict areas. The civilian society has encouraged the development of a fast and highly prepared centre, which is supposed to be virtually immediately available in case of major incidents or disasters in the Netherlands. To accommodate the wishes of both parties the stand-by hospital was built with 200 available beds that can be deployed within 30 min. The stand-by situation

Table 1. Overview of characteristics of the hospitals

	The Netherlands	Italy	Israel	
	MIH	**GUMIH**	**FUEH**	**GMC**
Scenario				
Preparedness goal	Acute	Short term	Planned	Planned
Fortified	Yes	No	Yes	Yes
Max duration of deployment	5 days	*	Long term (war)	Long term (war)
Activation				
Time needed	30 minutes	2 hours	72 hours	90 minutes
Scenario	Additional Surge Capacity	Overflow capacity	Fortified capacity	Fortified capacity
Capacity (beds)				
Total capacity	200 *	100	2000	700
Funding	Government	In Progress	Private and Government	Government
Deployment				
Times deployed	43	n.a.	0	1
Patients received	787	n.a.	0	1750

* Functions as a hybrid overflow capacity for the A&E department
** Can be extended to 300 after 24h

of the MIH is shown in Figure 1. The hospital functions as a buffer capacity for the healthcare system. In case of a sudden high demand for medical capacity, additional capacity can be offered by deployment the MIH. Because of this buffered nature, the MIH is required to function as extra capacity and can do this for a maximum of five days, after which the patients should be referred to regular care centres throughout the Netherlands. This distribution of patients prevents the local medical systems from being overwhelmed by the increase in care demand. The MIH aims to use the same standard of medical care as under normal circumstances; it benefits from the shared resources and infrastructure of the UMC Utrecht and CMH. In addition to the regular care capacity, the hospital is equipped with four Biosafety Level 4 isolation rooms to care for patients with (suspected) highly pathogenic diseases. The MIH is characterised by its credo "Routine work under exceptional circumstances," meaning it is designed to be equipped with similar equipment and materials as the UMC Utrecht and CMH to create equal work processes as under normal circumstances for the medical and support staff. Regular training is conducted for all possible scenarios. A yearly trauma drill is organised to train the MIH at full strength and perform stress tests. The lessons learned are then implemented on a daily basis.

The intermediate "hybrid" solution: Rome, Italy

Italy and Rome especially prepare for various natural and man-made MCI scenarios. Most importantly, the mass-gathering events, large tourist population, Vatican City, political institutions, two airports, and a stressed subway system contribute to possible MCIs. Furthermore, the risk of terrorist attacks is increasing due to the advancement of ISIS in Northern Africa as well as the general rise in threats with the recent terrorist attacks in Europe. The project to design a dedicated MCI hospital in Italy started in 2013. The plans were developed based on shared experience from the centres in Israel and the Netherlands. The centre is planned for construction in an underground facility, adjacent to the accident and emergency (A&E) department of the Policlinico A. Gemelli (PAG) in Rome, Italy. The PAG is the largest hospital in Rome, a level-one trauma centre equipped with over 1300 beds, of which 90 are intensive care unit (ICU) beds, and 30 operating theatres. It has a close cooperation with the Italian poison centre and the military forces. The choice to construct the centre underground was based on the limited availability of space above ground. The Gemelli Underground Major Incident Hospital (GUMIH) will be equipped to provide an additional 112 beds for T1 and T2 patients and function as a resuscitation area as well as including four treatment rooms for patients (suspected of) highly contagious infectious diseases. Patients from the T3 category are expected to be treated in the regular A&E department of PAG. The GUMIH will be further equipped with a VIP room

Figure 1. One of the Major Incident Hospital wards during the stand-by phase

for high-profile casualties, 2 operating rooms and a computed tomography scanner. The GUMIH is expected to serve as an overflow capacity for the A&E department and will be built and deployed in phases; for example, if 40 beds are needed, only an area containing that number of beds will be opened. The design plans of the hospital have been finalised and the recruitment of funds to construct the GUMIH is currently in progress.

The long term "under-siege" solution: Israel

Israel has long-standing experience in preparing for various MCI scenarios including conventional and non-conventional warfare. The threats faced by this country have forced the Israeli healthcare system and hospitals to prepare for short-, and more importantly, long-term hospital under-siege scenarios. During the 2006 war between Israel and Lebanon, the hospitals in the border region of northern Israel faced multiple missile attacks on a daily basis. The lessons learned during the war have had a great impact on the organisation of the nation's healthcare system and hence led to fortification of hospitals and further preparations to improve preparedness. Two of those initiatives are presented here.

Galilee Medical Centre, Nahariya.

The Galilee Medical Centre (GMC) at Nahariya, Israel, experienced direct missile hits in the 2006 conflict and has become highly experienced in the treatment of war-related injuries and trauma. The hospital began a process of fortifying the hospital's structures including the recently constructed A&E department and Woman's Health Wing.[16] As of 2016, the hospital has a capacity of 722 beds, with an additional 700 protected beds in fortified areas, including the gynaecology, A&E, ICU and imaging departments. Of the 700 beds, 300 are in locations fortified to withstand both conventional and unconventional warfare. The fortified areas are connected by tunnels to allow a continuous supply of resources to enter the hospital during under-siege situations. Vacant areas under the hospital can be reorganised in order to provide 90 additional beds for patient care. The hospital specifically prepares for under-siege situations by organising regular small-scale drills and annual large-scale trauma and logistics drills. The fortified areas were used for 33 days during the 2006 conflict and received 1750 patients.

Sammy Ofer Fortified Underground Emergency Hospital, Rambam Health Care Campus, Haifa, Israel

The Rambam Health Care Campus (RHCC) in Haifa suffered numerous missile attacks during the 2006 war and in the 2014 Operation Protective Edge. The circumstances forced the hospital to relocate wards to underground spaces and corridors; however, owing to a shortage of shielded spaces, not all wards and patients could be relocated to safer areas. During the 2006 conflict, the injured were treated "under fire" as the A&E department lacked proper fortified protection. This experience has underlined the necessity to construct a safer hospital.[17] Following these experiences, two plans were made: first, a new fully fortified A&E department was constructed; second, the hospital started construction of the Sammy Ofer Fortified Underground Emergency Hospital (FUEH) a three-storey underground car park which is a dual-purpose facility capable of conversion within 72h into a fortified 2000-bed underground hospital in case of conflict, making it the largest hospital of its kind. The FUEH was built to withstand both conventional and unconventional warfare and can continue functioning during under-siege circumstances. The construction of the hospital was completed in 2014, its design a result of the lessons learned during the 2006 war combined with an international exchange of experience in constructing this type of facility. The infrastructure for the hospital is fully integrated into the walls of the car park. The deployment procedure starts with the removal of cars occupying the area followed by thorough cleaning, after which all the necessary infrastructure for air conditioning, sanitation, medical and other purposes is put in place. Closing down a layer of the car

park during the early stages of an alert can shorten the deployment time. The regular capacity of the RHCC is 1000 beds; all patients are to be evacuated to the FUEH in times of conflict, thus providing the Israeli healthcare system with an additional 1000 beds for war victims or patients from other hospitals. Every department in the regular hospital is equipped with disaster plans containing specific information on where their respective area is located in the car park. Both patients and equipment would be moved during deployment; therefore, the working equipment and procedures in the FUEH are similar to the RHCC, and this is also the philosophy of the MIH as well. The FUEH is equipped with 4 operating theatres, a decontamination facility, and 94 beds for ICU care. Furthermore, the FUEH is equipped with a kindergarten, kitchens, and resting places to enable medical staff and their families to provide care during long-term crises, as during the 2006 war.[18] Regular training is performed to ensure awareness of disaster plans and fast transfer to the underground hospital. In light of the 2014 Ebola virus outbreak in Western Africa, the FUEH has now equipped the lowest floor with isolation equipment to care for suspected or diagnosed EBV patients from all over Israel.[19] Regular training takes place; in 2014, a large-scale training exercise was organised to fully deploy the FUEH with good results. Regular small-scale exercises take place to create awareness of the disaster plans and the FUEH protocols. Fortunately, the FUEH has not been deployed since its opening in 2014.

Discussion

A hospital's response to mass casualty care and MCIs specifically caused by terrorist attacks requires a high level of preparedness. Hospitals worldwide increase preparedness by drafting hospital disaster plans, educating staff, and carrying out regular training exercises for MCI scenarios, and terrorist attacks in particular. Major challenges in preparedness can be overcome by construction of dedicated MCI hospitals with specific solutions for the high patient surge during a MCI. In order for such a facility to function, the situation and risks of the country need to be considered during the design stages of these facilities. This can be seen in the variation between the three countries presented here: the Netherlands, on the one hand, as a country without the threat of war and in need of short-term capacity for isolated MCIs, and Israel, on the other hand, with the constant threat of long-term conflicts with mass casualties and hence, in need of a more permanent solution during times of conflict. Italy, however, is looking at an intermediate solution. In Europe, preparedness is therefore mostly focussed on surge capacity, whereas Israel requires protection from warfare and longer-term solutions for under-siege situations. This can further

be concluded with regard to capacity: in the Netherlands, there is a strictly reserved capacity, which is fully on standby, while the Italian solution can be used as an overflow capacity of the emergency department. In the Israeli model, the capacity replaces the daily-care capacity for a fortified, safer option, instead of aiming to provide extra capacity to handle a high surge of patients. Therefore, the design of a dedicated MIH depends mostly on the threats a country faces and the choice to create a long-term "under siege" or short-term "buffer capacity." One thing all centres have in common though is the policy to create equal work procedures in the emergency facility as in the regular hospital. This enables the medical professionals to provide routine care under special circumstances with only a few trained key players adopting coordinating functions in order to support the remaining staff in their work. Various MCI reports in the literature have underlined the difficulty of coping with a high surge of casualties in civilian hospitals.[2, 3, 5-7, 9] These reports mostly describe a successful response to the MCI; however, the surge is not always distributed between the available centres and patients are sometimes transported to inappropriate care centres; for example, a neurotrauma patient may be taken to a level-three trauma centre. During the Boston MCI, six severely injured patients were all transported to one centre even though another, equally equipped, centre was within the vicinity of the incident.[2] A dedicated MCI hospital should be built alongside a level-one trauma centre, thus ensuring the necessary expertise to respond to a MCI as well as having the correct infrastructure to handle a surge and also perform the appropriate registration of patients. This then resolves the above-mentioned issues of patient distribution as one centre handles the initial response to the MCI. The Dutch MIH aims to maintain a standard level of care, even under disaster circumstances. The high level of preparedness ensures the availability of resources necessary to maintain the standard of care. This is exemplified by an incident in 2012 when 46 elderly patients were evacuated from a home for the elderly to the Dutch MIH; nine of the patients suffered from severe inhalation trauma and were intubated within the hour. All patients received the maximum level of care and, despite their vulnerability, the mortality rate was zero.[20] The cost-effectiveness of the Dutch MIH is clear when analysed alongside other regional hospitals: for example, the costs of closing a hospital for one day exceed the costs of maintaining the MIH for a year. Since its construction 25 years ago, the Dutch MIH has been deployed, on average, twice per year, thus covering the budget of its maintenance.[13] Furthermore, it serves as a training facility for disaster medicine for various institutions throughout the Netherlands. The idea of having the MIH present in the region has been reassuring to inhabitants as well as to care providers. With regard to the Israeli facility, this generates income as a paid underground car park during non-combative times. The

budget of the Italian design has not yet been finalised. It should however be taken into account that besides the initial costs of construction the maintenance of dedicated MCI hospitals is costly and should be taken into consideration during its design. On-going training with comprehensive evaluation will provide the lessons learned to further improve preparedness and functioning of these hospitals. Exchange of information is of great importance in order to advise others in designing, constructing, and optimising dedicated MCI hospitals.

In conclusion, the question is not if a major incident will happen but when it will happen. Hospitals should therefore prepare themselves to be able to provide the best possible care under these circumstances. As a solution to handle the high patient surge during MCIs, several countries have constructed dedicated MCI hospitals. These facilities are built to provide additional stand-by capacity for the healthcare system and are equipped to optimise the registration and treatment of large groups of patients at the same time, something which remains a challenge given the lessons learned from various terrorist MCIs in Europe and the United States. The designs of these facilities have to be adapted to local circumstances, likely MCI scenarios, and threats faced. The initiatives presented in this study range from functioning as a short-term buffer for surge capacity to a long-term hospital under-siege scenario. However, they all emphasise the need to create similar working practices for medical professionals by keeping procedures and equipment similar to regularly used resources. Therefore, this type of facility should be seen as an insurance policy or guard rail; they are invisible during normal operations, but can help save lives during MCIs.

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Chapter 4

Continuous development of a major incident in-hospital victim tracking and tracing system, withstanding the challenges of time

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Abstract

Objective: To describe the development of the Patient Barcode Registration System over time and confirm the usability and feasibility of the systems latest version during a large trauma drill.

Methods: The development of a Patient Barcode Registration System (PBRS) started around 1993 aiming to provide an effective tool for patient registration, tracking and tracing during major incidents. The PBRS uses wristbands with barcodes to follow and register patients in the care process. During a large trauma drill 120 patients and 40 relatives will be registered and traced in the system. Errors in registration, tracking and tracing of persons are registered.

Results: Out of the 120 patients, no patient data was lost and patients could be traced in real-time throughout the treatment process by the command team. Strategic decisions could be taken based on the information provided by the system. Patient relatives were easily matched and government agencies received regular updates on the number and characteristics of the patients.

Conclusion: The PBRS is a usable, feasible and sustainable patient tracking and tracing tool to be used during the hospital response to major incidents. Lessons learned during the last 20 years include the need for continuous updates to withstand the challenge of time.

Introduction

In-hospital patient tracking during major incident responses is a huge challenge. During disasters, pre-hospital registration of patients is often limited because of the high workload and chaos at the scene. Therefore, hospital disaster plans should focus on optimizing in-hospital patient registration. Most current victim-tracking systems focus on the pre-hospital response, and experience has shown that patients are often untraceable for significant periods, even after they have been admitted to a hospital. This was emphasized during a plane crash in the Netherlands, where it took 4 days to locate 136 victims because of insufficient patient registration, both pre- and in-hospital.[1]

The development of the Patient Barcode Registration System (PBRS) started in 1993 in the Major Incident Hospital (MIH) of the University Medical Centre Utrecht (UMC Utrecht), the Netherlands, with the aim of improving patient registration during major incidents.[2] The MIH was constructed in 1991 as part of a civil–military cooperative effort. It is a highly prepared, standby, 200-bed buffer hospital for the Dutch healthcare system that can be deployed within 30 minutes of a major incident or disaster, as described elsewhere.[3, 4] The PBRS was created to optimize the in-hospital disaster response and patient registration. It uses wristbands with barcodes to register and follow patients from the ambulance hall to their final destination. Over the last 20 years the PBRS has proven its value, although the initial version lacked the speed to register high numbers of casualties.[5] An entirely redesigned version, with new features, was developed in 2014 to match the system to current IT standards. This paper describes the ongoing development of the PBRS, including the results of a feasibility and usability test during a large trauma exercise and the lessons learned.

Methods

The MIH was constructed in 1991 in a nuclear shelter under the UMC Utrecht. The hospital aims to provide immediate medical emergency care for multiple casualties under exceptional circumstances. This unique facility is strictly reserved for and dedicated to mass casualty care, with the expertise and complete infrastructure to provide large-scale emergency care following disasters and major incidents.[3]

Deployment of the MIH takes place after five possible scenarios.

1. War (threat), crisis or conflict management in which large numbers of casualties are in need of care.
2. Accidents abroad involving Dutch citizens, civilian or military, in need of repatriation and medical care.
3. Specific incidents, attacks or large-scale accidents in the Netherlands that exceed the regular care capacity.
4. International incidents, in which medical assistance is provided by the Dutch government for the treatment of foreign victims.
5. Quarantine care for patients with special infectious and highly contagious diseases, such as severe acute respiratory syndrome or viral haemorrhagic fevers such as the Ebola virus.

The MIH deployment procedure is an essential part of the disaster plan of the UMC Utrecht and the Central Military Hospital. An emergency response protocol enables up to 100 patients to be admitted to the normally standby hospital after a start-up time of only 15 minutes. With an additional 45 minutes the capacity can be extended to 200 patients, and up to 300 patients can be admitted after 24 hours. Personnel are alerted through a personnel alert system. The organization, infrastructure and training are all directed around triage to guide patient flow through successive echelons of care, in order to deliver the greatest care to the greatest number of people.[3]

The PBRS was developed to optimize patient tracking and tracing during deployment of the MIH. The PBRS functions as an addition to a handwritten or digital hospital information system. It enables quick registration and tracking of patients during the acute phase of an emergency with high patient surge. Development of the PBRS started during 1993, using the dBase database system (dBase LLC, 31 Front Street Binghamton, NY 13905, USA). The second version of the PBRS, developed in 2000, used a Microsoft Access database system (Microsoft, 15010 NE 36th Street, Redmond, WA 98052, USA), which limited the number of systems that could be used and the number of users that could simultaneously access the database.[2,5] The 2014 PBRS has been built using the Delphi program language with an SQL server (International Business Machines Corp; New Orchard Road, Armonk, New York 10504, USA) in the background. The database and the server application can be located on separate devices, and the system has a two-tier architecture.

Barcodes conforming to the GS1-128 (formerly EAN-128) code system (Anonymous, 1996) are used to process data. GS1 Netherlands (GS1 Netherlands, Amsterdamseweg 206, 1182 HL, Amstelveen, the Netherlands, formerly EAN Netherlands) participates in GS1, a non-political, not-for-profit, international organization that develops and maintains standards for supply and demand chains across multiple sectors. Barcodes were chosen because of the system's simplicity, which is the key to success in disaster management.[6] Barcodes are easy, quick and accurate to use, low-cost and can be entered manually in case of hardware malfunction.[2,5,7]

When patients arrive at the ambulance hall of the MIH, they receive a wristband with a unique barcode corresponding to a dedicated patient number in the hospital information system. Subsequently, the patient is triaged by the triage doctor and given a triage code and next destination. This can either be the trauma bay for red priority-one and yellow priority-two patients, or the low care ward for green priority-three patients; deceased patients go to the temporary morgue.

Patients' wristbands are scanned by an administrative officer, followed by the scanning of triage codes and destination codes. The process consists of five steps and takes 15 seconds per patient. At the first scanning station, photos of the patient are taken from four different angles for identification purposes. Upon arrival in a trauma bay or ward, administrative officers check-in the patient again; and when leaving a department, the patient is checked-out and the next destination is scanned. Patients who arrive at the ward are checked-in at a bed location. Personal details are usually gathered in each department by administrative officers, but can be entered into the system at every station. The PBRS 2014 is linked to the hospital's information system, which enables the exchange of data. The link with the hospital information system is one of the reasons that continuous development is warranted. Furthermore, the PBRS can operate on wireless systems, creating a backup in case of computer malfunction. The layout of the 2014 version of the PBRS is identical to that of the original PBRS; therefore, it can be implemented with very limited or no additional staff training.

The PBRS has several management features, including real-time monitoring of department capacity for the command team (Figure 1). Each department's capacity (whether at 50%, 75% or 100%) is indicated by a colour-coded system on the overview screen. In addition, to improve information flow and accommodate announcements from the command team to staff in the various departments, a marquee option has been developed and is shown at the bottom of each screen (Figure 2).

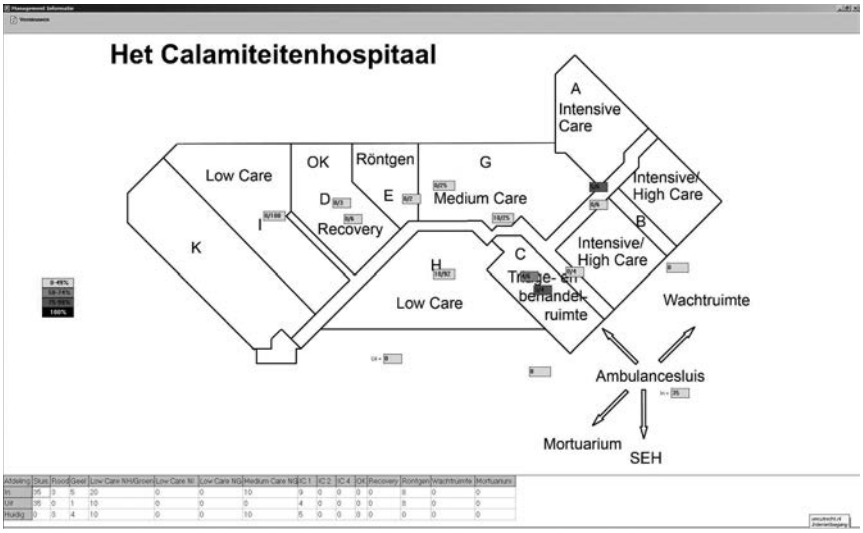

Figure 1. Department capacity overview screen, with real-time colour coding

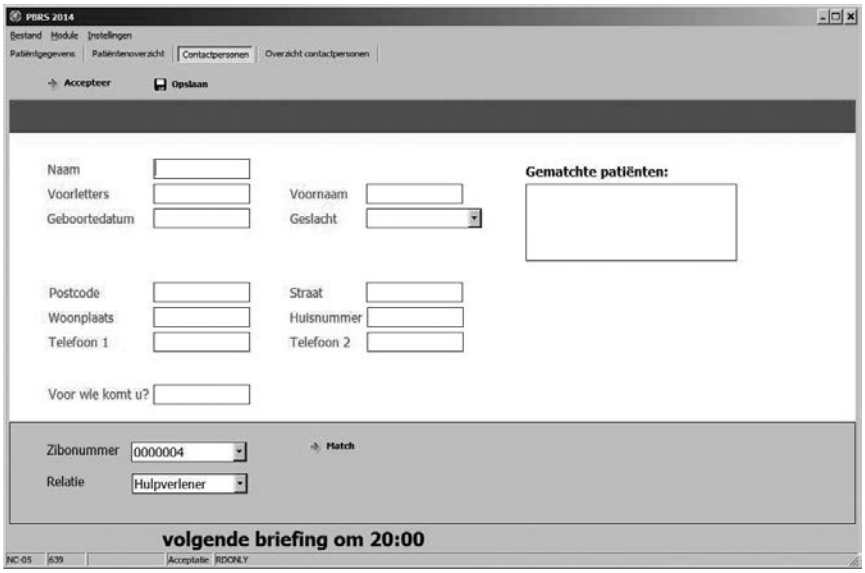

Figure 2. Relative registration screen of the PBRS 2014. Note the marquee at the bottom of the screen, announcing the next briefing

An important improved feature is the ability to match relatives to patients. Relatives are taken care of by social workers in a location adjacent to the MIH, but without direct access to the facility so that full access control of the MIH is maintained. After an identity check, the social workers can register relatives in the PBRS, including their relationship to the patient (Figure 2). After relatives have been matched to a patient then the appropriate information is given, and patients and relatives can be reunited when both the overall situation and the medical condition of the patient allow it.

To illustrate the feasibility and usability of the PBRS, we extracted all data processed by this tool during a large trauma drill, and reviewed the performance of the registration, tracking and tracing functions.

Results

A number of small tests were initially performed on concept versions of the PBRS 2014 to optimize workflow and identify minor bugs. The system was made fully operational during a large, real-time trauma drill in November 2014. The drill included 120 casualties from a major incident and 40 individuals reporting to the hospital in search of relatives.

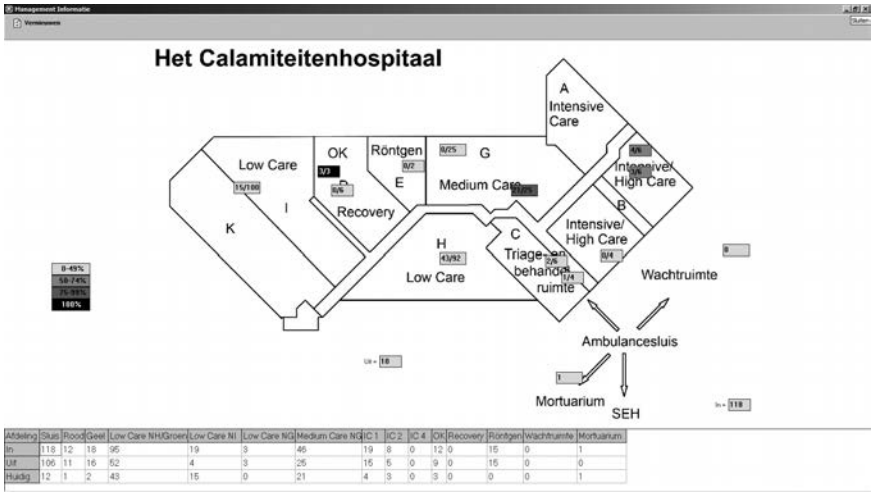

Figure 3. Capacity overview screen after 118 patients have been admitted

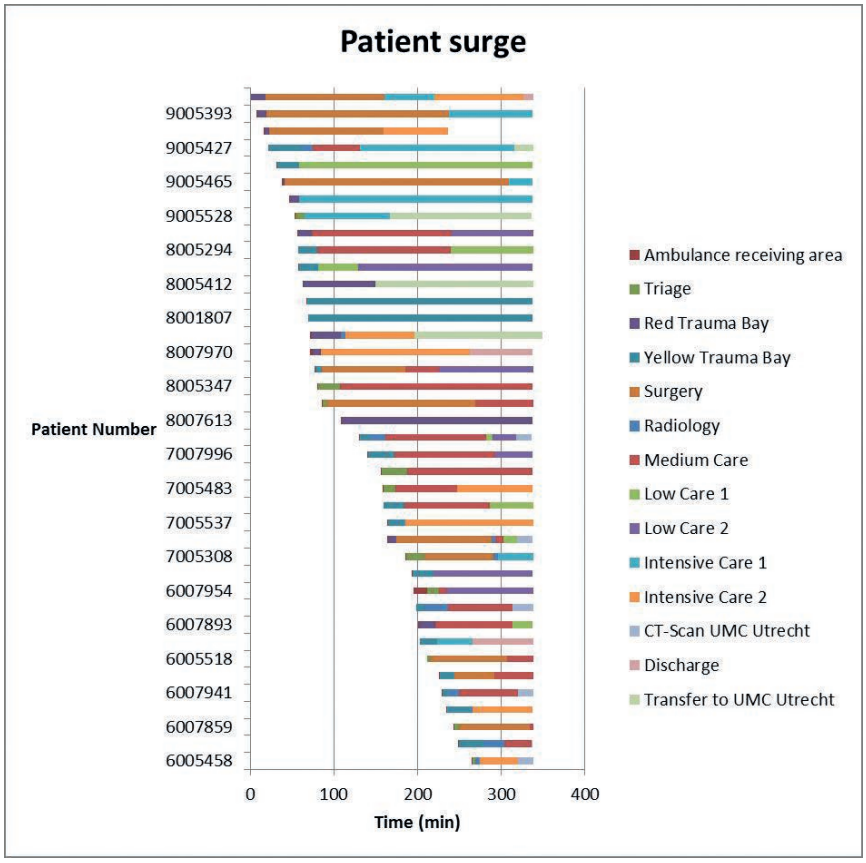

Figure 4. Overview of the flow of red priority-one patients from first registration in the ambulance receiving area until their definitive station. The y-axis shows each patient's barcode number

All 120 patients were successfully registered in the system and no patient data were lost. Patients could be tracked and traced in real time by the command team throughout the treatment process.

The pictures taken at the triage station from four angles proved to be a major improvement; at least one image of sufficient quality for identification was obtained for each patient.

Management features: Real-time bed capacity was visualized on a map of all departments, allowing the management team to see the available beds. When the

overview screen (Figure 3) showed a high strain on the medium-care capacity, the command team reallocated nursing staff from the low-care wards to the medium-care wards. In addition, the command team decided to prioritize the outplacement of patients to other hospitals. Because the information was shown in real time, decisions could be taken well in advance, prior to the exhaustion of capacity.

Based on the displayed data, government agencies were informed of the number and characteristics of the patients. With the click of one button, accurate information could be provided to the press and community.

Matching with relatives: During the exercise, nine relatives were matched to the correct patients. The remaining 31 relatives were registered in the PBRS system but were not matched, because the administrative officers had not yet taken the names and addresses of the patients, since medical treatment had priority. The exercise was finished before this process could be finalized.

Evaluation: Hospital responses to major incidents should be properly evaluated to enable future improvements. The data from the PBRS 2014 can, apart from its prospective use, be retrospectively analysed. One of the most important evaluation goals from a high surge of patients is the identification of bottlenecks in the system. To identify such bottlenecks, the PBRS produces a list showing the time between patient check-in and check-out at any given location. Figure 4 shows the advancement of all red priority-one patients from their first registration in the ambulance receiving area until their definitive station (i.e. intensive care unit, theatre or medium care). In this example, all times were balanced; there were no particular bottlenecks. The graph further illustrates the main time-consuming elements of treatment.

In the exercise, three patients were scripted to die during treatment in the trauma bays. These patients were not checked-out of the trauma bays and into the morgue; as a result, they are shown as being in the trauma bays for the full duration of treatment, which led to misinformation being given to the command team.

Figure 5 illustrates the advancement of patients in the red and yellow trauma bays. The demand on the trauma bays was highest between 50 and 80 minutes after the beginning of the drill, with four priority-one and five priority-two patients simultaneously receiving treatment; patients were treated fast enough to accommodate the ongoing victim surge. The time spent in triage and the trauma bays is shown in Figure 6. The first three patients were all triaged within 1 minute and left

the trauma bays for surgery within 6, 10 and 16 minutes of arrival. The mean time spent in red trauma bays was 20 minutes (range 2–87 minutes) and the mean time spent in yellow bays was 21 minutes (range 6–39 minutes). This includes transport to the check-in and check-out location, which took a maximum of 5 minutes. Figure 6 excludes the three deceased patients to give a better overview of treatment times.

Administrative officers operating the barcode scanners reported improvements in overall system stability and speed.

Discussion

The PBRS provides a simple but very efficient way of tracking and tracing patients during mass casualty care in hospitals. The developments over the past 20 years have resulted in several considerations for the future improvement of such systems (Table 1). Ongoing development is warranted to withstand the technological changes that will occur over time. Such development should be aimed at expanding systems' capabilities and keeping up with technological challenges.
With the recent implementation of management features in the 2014 version of the PBRS, a command team can now use the tool to monitor patient flow in real time, enabling decisions to be made prior to the occurrence of the bottlenecks that can arise with sudden high surges in patient numbers. In addition, matching relatives to patients has now been made possible. This feature, in addition to the ability to provide overviews with patient names and injury-severity characteristics, responds to the need for information from government agencies, relatives and the general public, which is usually one of the weaker links during mass casualty incidents. Furthermore, the new two-tier design increases the speed and stability of the system.

A large trauma drill demonstrated the superb performance of the PBRS 2014. No system errors were found in patient registration, and all patients could be identified from a four-angle picture. User errors did occur, however; three deceased patients were not checked-out from the trauma bays and checked-in to the morgue, leading to a minor misunderstanding with the command team. The overall speed of the system was found to offer major improvements over the former version of the PBRS and the administrative officers also reported superior system stability. Some modifications have been made after the analysis of this drill and are expected to further improve the efficiency of the indexing system.

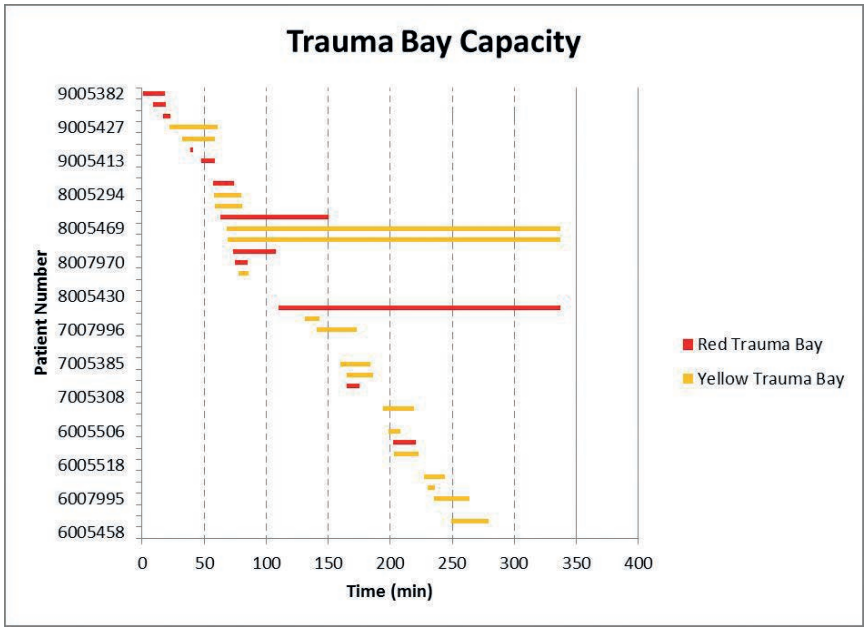

Figure 5. Red and yellow trauma bay capacity

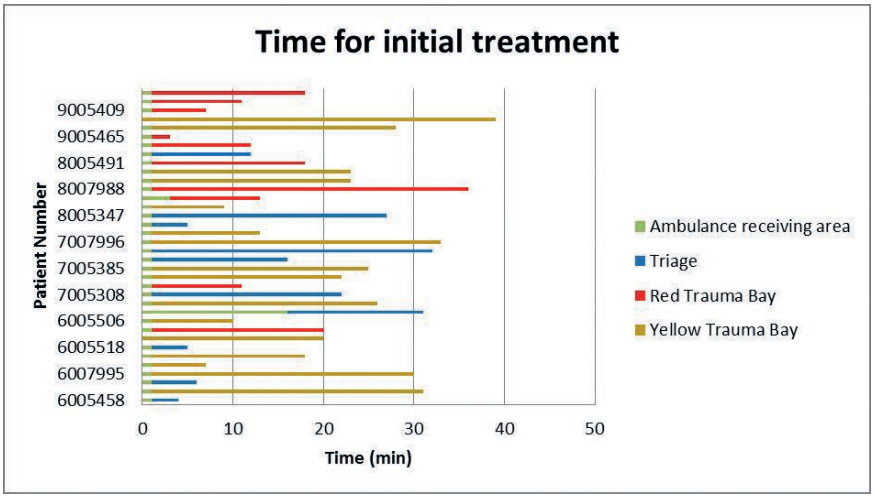

Figure 6. Time taken for initial treatment steps

Table 1. Considerations for the future development of victim tracking and tracing applications

Considerations for the future
• Simplicity is key in the design of disaster medicine systems.
• Patient track and trace systems need ongoing development.
• The link between the system and the hospital information system should be leading during development.
• Systems should be developed not to rely on external systems during disaster situations.
• Generic, easily replaceable hardware, should be used.

The key to successful systems for high patient surge situations, such as disasters and major incidents, is simplicity.[6] The choice to use barcodes instead of more modern solutions such as radiofrequency identification (RFID) was made to reduce the risk of system failure during disaster scenarios. RFID is a completely digital system that relies on electromagnetic fields for wireless data transfer and requires dedicated RFID scanners. In contrast, barcode scanners are available in most hospitals and are low-cost. In the case of hardware failure, barcode numbers (but not RFID codes) can be entered manually. Even in regular healthcare situations the implementation of RFID is slow, as hospitals struggle with cost and complexity issues.[8] Furthermore, only a few studies have focussed on victim tracking and tracing after disasters with more advanced systems.[9] Another reason to choose barcodes over RFID is because they are used in the UMC Utrecht and the Central Military Hospital, thus matching standard work procedures.

The use of any electronic system is a weak link during disasters, since electronic systems are prone to failure due to power-supply problems or system overloading; however, such events have not yet been encountered in the MIH. All systems running the PBRS are connected with the back-up power supply of the hospital.

Ideally, a victim tracking and tracing system should cover both the pre-hospital setting and the in-hospital patient surge. Several systems have been developed for this purpose, but are often not supported by the full chain of medical relief.[7] The next step in the development of the PBRS 2014 will be introducing it into in regular emergency care. This will allow more people to become accustomed to the system, thus enhancing awareness of its use. Ideally the system will be able to cooperate with a pre-hospital victim tracking and tracing system, thus enabling adequate patient registration and real-time overviews during mass casualty incidents. The technical

design of the software system enables it to be run in different institutions with minor modifications since the software itself is designed for generic hardware. The main challenge for introduction in other facilities include the implementation of different layouts and capacities of these hospitals. Therefore a supra-regional implementation where a further developed version is used in all hospitals and by all regional ambulance services would be possible with the addition of a barcode scanner to the computers that are already used. A basic version of the software without schematic overview would be usable in all other setting such as pre-hospital and field hospital situations where the focus is mainly on the registration and less on the tracing of patients.

Conclusions

The PBRS is a feasible, usable and sustainable application with which to track and trace patients and organize the patient surge during a hospital's response to a major incident. The tool can help prevent additional suffering caused by a lack of information about patients and their locations, which can lead to suboptimal use of resources and uncertainty among relatives. The benefits of tracking and tracing systems during such situations are not only in patient registration but also in management possibilities, including real-time overviews of hospital capacity and patient characteristics. Data extracted from such systems should be used to meticulously evaluate a hospital's response in order to optimize care in high-surge situations. Future developments will focus on pre-hospital victim tracking and the application of the PBRS 2014 in regular trauma care.

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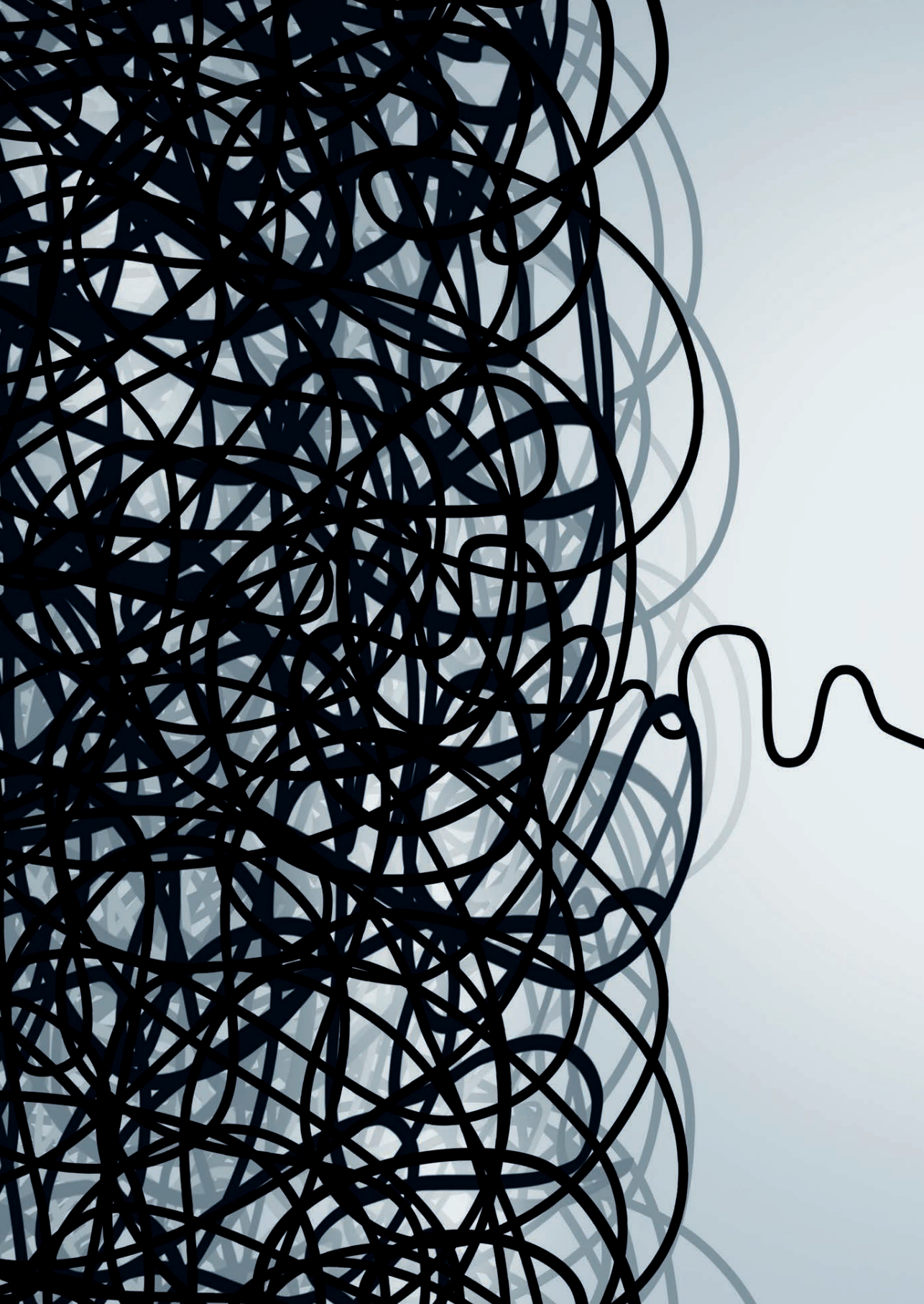


Chapter 5

Designing a dedicated triage registration form for hospital admittance during major incidents

J.J. Mark Haverkort, Salomon W. Koning, Luke P.H. Leenen

Submitted

Abstract

Introduction: Triage is essential to the medical response to mass casualty incidents. Upon arrival at a hospital it is important to perform both quick triage and adequate registration of patient characteristics and parameters. During a major incident any medical trained staff member should be able to perform these tasks. This study presents a newly designed triage registration form and aims to determine its feasibility.

Methods: A new, one page, triage registration form was designed in cooperation with various specialists involved in the hospitals disaster preparations. The form was implemented on four occasions, two drills and two real events. A questionnaire was spread amongst involved medical personnel to determine the clarity, ease of use and added value of the form.

Results: In total 161 persons of the medical staff responded to the questionnaire. The form is judged to be clear (7,2 out of 10), easy to use (7,3 out of 10) and be of added value (7,6 out of 10).

Conclusion: A dedicated triage registration form for use during a hospitals major incident response has been designed and proven feasible. The concept is shared as a responder tool to guide other hospitals in the development of a triage registration form or as part of a specific disaster medical record to improve disaster preparedness.

Introduction

The threat of mass casualty incidents (MCI), man-made as well as natural, remains high as described in the World Disaster Report 2015.[1] MCI's and disasters, by definition, create a patient surge above the available resources of the healthcare system. To minimize the initial chaotic situation, triage needs to be performed to prioritize patients and resources need to be reallocated. Triage plays a very important role in victim distribution, it aims to give the right patient the right care at the right time in the right place. Therefore, on scene, triage aims to adequately distribute patients in priorities of care and ensure transport takes place to adequate medical centres, i.e. trauma centres with neurosurgery or burn units. In the Netherlands the Major Incident Medical Management and Support (MIMMS) system was adopted and triage is performed through triage sieve and triage sort.[2]

Triage upon hospital admittance is essential to cope with the increased surge capacity.[3] During this stage triage is performed in the ambulance bay with more vital parameters, since patients are monitored during transport. The aim of triage in the ambulance bay is to differentiate between patients in need of high resource consuming care and patients needing less prioritized treatment. During regular hospital care situations triage is performed mostly by emergency department nurses, however, during a MCI triage is to be performed by a senior doctor to ensure the best level of triage under the circumstances.[4-6] However during a MCI a senior doctor might not be available to perform triage. To ensure that any trained medical staff member is able to perform adequate triage the Major Incident Hospital (MIH), Utrecht, the Netherlands, has developed a dedicated major incident triage registration form. This triage registration form is to be used in addition to the medical record aiming to improve the speed of triage and provide a tool for physicians who aren't trained with triaging on a regular basis. By using simple and concise forms we also aim to improve registration of patient data. Furthermore it ensures a protocolled approach, ensuring a smaller chance of human error during the chaotic and stressful initial disaster response.[7]

The Major Incident Hospital (MIH) continuously develops new strategies for in hospital disaster management, such as this triage form. The MIH has previously been described elsewhere, in short it is a dormant 200-bed hospital that can be activated within 30 minutes after any MCI. During activation patients are given a random, pre-printed hospital information number through which they are registered and traced.[8,9] This proof of concept study aims to prove the feasibility of such a form and share the concept with other centres.

Methods

The design of the triage registration form had to consist of 1 A4 size paper with the pre-printed hospital information number. Handwritten forms are chosen over digital forms because of their flexibility, simplicity and absent risk of hardware or software failure. The form should include space for patient details, triage and medical details comprised of the AMPLE (Allergy, Medication, Past, Last meal, Event). The revised trauma score is used to stepwise approach the triage categories, therefore the form is based on the triage sort.[10] This triage is to be used as a reference, an experienced physician should always be able to prioritize based on their anatomical knowledge by utilizing anatomical triage. Furthermore, the name and date of birth of the patient can be noted. In consultation with the hospital infection prevention department we have included a space to indicate a patient at risk of carrying multi resistant bacteria. The form, as presented in Figure 1, was implemented in 2014 and has been used in four occasions in the MIH. Twice in a large scale trauma drill and twice in real life deployments. All of the deployments of the MIH are subsequently evaluated through electronic questionnaires, three specific questions were added to evaluate the clearness, ease of use and added value of the triage form during MCI response. The form was scored on a scale of one to ten, with ten being the perfect score.

Ambulance bay

Predefined patient number and barcode

Triaging physican ambulance bay

GCS		Respiration		Blood pressure	
E M V		Breathing Frequency		Systolic	
	Score		Score		Score
13-15	4	10-29	4	>89	4
9-12	3	>29	3	76-89	3
6-8	2	6-9	2	50-75	2
4-5	1	1-5	1	1-49	1
3	0				

Last Name

Date of birth

MRSA/ESBL Risk

Yes / No

1-10 points	*11 points*	*12 points*
T1	T2	T3

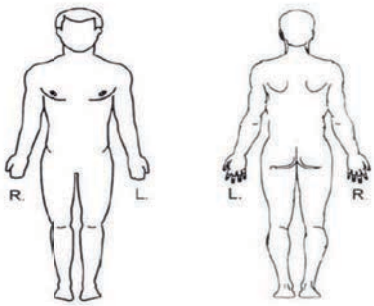
Allergy

Medication

Past

Last Meal

Event



Form must remain in the Major Incident Hospital. In case of patients transfer provide copies of the form and hand the original over to the command team.

MAJOR INCIDENT HOSPITAL

Figure 1. The triage registration form as it has been designed in the MIH

Results

In total 161 persons of the medical staff responded to the questionnaire. The forms were used by 71 physicians and 95 nurses, an overview is presented in Figure 2.

The results from the survey amongst involved staff confirmed the added value of the form. The clarity (7,2), ease of use (7,3) and added value (7,6) during acute situations are all positively rated as reported in table 1. All 301 patients had a registered triage class, prior to the introduction of the triage registration form no registration took place in the patients' medical record.

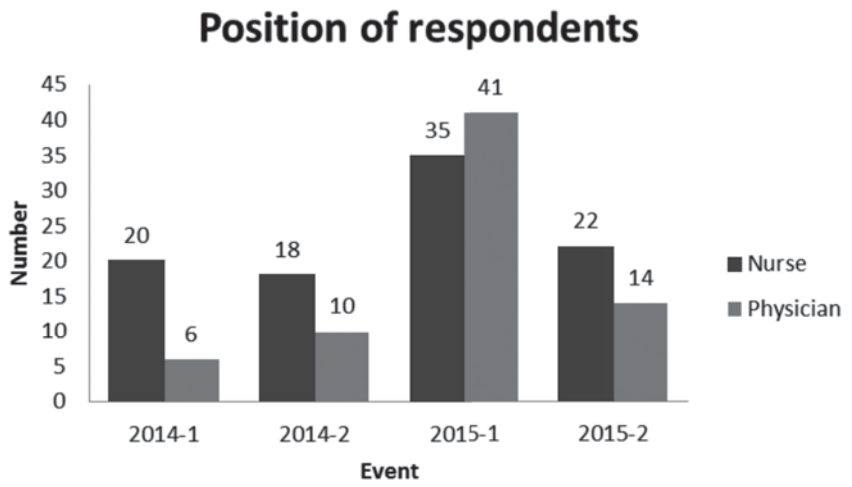


Figure 2. Overview of the respondents' position per event

Table 1. Results from staff survey

Event	2014-1 n=26	2014-2 n=28	2015-1 n=71	2015-2 n=36	Total n=161
Is the triage form clear	7,5	7,5	7,1	7	7,2
Is the triage form easy to use	7,5	7,6	7,3	6,8	7,3
Is the triage form of added value during an MCI	7,7	8,6	7,2	7,8	7,6

Scale 1-10, 1 = fully diasgree - 10 = fully agree

Discussion

This study aimed to describe the development and test the feasibility of a new, one page, triage registration form to be used in the ambulance bay of a hospital during a MCI response. The proposed registration form has been used on four occasions and evaluation has taken place through a questionnaire. The form was judged to be, clear, easy to use and of added value during MCI circumstances. The registration form was based on the triage sort method, with the revised trauma score as a core component. Other triage methods such as START and Careflight triage could be easily integrated into the registration form and have shown good results in the literature, however the MIMMS principles have been adopted in the Netherlands.[11] Preferably triage is to be performed by a senior staff member, however during a MCI response any medical officer should be able to perform triage through a triage algorithm.[4-6] By including the algorithm in the registration form itself the usability of the form is enhanced.

This study limits itself to the usability and the added value of the triage registration during MCI response. Given the absence of a dedicated previous triage registration form no comparative results are presented.

Future endeavours will include development and analysis of a disaster medical record combined with the triage registration form and comparative studies on the amount of registered patient data using such records during MCI response.

In conclusion, our new, one page, triage form was created to improve registration of triage categories and the most important patient details during hospital admittance in a MCI or other high surge situation. By using a one page and easy to use triage registration form we aim to ensure fast triage, registration of the main parameters and patient characteristics and provide a tool to be used by any medical staff member. The form is shared as a responder tool to guide other hospitals in the development of a triage form or as part of a specific disaster medical record to improve disaster preparedness.

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Chapter 6

Medical record keeping during a mass casualty incident: development of a disaster medical record

Salomon W. Koning, J.J. Mark Haverkort, Luke P.H. Leenen

Submitted

Abstract

Objective: Proper documentation during Mass Casualty Incident (MCI) is difficult. Due to the high surge, treatment of victims is top priority, record keeping is secondary. Until now the Major Incident Hospital used an extensive paper medical record: the Hospital under Special Circumstances record (HSCMR). A concise and easy to use primary survey form was developed and attached to the HSCMR, forming the pilot Disaster Medical Record (pDMR). The hypothesis was that this form would improve record keeping.

Methods: A retrospective chart review was conducted from two events. One real deployment wherein the HSCMR was used and one MCI exercise where the pDMR was used. A selected number of registered medical parameters and data was scored.

Results: The registration of data was significantly higher in the pDMR than in the HSCMR 89% versus 61% (p=0.001), especially in T1- and T2- patients (respectively p=0.013 and p=0.000). Overall documentation improved significantly on all scored items except cervical spine and temperature.

Conclusion: Significant more primary survey forms were used and more data was documented using the pDMR, especially in the T1- and T2- patient groups. A MCI medical record should be simple and concise and should not change daily routine for medical staff.

Introduction

Medical record keeping is not only an important duty for the medical professional, the record is also a legal document. During a mass casualty incident (MCI) the surge of patients is high, making proper patient documentation a difficult task. In general, the increased documentation burden is time consuming.[1] However, accurate record keeping is important to guarantee continued care and gives insight in a patient's condition during admission. Secondary, this data can be used to evaluate the hospitals response to the MCI. Documentation or guidelines on how to keep and manage patients records during a MCI is non existing.[2] One study showed that medical records during a MCI exercise contained significant more errors in registration of medical parameters and procedures, medication and accuracy of diagnosis compared to regular care.[3] Several papers have described novel ways for record keeping, including the use of medical digital pens and voice recognizing systems.[4-6] However these systems have not yet been tested during a MCI and are not in accordance with the basic rule to maintain simple methods.[7] Finally during an MCI digital systems cannot be relied on given that can slow down or are at risk of failure due to the MCI.

Medical record keeping during a MCI is imperfect almost by definition. Therefore the Major Incident Hospital (MIH) hypothesized that a dedicated, concise and practical primary survey form, which follows the systematics of the trauma care protocol of the Advanced Trauma Life Support (ATLS), could improve documentation during a MCI.[8] Based on these principles a new primary survey form was developed and used as a pilot during a MCI drill.

Material and methods

Setting: This pilot study addresses patient documentation of the dedicated MCI hospital in the Netherlands, the Major Incident Hospital. The Major Incident Hospital is described elsewhere in the literature, in short it is a stand-by, highly prepared, hospital with 200 beds in the centre of the Netherlands which can be deployed within 30 minutes after any MCI.[9, 10] It is a collaboration between the Central Military Hospital and University Medical Centre Utrecht.

Medical records: Before this pilot, the Major Incident Hospital used a paper medical record called the Hospital under Special Circumstances Medical Record (HSCMR). This record was used both in the acute- and continued care phase. During the acute phase,

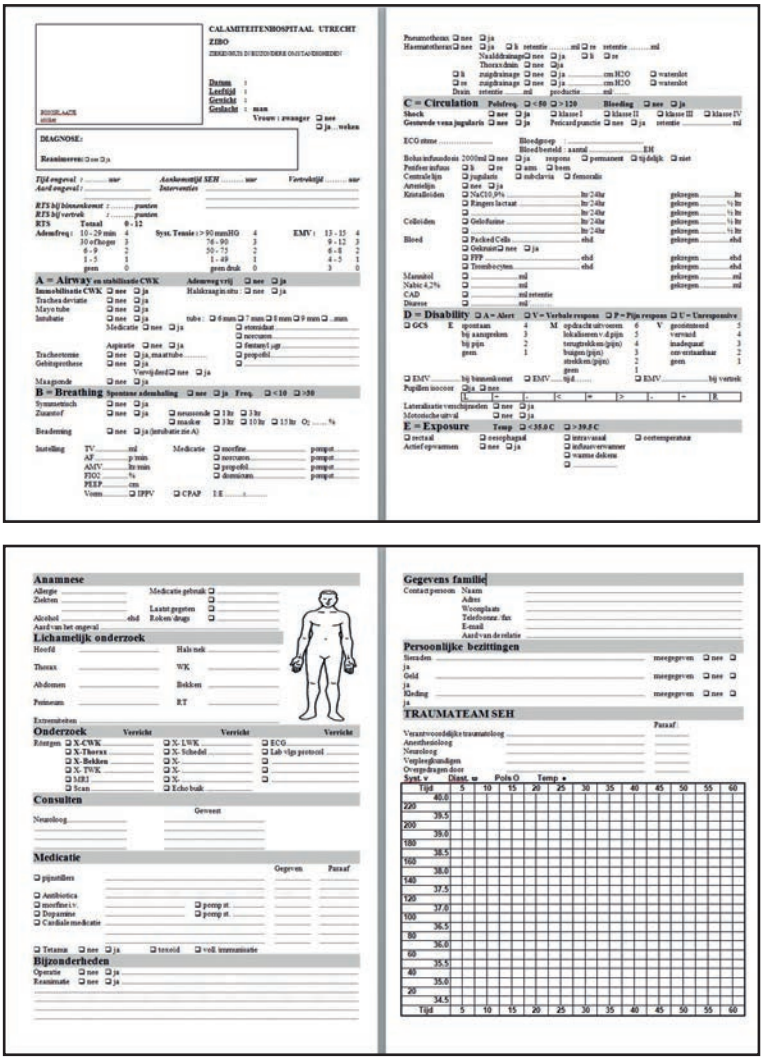
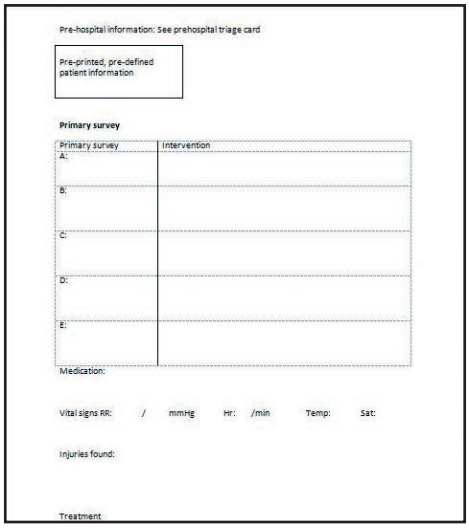


Figure 1. Primary survey form Hospital under Special Circumstances Record

two foldout primary survey forms were available with over 150 predefined checkbox items (figure 1). Further, six medical forms and five forms to order diagnostic tests such as blood chemistry, imaging and ECG's were included.

The new pilot primary survey form (figure 2) consisted of only nine predefined items concerning trauma care according to ATLS guidelines, interventions, vital signs, given medication and a treatment plan. This new pilot primary survey form


Pre-hospital information: See prehospital triage card

Pre-printed, pre-defined patient information

Primary survey

Primary survey	Intervention
A:	
B:	
C:	
D:	
E:	

Medication:

Vital signs RR: / mmHg Hr: /min Temp: Sat:

Injuries found:

Treatment

Figure 2. Primary survey form pilot Disaster Medical Record

was attached to the front of the HSCMR, forming the pilot Disaster Medical Record (pDMR). Staff was not specifically trained or informed on how to use the pilot primary survey form.

Data collection: A chart review was conducted to compare the data registered on the HSCMR old primary survey forms with the data documented on the new primary survey form. Only primary survey data documented on the appropriate forms was scored. Scored variables were: airway (obstruction and cervical spine), breathing (breathing sounds, breathing frequency and saturation), circulation (any form of shock or major blood loss, heartrate, blood pressure), disability (Glasgow coma score) and exposure (temperature and other found injuries). In the pDMR a dedicated area for treatment plan was available, this option was not present in the HSCMR. Age and gender were documented as baseline information. Information on triage and routing of patients was retrieved from our Patient Barcode Registration System.[11] Three triage categories were used, T1 immediate, T2 urgent and T3 delayed.

The statistical analysis was performed using IBM SPSS version 23 (International Business Machines Corp, Armonk, NY, USA). A 0.05 level of significance was maintaned for all data. Bivariate analysis was performed using the Chi square; Fisher's exact test was used when group size was smaller than five.

The medical ethical committee of the University Medical Centre Utrecht signed a waiver for informed consent as this was a post hoc observational study (protocol number 16-201/C).

Results

Scenarios: Data was gathered during two events; one real deployment and one MCI drill exercise.

Firstly, in 2011 the MIH was deployed to receive 46 patients after a major fire in a nursing home. Most patients were elderly with (possible) inhalation injuries.[12] Six patients were intubated during primary survey; during this MCI the HSCMR was used. In 2012, during the yearly major disaster drill, a shooting incident was simulated. A total of 56 patients were transported to the Major Incident Hospital. The victims consisted of actors with simulated traumatic, blast and/or penetrating injuries. The new pDMR primary survey form was used in this event. Baseline characteristics of both events are depicted in table 1.

Use of primary survey form: The pDMR has led to significantly more (p=0.001) registration of primary survey data, 89% of the forms contained information, the HSCMR only contained information on the primary survey in 61% of the forms. In subgroup analysis of the patient categories, the new primary survey form was significantly more used in the T1 (p=0.013) and T2 (p=0.000) patients (table 2).

Documentation: Documentation on airway (p=0.002), breathing (p=0.045), breathing frequency (p=0.039), saturation (p=0.010), circulation (p=0.000), heart rate (p=0.000), blood pressure (p=0.000), Glasgow Coma Score (p=0.001), exposure (p=0.004) and given medication (p=0.000) was registered significantly more in the new pDMR primary survey form. Documentation on cervical spine (p=0.776) and temperature (p=0.688) did not differ between the forms. The new treatment plan space was used in 77% (n=43) cases in the pDMR (table 2).

Subgroup analyses (table 3) showed that in the T1 category airway (p=0.009), breathing (p=0.009) and saturation (p=0.013) were documented significantly more often in the new primary survey form. In the T2 category, airway (p=0.000), cervical spine (p=0.021), breathing (p=0.000), saturation (p=0.000), circulation (p=0.001), heart rate (p=0.000), blood pressure (p=0.000), Glasgow coma Scale (p=0.000), exposure

Table 1. Baseline recordkeeping and patient distribution

	HSCMR	pDMR
Total victims (n)	46	56
Age (years)	46	41
Gender		
Male	21	17
Female	25	9
Undocumented *	-	30

* Incomplete processed information, due to the predefined end time of the exercise

Table 2. Primary survey form used in the Hospital under Special Circumstances vs pilot Disaster Medical Record

	HSCMR n = 46	pDMR n = 56	*p*
Primary survey forms (n)	28	50	**0.001**
Triage categories			
T1	1/6	10/12	**0.013**
T2	2/11	14/15	**0.000**
T3	25/29	26/29	0.687
Airway	21	42	**0.002**
Cervical Spine	16	21	0.776
Breathing	24	40	**0.045**
Breathing frequency	1	8	**0.039**
Saturation	13	30	**0.010**
Circulation	12	34	**0.000**
Heart rate	11	39	**0.000**
Blood presure	11	41	**0.000**
Disability			
Glasgow Coma Scale	13	35	**0.001**
Exposure	18	36	**0.004**
Temperature	2	4	0.688
Treatment			
Medication given	5	25	**0.000**
Treatment plan	*	43	-

Data shown represent times registered

* Not available

Table 3. Documentation per triage category

	Triage 1			Triage 2			Triage 3		
	HSCMR n=6	pDMR n=12	*p*	HSCMR n=11	pDMR n=15	*p*	HSCMR n=29	pDMR n=29	*p*
Airway	0	9	**0.009**	2	14	**0.000**	19	19	1.000
Cervical Spine	0	6	0.054	2	10	**0.021**	14	5	**0.012**
Breathing	0	9	**0.009**	2	14	**0.000**	22	17	0.162
Breathing frequency	0	2	0.529	0	5	0.053	1	1	1.000
Saturation	0	8	**0.013**	0	11	**0.000**	13	11	0.594
Circulation	0	6	0.054	1	12	**0.001**	11	16	**0.009**
Heart rate	0	6	0.054	1	13	**0.000**	10	20	**0.009**
Blood presure	1	6	0.316	0	13	**0.000**	10	22	**0.002**
Disability									
Glasgow Coma Scale	0	5	0.114	1	13	**0.000**	12	17	0.189
Exposure	0	5	0.114	2	13	**0.001**	16	20	0.279
Temperature	0	0	-	11	15	**0.492**	2	2	1.000
Treatment									
Medication given	0	2	0.529	0	12	**0.000**	5	11	0.078

(p=0.001) and medication given (p=0.000) were significantly more documented. In the T3 category, cervical spine was significantly more documented in the old primary survey form (p=0.012); heart rate (p=0.009) and blood pressure (p=0.002) significantly more in the new primary survey form.

Discussion

The addition of a simple and clear form improved patient documentation during primary survey in a mass casualty incident response. Both the use of the primary survey form itself and the amount of data documented on the forms improved significantly. Importantly, the documentation of the most severely injured, T1- and T2-, patients increased.

However, there is still room for improvement. In the MCI drill, 89% (50/56) of the pDMR new primary survey forms were used, six were not. In three cases the old HSCMR primary survey form was used and in one case the new pDMR primary survey form was only used to document the decease of one of the simulation patients. Thus primary survey data was documented in a total of 96% (54/56) cases. This improvement is most likely explained by the simplicity of the new format. Furthermore this new

primary survey form is a concise and simple representation of the ATLS guidelines used by our medical staff during their normal day to day work, also eliminating the need for additional training to use the forms.

Moreover, the amount of data documented on the primary survey forms improved significantly. Even though the real MCI was characterized by (possible) inhalation injury, airway, breathing sounds, breathing frequency and saturation were documented more frequently in the exercise (a regular trauma scenario without emphasis on inhalation trauma).

In contrast to the increasing adaption of electronic medical records worldwide, the Major Incident Hospital prefers a paper version, given the reliability and versatility under special circumstances. As mentioned before there are novel ways for record keeping however these systems have not been tested during a MCI.[4-6] Furthermore there is no consensus on whether use of electronic medical records in the emergency department improves documentation speed, time of admission and completeness of medical records.[13-17] Some data suggest improvement of MCI documentation by using electronic means in the pre-hospital phase.[18-20] No studies have described data on in-hospital (electronic) record keeping during an MCI. In our opinion it is essential that in the acute phase, during the high patient surge, documentation can be performed quickly without interruption and without possible technological delay. After the acute phase, during the admission phase, documentation is to be performed as regular in the Electronic Hospital Information System.

The main limitation is that, as a result of the small subgroups, this study should be repeated with a bigger sample size. Significant improvements were seen on specific parameters; others showed a tendency to significance.

During the real deployment, staff members could have been under more stress and experienced more time pressure that might have contributed to inferior documentation. However it can also be argued that documentation during the exercise had no clinical consequences and thus staff could have been less accurate as usually seen during the trauma exercises.

After the development of the new primary survey form a complete and concise Disaster Medical Record was developed for the MIH. A future study, with considerable group sizes should be done in order to validate current findings.

Conclusion

The new primary survey form improved data documentation during a hospitals MCI response. By development of a simple and concise primary survey form, adapted from the ATLS guidelines, medical staff was offered a documentation modality that followed the course of the patient care. Results demonstrate significantly more complete documentation with the new form, especially in the T1 and T2 patient groups. The golden MCI rule should be applied to medical record keeping as well: Keep it simple and concise and don't change the daily routine for medical staff. After this pilot study a full Disaster medical record will be designed and validated.

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Chapter 7

Hospital preparations for viral haemorrhagic fever patients and experience gained from admission of an Ebola patient

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Abstract

The Major Incident Hospital of the University Medical Centre of Utrecht has a longstanding history of preparing for the management of highly pathogenic and infectious organisms. An assessment of the hospital's preparations for an outbreak of viral haemorrhagic fever and its experience during admission of a patient with Ebola virus disease showed that the use of the buddy system, frequent training, and information sessions for staff and their relatives greatly increased the sense of safety and motivation among staff. Differing procedures among ambulance services limited the number of services used for transporting patients. Waste management was the greatest concern, and destruction of waste had to be outsourced. The admission of an Ebola patient proceeded without incident but led to considerable demands on staff. The maximum time allowed for wearing personal protective equipment was 45 minutes to ensure safety, and an additional 20 minutes was needed for recovery.

Introduction

The Ebola virus disease (EVD) epidemic during 2014–2015 led hospitals worldwide to prepare for the triage and admission of Ebola virus (EBOV)–infected patients.[1] During the fall of 2014, the Ministry of Health, Welfare, and Sport of the Netherlands requested that the Major Incident Hospital (MIH) provide 4 beds for the admission of EBOV-infected international healthcare workers and military personnel. The MIH is a government-funded, standby facility in the basement of the University Medical Centre of Utrecht (UMC Utrecht) that provides 200 beds to ensure capacity and optimal infrastructure for the triage and care of victims of large-scale trauma, nuclear, chemical, or biological incidents.[2] The MIH benefits from a substantial amount of resources (e.g., materials and personnel) shared with UMC Utrecht and the adjoining Central Military Hospital.

The MIH contains an isolation facility separate from other hospital infrastructure and air systems for the care of patients infected with highly pathogenic and infectious organisms (those designated as Biosafety Levels 3 and 4). This facility contains 4 isolation rooms equipped with a negative air pressure system and double air filtering. For the past 14 years, the MIH has been training staff to care for patients with viruses with aerosol transmission, and the MIH is the only centre in the Netherlands designated to treat smallpox. Following the request of the Ministry of Health, Welfare, and Sport to prepare for the admission of EBOV-infected patients, all previously developed procedures were revised for the treatment of patients with viral haemorrhagic fever (VHF). We present an overview of the preparations made at the MIH in the fall of 2014, pending a possible VHF outbreak, and the experience gained from the admission of an EBOV-infected patient.

Preparation Phase

A task group, which consisted of infection prevention experts and specialists in infectious diseases, virology, acute medicine, intensive care, paediatrics, and occupational medicine, prepared for all procedures involved in handling VHF. Other members included team leader nurses; officers for communication, security, waste management, and support services; and management representatives.

Command: The chain of command was demarcated in 4 levels (Figure 1). First, the crisis management team would be responsible for external communication and coordination with the adjoining hospitals. Second, the crisis coordination team would operate between the crisis management team and the command team to ascertain

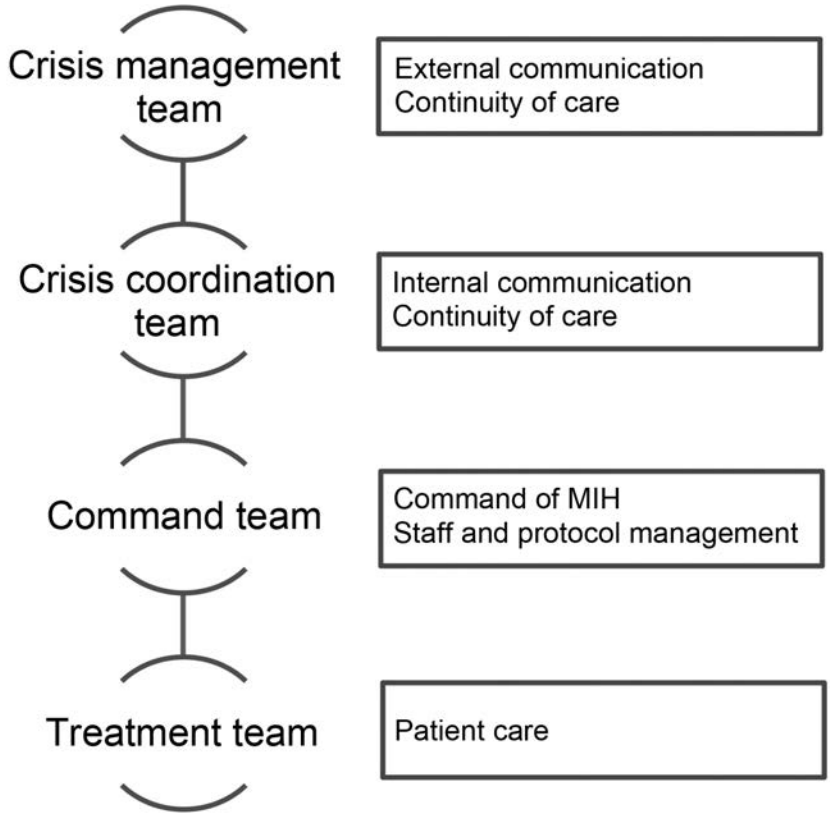

Figure 1. Planned command structure for potential admission of a patient with viral haemorrhagic fever, Major Incident Hospital (MIH), University Medical Centre of Utrecht, the Netherlands, 2014.

continuity of care at UMC Utrecht. Third, the command team would oversee the admission of a patient to the MIH. Finally, the treatment team would provide medical treatment for the patient.

Scenario Description and Routing: Flowcharts were developed that described 3 scenarios for routing a patient with suspected or confirmed VHF: 1) self-referral, 2) external referral, and 3) in-hospital referral from another ward. Security staff and a nurse would guide the patient to the MIH via a designated cleared route. Meanwhile, an emergency department nurse would open the MIH, activate the negative pressure system, and alert a team of trained nurses and an infectious disease specialist, all of whom would perform triage and assess the need to scale up the response.

Figure 2. Entrance of isolation unit with demarcated zones, Major Incident Hospital, University Medical Centre of Utrecht, the Netherlands, 2014. Markings on the floor indicate a safe zone and potentially contaminated zones and delineate doffing zones (where potentially contaminated clothing and gear are removed) for ambulance and disinfection personnel.

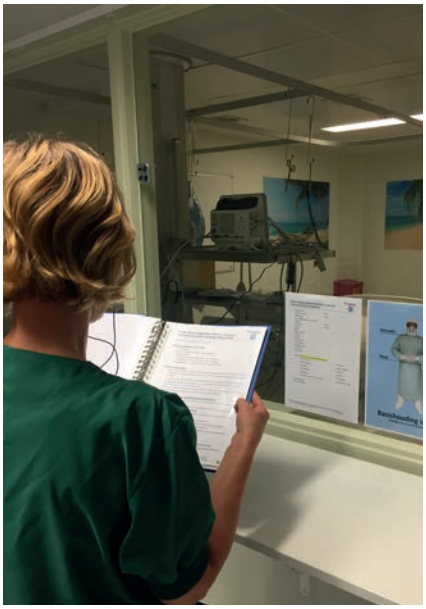

Figure 3. A buddy nurse demonstrates reading instructions in front of the isolation unit glass window for healthcare personnel working inside the unit, Major Incident Hospital, University Medical Centre of Utrecht, the Netherlands, 2014.

VHF patients arriving by ambulance would enter the MIH through a separate entrance in the MIH. At this entrance, a 3-zone area was drawn on the floor to indicate the safe zone and potentially contaminated zones and to delineate doffing zones (where potentially contaminated clothing and gear are removed) for ambulance and disinfection personnel (Figure 2). Personnel from the appointed ambulance services also were trained in accordance with the revised protocols.

Infection Prevention Measures

Personal Protective Equipment: The selection of personal protective equipment (PPE) was based on national and international guidelines and tested for workability and comfort.[3, 4] A protective overall with a fluid-protected surgical gown combined with an FFP2 respirator (which filters >94% of airborne particles), a face shield, double-layer gloves, and double-layer foot protection would be worn over the standard surgery scrubs and clogs. Full-face masks conferring FFP3-level protection (i.e., filtering >99% of airborne particles) would be available for those performing high-risk procedures. PPE would be stocked to the extent that 1 patient could be treated for up to 14 days, and a list for backup suppliers and materials would be set up.

Medical and Other Equipment: In the patient's room, disposable equipment would be used, such as cardboard pots with fluid-absorption granules for urine and faeces, eating utensils, and other accessories. Exceptions would only be possible for items that could withstand final disinfection procedures after discharge.

Working Procedures: To ensure the safety of personnel, the "buddy system," an extended version of the trainer-observer method, was introduced.[4] In this system, a specialized nurse (buddy) guides and monitors all activities of the staff who are wearing PPE, starting with the donning of clothing and gear and ending with discarding all PPE. The buddy would be seated outside the unit in front of the glass window looking into an isolation room (Figure 3) and would guide the care provider in the room by reading aloud every step of the protocol being used, ensuring the minimization of risk behaviours arising from haste, stress, and the uncomfortably warm conditions felt while wearing PPE. The buddy and care provider would communicate by speakerphone inside the room connected to a mobile telephone. The glass windows would also facilitate monitoring of and communication with the patient. The maximum number of medical personnel present in an isolation unit was set to 1 at a time to ensure maximum safety. The maximum time spent in PPE was set at 45 minutes to minimize the loss of concentration caused by discomfort.

While a patient is in an isolation room, the nurses would work 8-hour shifts in teams of 3 persons (i.e., a bedside nurse, a buddy nurse, and a coordinating nurse). All procedures were summarized in task cards that would be used by the buddy to guide the bedside nurse. All protocols and task cards were made available through the hospital intranet.

Waste Management: Preparations for waste management were a major concern given the expected amount of waste and the time-consuming procedures involved (replacing a single waste container in the isolation unit can take as long as 20 minutes). Designated, sealable, 60-L waste containers would be used for waste storage, and waste management procedures were strictly protocolled and repeatedly conveyed through training.

In-hospital autoclave capacity appeared insufficient; therefore, waste destruction would be outsourced to an external facility. In accordance with transportation laws, one specific 20-L container had been approved for transport by public road.[5] However, these containers were too small, and opening and closing them presented a safety risk. Therefore, category A medical waste (UN2814) containers were chosen; these were to be packed in a large plastic drum and the waste stored in a guarded and certified cooled sea container outside the hospital before transport.

Cleaning Procedures: The nursing staff were trained to perform the daily cleaning in the isolation unit. A limited number of cleaning staff were trained to perform the first disinfection after a patient transfer. For the final cleaning of the unit, an external company was contracted to perform disinfection with hydrogen peroxide treatment.

Personnel: The required number of personnel was calculated for the admission of multiple patients to guarantee successful upscaling. During preparations, it proved necessary to activate the crisis coordination team to guarantee the availability of personnel from the hospital for frequent training sessions to ensure maximum availability during the admission of a patient. Flowcharts directed the alerting of in-house staff by team leaders during the acute phase; as necessary, a computerized alarm system would be activated to warn personnel by telephone.

Some personnel were excluded from participation because of certain conditions (e.g., claustrophobia). Personnel were repeatedly trained in sessions of 1.5 hours, during which the donning and doffing of PPE, the buddy system, and other procedures were rehearsed (e.g., waste management, cleaning, and diagnostic procedures). These sessions were repeated every 10 weeks and resulted in a noticeable increase in the quality and safety of working conditions. The nursing staff of the MIH were prepared to fulfil the roles of buddy and trainer. A total of 126 staff members were trained (Table 1). After 2 training sessions, a survey conducted among personnel indicated that they felt sufficiently prepared (Figure 4).

Table 1. Personnel trained in preparation for admission of a patient with viral haemorrhagic fever, Major Incident Hospital, University Medical Centre of Utrecht, the Netherlands, 2014

Specialty/title	No. trained
Anaesthesiology specialist	1
Nurse trainer	13
Infectious disease specialist	8
Intensive care specialist	4
Internal medicine specialist	6
Nurse, emergency department	33
Nurse, intensive care unit	18
Nurse, infectious diseases	13
Paediatric infectious disease specialist	3
Paediatric intensive care specialist	5
Nurse, other department	11
Nurse, paediatric intensive care	5
Nurse, paediatrics	4
Resident infectious disease specialist	2
Total	126

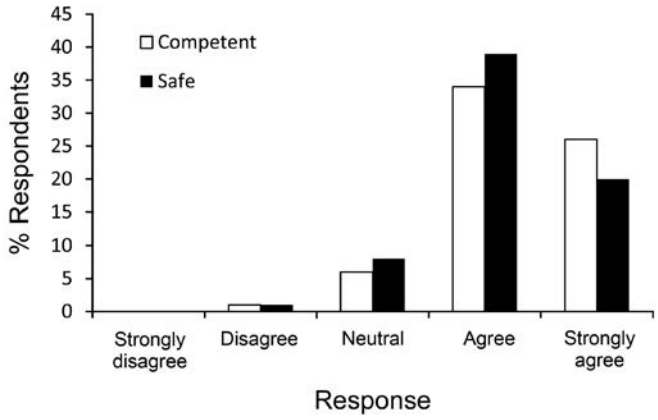

Figure 4. Results of a post-training survey conducted among staff indicating whether they felt competent and safe in caring for patients with Ebola, Major Incident Hospital, University Medical Centre of Utrecht, the Netherlands, 2014.

Occupational health and safety service guidelines were developed for staff. All employees whose work involved contact with a VHF patient under protected conditions would be registered and required to monitor their temperature. In the event of unprotected contact with a VHF patient, personnel would be excluded from activities in the hospital and closely monitored by the public health service. If onset of VHF-associated symptoms occurred, personnel would be requested to contact the hospital's occupational health and safety service and would be admitted to the isolation unit.

Diagnostics: PCR testing for VHF was to be performed in 2 reference centres (the Erasmus Medical Centre, Rotterdam, the Netherlands, and the Bernhard Nocht Institute for Tropical Medicine, Hamburg, Germany), which were appointed in accordance with national regulations and are in compliance with safety protocols.[6, 7] PCR testing was to be performed for EBOV, Marburg virus, Lassa virus, Crimean-Congo haemorrhagic fever virus, HIV, Plasmodium spp., and Leptospira spp. All materials were to be stored in plastic safety bags, placed in plastic containers, and then placed in cardboard shipping boxes (i.e., the "box-in-box" method).

Point-of-care laboratory tests were to be performed in the isolation unit by using I-STAT portable clinical analyser (Abbott Point of Care, Inc., Princeton, NJ, USA). More extensive testing would be possible in one of the appointed external diagnostic centres.

A stethoscope equipped with a Bluetooth connection was acquired for auscultation of patients without physical contact. The radiology department was consulted to explore the possibilities of imaging in certain circumstances, such as the localization of a central venous catheter. However, these possibilities were limited by the confined space in the isolation rooms and by the need to decontaminate the equipment. It was then decided that the use of conventional radiography would not be possible. The option of a small portable ultrasound device was explored; however, the quality of the imaging was insufficient.

Isolation Department and Adaptations: Only small adaptations to the isolation units were necessary. To prevent spread of the virus, running water taps were shut off, and sinks were disconnected from the sewage system. To ensure safety in cases of patient delirium and to enforce involuntary quarantine, the units were equipped with locks and safety glass. A schematic overview of the isolation department is shown in Figure 5.

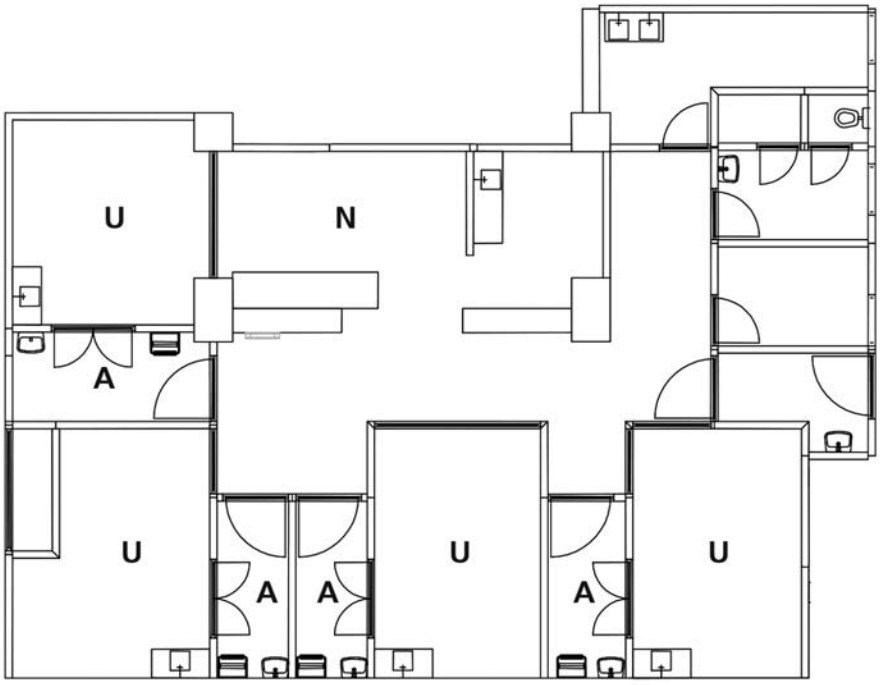

Figure 5. Schematic overview of the isolation department, Major Incident Hospital, University Medical Centre of Utrecht, the Netherlands, 2014. U, isolation unit; N, nursing station; A, access valve.

Medical Treatment Protocol: A medical protocol was developed to describe the standard diagnostic procedures and medical treatment according to the available guidelines. The protocol included pre-emptive treatment for malaria and administration of antimicrobial drugs for possible bacterial sepsis.

Communication and Information: Flyers and banners were posted in the outpatient departments and in hospital entryways, requesting that patients, visitors, and personnel who had recently travelled to a high-risk area for EBOV infection inform hospital staff. Additionally, information was broadcast on a television screen in the emergency department entryway and waiting room. Staff at the emergency department and hospital wards were instructed to enquire actively about risk factors for VHF for patients with fever.

Local hospitals and other external partners were informed and advised about VHF procedures and referral to the MIH. Meetings to inform non-involved hospital staff about EVD and the precautions taken by the hospital were organized and, before the arrival of an actual patient, repeated for the relatives of involved staff.

Experiences during the Admission of an Ebola Patient

On December 4, 2014, the Ministry of Health, Welfare, and Sport requested that the MIH admit an EBOV-infected soldier who was residing in a hospital in Liberia. Arrival was planned for 2 days later. Daily updates about the health status of the patient and his transport allowed optimal preparation. The command structure functioned as outlined. Additional informational meetings were held for staff and relatives and were especially appreciated by the families of personnel, whose anxiety had been amplified by the increased media coverage of Ebola.

Transfer and Admission: Before arrival of the patient, the transfer procedures were rehearsed twice with the involved ambulance and MIH personnel. Some changes had to be made to the infrastructure of the hospital entrance because of the differing PPE doffing procedures used by the designated ambulance services. It was then decided to involve no more than 2 ambulance services for future transport of VHF patients to the MIH.

At the time of patient admission, the command team, 4 trained nurses, and an infectious disease specialist were present, and intensive care unit (ICU) personnel and a cleaning team were on standby. Security personnel were present to prevent unauthorized persons from entering the unit and to prevent members of the news media from entering the hospital grounds.

The command team was continuously updated about the progress of the ambulance en-route to the hospital. At 15 minutes before expected arrival, the first team of nurses started PPE donning procedures. The transfer of the patient at the hospital entrance was time-consuming because the patient was enveloped in a body bag, which resulted in more time required for triage by the first crew in PPE. The initial triage indicated no need for ICU admission. The initial diagnostics and medical treatment proved to be more time-consuming than expected. Cleaning and disinfection of the hospital entrance took >1 hour instead of the planned 45 minutes.

Treatment: All necessary medical and nonmedical activities (e.g., food delivery) were bundled to minimize the number of entries into the isolation room, resulting in 2–3

entries per 8-hour shift. Diagnostic blood samples were collected from an intravenous line to avoid high-risk procedures. Microbiological diagnostic procedures and sample transport to the diagnostic centres were supervised by the attending virologist and proceeded without incident. The results became available the same day. Coagulation tests were not available at the time; however, they were not required in this particular case.

Daily physician visits, except for replacement of the intravenous tube, were primarily conducted through the glass window by telephone. Spiritual counselling was provided at the request of the patient, and a tablet computer was provided for distraction and contact with family. The continuous presence of 3 nurses proved necessary during all 3 daily shifts. The availability of a coordinating nurse ensured that the interaction between the buddy and the bedside nurse was never disturbed. No safety incidents occurred. The limited working time of 45 minutes in PPE proved to be appropriate; however, an additional 20 minutes for recovery seemed to be warranted. PPE stock levels were always adequate.

Waste production was lower than expected because of the relatively stable condition of the patient. The maximum number of 60-L barrels used was 8 on the first day and 3 on every following day. Guided transport of the barrels to the external facility was necessary only twice weekly. A complicating factor was the difficulty of appropriately closing the barrels in 5 instances, which necessitated the resealing of boxes inside other boxes before further transport.

Discharge: After 6–7 days, all signs and symptoms of EVD in the patient had disappeared; however, the patient was dismissed from isolated treatment another 7 days later, after 2 PCR blood test results were negative for EBOV. The discharge procedure had been described only minimally in protocols and was developed in the days before dismissal. The isolation unit was sealed awaiting decontamination of the room by hydrogen peroxide gassing, which was performed 1 day after discharge. The isolation room was not made available until 14 days later because of the mandatory incubation period, the time required to interpret biostrips used to monitor the space, and the unavailability of staff from the external company during the end-of-year holidays. The entire isolation unit was unavailable for the admission of patients on the day of gassing because of interconnected air systems.

Evaluation: All involved personnel were monitored daily for 3 weeks after their last shift, and none experienced onset of symptoms. The experiences of the admission were shared with other medical centres and the National Institute for Public Health. Revisions to the design of the isolation unit are under way and include the installation of automatic sliding doors and improvement of the communication equipment.

Discussion

The EVD epidemic in West Africa during 2014–2015 underscored the need for hospitals worldwide to prepare for outbreaks of disease caused highly pathogenic and infectious organisms.[8, 9] During the fall of 2014, UMC Utrecht, which was already equipped with the MIH, intensified its preparations for the admission of VHF patients. These preparations proved to be time-consuming for all key players. In addition, the frequent training of staff led to scheduling complications; however, after activation of the crisis coordination team during the preparation phase, the sense of urgency increased, and departments were more motivated to provide staff.

Tracing procedures in the hospital resulted in increased alertness for VHF in patients with fever. Simulation exercises confirmed the value of protocols for triage and care and led to improvements of the procedures. Regular repetition was needed to sustain the level of alertness and knowledge of procedures. The value of protocols has been confirmed by the experience of other Western hospitals that have cared for patients with suspected or confirmed EBOV infection.[10, 11] However, data about preparedness and infection prevention measures are scarce; a single report about hospital preparations indicates that the trainer-observer method was used during PPE doffing and donning and that autoclaving took place at the hospital, but other procedures were not described.[12]

The admission of an EBOV-infected patient was an opportunity to test all developed procedures. The initial transfer proved time-consuming and warrants further training with ambulance services. Moreover, because every regional ambulance service has slightly different PPE procedures, it proved appropriate to restrict the number of involved ambulance services for a single hospital.

The treatment of 1 patient was demanding on staff resources. Because the isolation unit was located outside the regular hospital wards, additional personnel were needed to staff the front office and to secure the cooling container on the premises.

PPE use occurred without incident, but the discomfort caused by PPE was the largest complicating factor and warranted limiting the time spent in PPE to 45 minutes, with a 20-minute recovery period.

Minimal requirements for the selection of PPE had already been determined by national authorities on infection prevention. However, the selection of PPE differed among the UMC Utrecht and other hospitals in the Netherlands appointed for admission of Ebola patients; for example, some centres used rubber boots (instead of clogs), a hood with a powered air supply, or cooling vests. Although some of these options might provide more comfort, they are more costly and do not always provide additional safety. The buddy system was based on the trainer-observer method of donning and doffing PPE but was extended to all high-risk procedures conducted in the isolation unit and ensured the safety and confidence of personnel.[4] However, it was determined that the admission of >4 patients simultaneously should be avoided because the presence of multiple buddies in the isolation unit would compromise the audibility of instructions.

Waste destruction had to be outsourced because of the lack of autoclave capacity at the MIH, which led to additional costs and workload. Apart from the incidental failure to close a waste container, no safety incidents occurred.

Although the patient did not need care in the ICU, the admission increased awareness that the number of trained ICU staff would be insufficient to treat a patient in need of mechanical ventilation or haemodialysis for any extended period.[13] The staffing required for these procedures would certainly lead to a restriction of available ICU beds for other patients. An intensified training program for ICU staff was devised, and more detailed ICU protocols are in development.

Although the absence of coagulation tests did not lead to a problem in this case, it might have in the case of a severely ill patient. Limited coagulation tests became available later. Also, the use of conventional radiography was deemed impossible; portable ultrasound devices are now being tested. A recent report underscores the need for advanced protocols to perform radiologic imaging in these circumstances.[14] During admission, protocols for discharge were still under development, leading to last-minute changes and some agitation among staff; however, discharge itself went well. The final cleaning procedure took longer than expected; on the day the patient was discharged, all 4 rooms were unavailable because the air treatment systems were interconnected. The system will therefore be adjusted (bifurcated) in the future.

Table 2. Key lessons learned from admission of an Ebola patient, Major Incident Hospital, University Medical Centre of Utrecht, the Netherlands, 2014

Considerations for the future
• Protocols should be in place for all procedures.
• Limit the number of ambulance services eligible for patient transfer.
• The buddy system as extension from the trainer-observer role is invaluable in care for patients with viral haemorrhagic fever.
• Regular repetition of training is necessary.
• Time in personal protective equipment should be limited to 45 minutes, with an additional 20 minutes for recovery.
• The volume of biologic waste will be more than expected, and procedures for waste management need to be explored at an early stage.
• Remote, noncontact, sensors should be explored as possible tools in diagnostics.
• Specific engineering solutions are needed for every different infection scenario.

Communication was of utmost importance; not only did the hospital staff need information, but so did their relatives, who were concerned about the risks of working with Ebola patients. Also, the demand for extra security personnel was high because of the need to secure the stored waste and limit access to the MIH.

Although the isolation units in UMC Utrecht are located in a separate facility (the MIH), our experiences might be useful in other hospital settings (Table 2). Existing international and national protocols describe only the minimum requirements and therefore are not suitable for comparison. The preparations made and the lessons learned during the admission of an Ebola patient confirm the necessity of clear and practical protocols, a buddy system, and intensive staff training, all of which increase the safety of healthcare workers. Because of these measures, we experienced virtually no reluctance of personnel to be involved in the care of VHF patients. The demand on resources to treat VHF patients is high and can lead to understaffing at other departments at the expense of other patients. The availability of a dedicated major incident hospital has greatly increased the resources and preparedness of our centre.

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Chapter 8
Hospital evacuation: exercise versus reality

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Abstract

Introduction: The Dutch Major Incident Hospital (MIH) is a standby, highly prepared, 200-bed hospital strictly reserved to provide immediate, large-scale, and emergency care for victims of disasters and major incidents. It has long-standing experience training for various major incident scenarios, including functioning as a back-up facility for the Netherlands. In 1995, the MIH had experience with overtaking an evacuated hospital when that hospital was threatened by flooding. In November 2014, an exercise was performed to transfer an evacuating hospital to the MIH. The scenario again became reality when a neighbouring hospital had to evacuate in September 2015. This article evaluates the events and compares the exercise to the real events in order to further optimise future training.

Methods: All three events were analysed using the Protocol for Reports from Major Accidents and Disasters, a standardised protocol to evaluate medical responses to a major incident.

Results: During the 2014 exercise, 72 patients were received, compared with 143 and 70, respectively, in the real events in 1995 and 2015. Personnel from the evacuating hospitals accompanied the patients and continued working in the MIH. The patient surge differed on all three occasions. The information technology (IT) systems proved to be more prone to fail during the real event, and legal implications to have staff from another hospital work in the MIH had to be put in protocol during the deployment. The acute phase was comparable in all three events, and performance was good. However, the exercise did not last long enough to analyse the implications on multiday care, as experienced during a multiday deployment.

Conclusion: Large-scale major incident exercises are a great benchmark for the medical response in the acute phase of relief. The MIH was shown to be highly prepared to admit an entire evacuating hospital or large groups of patients in such a scenario. Experiences from the past, combined with regular training that closely resembles reality, guarantee the level of preparedness. Key differences between a true deployment and an exercise are the inability to train multiple days, and in our experience, a successful operation of IT systems in test environments does not guarantee their successful use during live events.

Introduction

The Dutch Major Incident Hospital (MIH) is a government-funded, standby facility located in and under the jurisdiction of the University Medical Centre of Utrecht (UMC Utrecht), which has been described previously.[1] In short, it is a standby, highly prepared, 200-bed hospital strictly reserved to provide immediate large-scale emergency care for victims of disasters and major incidents.

Training is one of the key opportunities to improve preparedness for major incidents. The MIH has a longstanding history of preparing for the medical management of major incidents.

Briefly, since the construction of the hospital in 1991, annual trauma exercises are organised to optimise preparedness. Over the years, all procedures have been put in protocol, and lessons learned from previous exercises have been implemented, leading to progression and maturation of the MIH. Smaller, more specific exercises, such as nuclear, biological and chemical events, have also been implemented to train key players. With the development of more specific major incident exercises, scenarios have focussed on other threats than just a high patient surge situation (i.e., chemical, biochemical, radioactive, nuclear [CBRN] scenarios with decontamination, terrorist attacks and full-scale evacuations of surrounding hospitals to the MIH). In the 24 years of experience, the MIH has been deployed 43 times and 787 patients have been admitted in different real-life scenarios.[2] The MIH has the capacity and infrastructure in place to overtake an entire hospital for a short duration, after which outplacement to other hospitals is initiated. The aim is to keep the patients together during the acute phase, after which outplacement can be started in a calm and orderly manner.

Experience with an evacuation scenario of an entire outside care facility to the MIH was gained in 1995, when 143 patients were evacuated from a local hospital due to flooding of that hospital. Moreover, several real-life deployments have occurred, with whole patient population takeovers for evacuations due to fires in nursing homes and international medical relief.[2, 3] Lessons learned from these deployments have been implemented to mature the MIH. In November 2014, a large trauma exercise was organised to further optimise preparedness for such a scenario. One of the training goals was to have personnel of the evacuating hospital join their patients and have them provide care in the MIH to guarantee the continuity of care. The exercise scenario became reality in September 2015, when a neighbouring hospital had to evacuate all patients from their facilities.

This article describes and evaluates the main differences between the exercise and two real deployments. The deployment of the MIH in both events is evaluated to provide recommendations to improve the validity and design of future exercises and deployments.

Methods

This article compares the medical response of the MIH during a major incident trauma exercise for patient relief due to a hospital evacuation and two real-life deployments (Figure 1). The evaluation of the prehospital response is beyond the scope of this article. In November 2014, a trauma exercise was designed with the aim of evacuating an entire neighbouring hospital to the MIH. The scenario was based on a chemical threat following a transport train crash, with the hospital positioned in the hazardous zone. The MIH had previously experienced this scenario in 1995 when a complete local hospital in Tiel, the Netherlands, was evacuated into its premises. In September 2015, the lessons learned from the past and training from the 2014 exercise were put to the test when the VU University Medical Centre Amsterdam (VUmc) had to be evacuated due to flooding of the area. In all three occasions, a request was made to have personnel of the evacuating hospitals accompany their patients to ensure the continuity of care. In the case of a short evacuation, the care is continued to be given by the evacuating hospital personnel, otherwise patients are transferred to the care of the MIH or the hospital to which the MIH refers the patients. Several protocols are available to evaluate and report the medical response to major incidents.[4] The Protocol for Reports from Major accidents and Disasters (PRMD) published in the *International Journal of Disaster Medicine* fits best with the in-hospital response, where most protocols focus on the pre-hospital area of expertise.[4, 5] This, combined with previous publications according to the protocol, made it the most suitable format to compare the evacuation takeover exercise with the 1995 and 2015 hospital evacuation.[2] The PRMD is divided into 18 headings to evaluate the different aspects of medical responses to major incidents. The standardised tables from the protocol were used when applicable. Data were gathered from the Patient Barcode Registration System and ABC system.[6, 7] The data from the 1995 deployment, although more than 20 years old, have been retrospectively retrieved from the evaluation reports and digital archives of the patient tracking system, which have been fully preserved over the years. Data are descriptive, and no statistical analysis was performed.

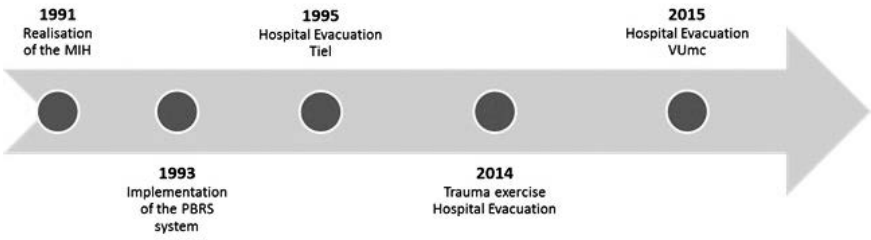

Figure 1. Timeline of the mentioned events.

Results

The subheadings in this paragraph are analogous to the 18 subheadings of the PRMD. **1/2/3 Short summary of the scenario/hazard, description of the accident:** The trauma exercise scenario was based on the derailing of a transport train stocked with a chemical substance that causes respiratory discomfort. These symptoms were not life threatening but caused sore throat and minor respiratory difficulty. Because the derailing took place in the proximity of a hospital, a large-scale evacuation was mandated. All patients fit enough were discharged; the remaining 72 patients were transferred to the MIH.

The evacuation in 1995 of 143 patients was caused by a rise in the river water levels threatening the integrity of the dyke system in the Rivierenland area of the Netherlands, leading to one of the largest evacuations in Dutch history.

The 2015 evacuation was mandated due to a broken main waterline in the vicinity of the VUmc hospital, a large university hospital with 700 care beds. A severe flooding of the streets and several crucial technical installations of the hospital led to a situation in which the primary needs of patients could not be guaranteed. An evacuation was started to several hospitals; the MIH received 70 patients.

4. Prehospital resources available and alerted: Prehospital considerations are beyond the scope of this report.

5. Hospital resources available and alerted: The Emergency Response Protocol enables admittance to the normally standby MIH of up to 100 patients after a start-up time of only 15 minutes. With an additional 45 minutes, the capacity can be extended

to 200, and after 24 hours up to 300 patients can be admitted. Figure 2 shows the MIH in a standby situation.

During the trauma exercise, the hospital was alerted to receive up to 100 patients. The evacuation was acute and started directly after the notification by the Crisis Command Team of the evacuating hospital and the dispatch centre.

The planning of the 1995 evacuation deployment started several days prior to the final decision to start the evacuation; therefore, it was a planned operation with all resources, such as transport, put in place. To guarantee swift progress, the patients were transferred starting at midnight and completing the evacuation within 4.5 hours.

The 2015 evacuation was a subacute process; the MIH was alerted 5 hours prior to receiving the first patient. Announced patient counts varied between 40 and 100. It was decided to upscale for a scenario of maximum 100 patients. The main difference between the exercise and the 2015 evacuation was the time between notification of evacuation and the admittance of the first patient, as well as uncertainty of patient numbers in the 2015 evacuation. This was mostly caused by the scattering of patients over multiple hospitals instead of evacuating the whole hospital to one single location, as performed in the 1995 evacuation.[2]

6. Utilisation of transport resources: The patient surge is illustrated in Figure 3. During the exercise, a constant surge of patients was planned, with a patient arriving every 3–5 minutes at a constant rate. The 1995 evacuation was well planned with many resources available; the broad availability of ambulances caused a high, though constant, surge of patients. During the 2015 evacuation, patients arrived cohort-wise with five ambulances arriving every 15–30 minutes under police guidance, showing a greater strain on the system due to the peak-wise surge.

7. Hospital alert plan and response: The opening of the MIH is an essential part of the disaster plan of the UMC Utrecht and the Central Military Hospital (CMH). The organisation, infrastructure and training are all directed around triage to guide patient flow through successive echelons of care to deliver the greatest care to the greatest number of people.[1] During a deployment, the staff is warned by an automated phone system. The emergency room is downscaled, and staff are transferred to the MIH. The trauma exercise was planned; therefore, it is not representative for evaluation of staff recruitment. The 1995 evacuation was carefully planned beforehand; therefore, there was no need to activate the phone alarming system. During the deployment of

Figure 2. One of the MIH wards in standby phase.

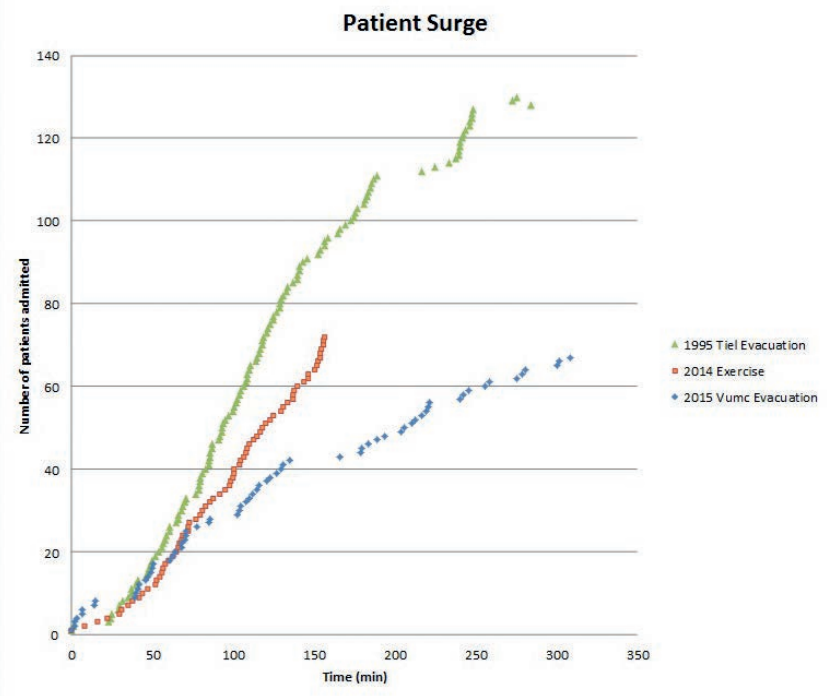

Figure 3. Patient surge through time.

the MIH for the 2015 evacuation, a limited scenario for the phone alarming system was activated to recruit mainly coordinating nurses and doctors because the request to evacuate staff and nursing personnel was granted. On both occasions, MIH staff supported external staff when possible and was responsible for all arrangements to facilitate the Tiel and VUmc staff.

8. Coordination and command: The trauma surgeon on call and a member of the board of directors decide whether or not to open the MIH.[1] Following deployment, three levels of command are discerned: first the Crisis Management Team (CMT) is responsible for external communication and the continuity of the processes in the adjoining hospitals. Second, the Crisis Coordination Team (CCT) operates between the CMT and the Command Team and ascertains continuity of care in the UMC Utrecht and the availability of resources and personnel. Third, the Command Team, led by the trauma surgeon on call, is responsible for the operations of the MIH. Trained medical doctors and nurses assume command in the wards. They are identified through green and red caps, respectively, to achieve visibility for all other personnel. During the exercise, command functioned as outlined and all levels operated in their respective roles. The command structure functioned as outlined in the 1995 evacuation, with the exception of the CCT, which had not yet been implemented. The 2015 evacuation was a subacute process; therefore, the deployment preparations started 5 hours prior to receiving the first patient. The Command Team has actively offered the MIH capacity to the VUmc and dispatch centre.

During the first few hours of the 2015 VUmc deployment, a problem was encountered with the permissions for external staff to work in the MIH. The medical doctors from the VUmc had no legal status within the UMC Utrecht. Only as an employee of the UMC Utrecht is it possible to be registered in the medical systems; therefore, no access to the medical systems to prescribe medicine and request examinations was possible.

This provided a challenge for the Command Team and the legal department. The solution during the first hours of the deployment was to temporarily implement dual treatment responsibility from both the VUmc and UMC Utrecht. After this initial period, all external staff was registered and granted a hospitality agreement enabling access to the digital medication prescription system because of a full legal status within the UMC Utrecht. This problem had not been previously encountered because the systems in 1995 were not digital and the 2014 exercise did not foresee to cover this element.

In the VUmc deployment, the chair of the surgical department or his/her substitute was available to the MIH Command Team as an external advisor and was involved in the process of the MIH; a representative of the VUmc management joined the CMT. There was added value in the presence of the external party, mainly for effective communication with the evacuating hospital and personnel management.

9. Hospital damage: VUmc had to partially switch off electric power (wards) to prevent electrocution or fire. Elevators were out of order, caused by damage to the electronic and security systems situated in the lower parts of elevator shafts. In addition, vital technical installations of the hospital, such as systems for heating, distilled water, hot and cold water for consumption and steam production, were destroyed. It took 2 weeks to build temporary utility systems, repair the damage to the elevators and execute end-to-end security and stability checks.

10. Communication system: The present communication system relies on a wireless, private GSM network. Mobile phones are reserved for all coordinating personnel. Other staff are able to use and carry the same phone as they use during daily care in their regular hospitals, namely the UMC Utrecht or CMH. Communication between the ambulance hall and trauma bays is handled through walkie-talkies, of which eight are reserved in the MIH. These walkie-talkies are continuously charged and are circulated with the walkie-talkies of the UMC Utrecht security services to assure their functionality. During the exercise, the mobile phone network was in a testing phase; in this phase, the network was unstable, and an insufficient number of phones were available for the medical staff. Only one mobile phone on every four persons was available. At the time of the 2015 evacuation, mobile phones had become standard equipment for the medical staff: one mobile phone for every person, with the pager system still functioning as backup. The network proved reliable and available for communication through the wireless phone system. This resulted in a tremendous improvement in direct communication between key personnel. During all deployments of the MIH, meetings with all coordinating staff members are organised at regular intervals. During these meetings, the Command Team provides a situation report and the department supervisors discuss crucial decisions and bottlenecks from their departments. Decisions are implemented after the meeting, and the department supervisors share the information with the remaining staff. This top-down system proved to be highly efficient, from the perspective of information exchange and management.

11. Computer technology and backup systems: Regular exercises take place to check the MIH computer systems. In addition to the hospital information systems of the UMC Utrecht and the CMH, the MIH has developed a Patient Barcode Registration System.[6, 7] The Patient Barcode Registration System has been in place since 1993 and has been used in every deployment thereafter. Barcodes are used to register, track, and trace the patient surge during a major incident or disaster. The system allows continuous monitoring of the patient surge and department capacity by the Command Team; this covers a large demand of logistic communication and improves anticipation of care needs and use of resources.[6]

During 2014, updates were implemented to enhance the system's speed. It was tested during the trauma exercise, and errors have been analysed. The program code was optimised to increase system stability.

During the 1995 deployment, the system was used to register all patients; however, there was no further digital integration with hospital information systems because these were all handwritten at the time. An attempt to integrate the Patient Barcode Registration System with the hospital information system was made in 2015. The integration depended on a data link between the systems, which was fully operational for the first time during the 2015 evacuation. This link would allow for all data from the Patient Barcode Registration to be transferred into the Hospital Information System without further operations by administrative staff.

In spite of full functionality of the test version link, the link in the operational version caused many errors. Given the failure of the attempt to link the systems, it was then decided to return to the previous solution, with both systems operating independently from each other.

12. Total number and type of injuries: A total of 72 patients were part of the evacuation scenario during the trauma exercise. During the 1995 evacuation, the entire hospital population was evacuated to the MIH, which resulted in 143 patients, including patients in need of Intensive Care Unit (ICU) treatment admission.

In total, 70 patients were admitted during the 2015 evacuation. Three patients were in need of ICU treatment and directly admitted to the ICU of the UMC Utrecht without entering the MIH. Another four patients were transferred to wards in the UMC Utrecht after triage in the MIH, due to their specific care needs for isolation and tracheostomy care. The remaining patients were triaged and then admitted to either a surgical or medical ward in the MIH. Patient characteristics are shown in Table 1.

Table 1. Overview of characteristics from the scenarios

	Exercise evacuation	**Tiel evacuation**	**VUmc evacuation**
	2014	**1995**	**2015**
Scenario			
Timeline	Acute	Planned	Subacute
Cause of evacuation	Chemical threat	Flooding	Flooding
Evacuation to one location	Yes	Yes	No, multiple
Patients			
Number	72	143	70
Sex			
M:F	40 (56%):32 (44%)	56 (38%):87 (62%)	35 (50%):35 (50%)
Average age (years)	63	65	58
Department Admitted			
Low Care Ward	59 (82%)	91 (64%)	27 (39%) *
Medium Care Ward	11 (15%)	43 (30%)	40 (57%) *
Intensive Care Unit	2 (3%)	9 (6%)	3 (4%) **
Outcome			
Admitted to UMC Utrecht / CMH	***	102 (71%)	35 (50%)
Referred to other hospital	***	35 (25%)	19 (27%)
Discharged	***	6 (4%)	16 (23%)
Mortality	0 (0%)	0 (0%)	0 (0%)
Deployment			
Time of notification	08:40 hours	14:00 hours	14:00 hours
Prior to arrival of first patient	35 minutes	10:00 hours	5:15 hours
Total duration of deployment	***	2 days	2,5 days

* Low care and medium care wards were separated to become surgical and medical wards
** ICU patients were directly transferred to the Intensive Care Unit of the UMC Utrecht
*** Not applicable in exercise scenario

13. Severity of injuries: Classification with Injury Severity Scores is inapplicable because patients were not admitted after trauma and covered a wide variety of disease entities (i.e., neurological, pulmonary, surgical, trauma, etc.).

14. Hospital load: During all three events, congestion and lack of materials or resources were not experienced. Volunteers from the Dutch Red Cross were available in large numbers to assist in patient care and transport. Their presence has proven a valuable addition to the professional pool for several years.[2] Personnel were sufficiently available during the 1995 evacuation; however, personnel availability proved more complex during the multiday deployment of the 2015 evacuation because all regular departments of the UMC Utrecht and CMH were still running at maximum capacity. It was mainly due to the addition of the VUmc staff to the MIH personnel that regular processes at the UMC Utrecht and CMH were not altered. The MIH aims to be operational for a maximum of 3–5 days in its buffer function for the healthcare system. After patients are fully treated, they are either discharged or referred to another institution with an adequate level of care, mostly the UMC Utrecht itself. This does cause a strain on the capacity of the UMC Utrecht. Data are shown in Table 1.

15. Psychological reactions and management: During the exercise and real-life deployments, staff from the psychological and psychiatric department were available to support victims. During the acute phase, there is a limited demand; however, during the treatment phase, their support is frequently called upon. Experiences have shown that the members of the Dutch Red Cross have an important role in comforting and providing a listening ear to the patients. Patients among the 1995 and 2015 evacuees were kept together as much as possible; this was perceived as a positive and supportive measure. An aftercare team for personnel is available to address the emotional impact after major incident victim relief. Their duties were not called upon after these specific incidents.

16. Outcome: The exercise focusses mainly on the acute phase; in this phase, there were no avoidable deaths. During the 1995 and 2015 evacuations, there was no in-hospital mortality. In 2015, one patient was outplaced to a hospice on the same day of admittance, as was planned before the hospital evacuation. The deployment of the MIH lasted approximately 2 days in both real deployments. Outplacement procedures started as soon as possible in the 1995 event: 102 patients were admitted to the UMC Utrecht and CMH, 35 referred to other care institutions and 6 were discharged home. In 2015, when it was concluded that the VUmc would not be

operational within the following week, patients were all outplaced from the MIH: UMC Utrecht received 35 patients, 19 were referred to other institutions and 16 patients could be discharged within closing time of the MIH. This aspect could not be practised during the exercise, given its short duration. However, it did affect the logistics of the UMC Utrecht in the 2015 deployment, due to congestion of the low-care wards. This was addressed by the Crisis Command Team by opening an unused ward with personnel from the VUmc supported by UMC Utrecht personnel.

17. Estimated number of people affected but not injured: The evaluation of this aspect is beyond the scope of this report.

18. Post-accident evaluation: A thorough post-incident evaluation takes place after every major trauma exercise and deployment of the MIH. This evaluation covers the operational procedures of the MIH, as well as the quality of care given, and constitutes the goals for the next major incident trauma exercise. Training a key group of coordinating staff has proven to be a key factor to success. With the training of this relatively small group of key players, the remaining staff can perform their work equally and with the same high standards, under exceptional circumstances, as they would usually perform it in the UMC Utrecht or CMH. This principle has once again been demonstrated by the capability of external staff to work in the MIH.

Discussion

Major incident exercises resemble a real major incident as much as possible. In 1995, we have gained experiences with evacuating an entire hospital to the MIH. During the following years, several deployments admitting patients from evacuating nursing homes have taken place. The lessons learned and experiences gained have been implemented in our protocols. Furthermore, many developments have taken place in IT systems over the past 20 years. To optimise preparedness for this scenario, a large-scale evacuation exercise took place in 2014, after which these preparations were put to the test in a deployment in 2015.

This study evaluates the implementation of the lessons learned from the past and compares it to our exercise in 2014 using the 18 criteria from the PRMD. The design of the exercise scenario showed close resemblance to the real events, including the capability to operate on a much shorter notice compared with the real events. During the 1995 and 2015 evacuations, the MIH has shown to be a flexible and highly prepared

facility to accommodate these patients at short notice. The buffer function allowed outplacement of patients to other hospitals. This process was completed within 2.5 days in both events.

Several key features of the training have proven to be different from the real-life deployment, thus providing pitfalls during deployment. Four main features of the trauma exercise proved to be inconsistent with the real event. First, the patient surge arrived in cohorts rather than the continuous rate as planned in the trauma exercise. In the case of a planned evacuation, the resources are optimised and the surge speed will be increased. Second, the IT systems were always used in an exercise mode during trauma exercise but did not work properly in the production mode. Third, major incident exercises have limited time available and therefore cover only the acute phase. The difficulty lies in arranging adequate numbers of staff, which starts from the second day and increases due to the extra capacity of the hospitals with the MIH deployed. This element can only be noticed during multiple-day exercises. Fourth, the legal implications for external personnel to provide care in the MIH were not fully put in protocols; however, this was resolved in a timely manner.

The experience in 1995, when the same scenario was the reason for deployment of the MIH, shows great resemblance to the 2015 deployment, despite the 20-year time difference. However, some data are difficult to retrieve and compare after 20 years, but the data from the digital patient tracking and tracing system give an objective insight in treatment times and patient characteristics. The PRMD provides a good tool to analyse the deployments of the MIH and other institutions; however, its design and the design of other templates mainly involve the prehospital response[4]. Because the MIH focusses on the hospital response, a template to evaluate functioning after the acute phase would add to the available tools for evaluation. Extensive analysis of surge rates from other deployments should be performed to give a realistic insight into the mean surge rate during these events.

The long-standing experience in training and major incident medical relief from the MIH should serve as a guidance to other centres to optimise the training for major incident response. After 24 years of experience, much has been learned and is to be learned, as this recent event has shown.

In conclusion, major incident exercises are a great benchmark for medical response in the acute phase of medical relief. However, it is difficult to train and measure the performance after the acute phase. Moreover, IT systems should be tested in

their regular production modes; in our experience, a successful operation in test environments does not guarantee a successful use during live events. The MIH has been shown to be highly prepared to admit an entire evacuating hospital or large groups of patients in such a scenario. The legal implications to allow staff of an evacuating hospital to work in another hospital need to be put in protocol in advance.

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Chapter 9

Developing the fourth evaluation dimension: a protocol for patient perspective video evaluation during major incident exercises

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Submitted

Abstract

Introduction: Presently used evaluation techniques rely on reports from observers, data from registration systems and observational cameras overviewing elements of the care process. These techniques are generally observer dependent and not reproducible. This proof of concept study aimed to test the feasibility of the extension of evaluation with a fourth dimension, the patient's perspective.

Methods: Footage was obtained during a large trauma exercise. Two mock victims were equipped with point of view cameras filming from the patients head. Based on a first experience during a major trauma drill, a protocol was developed for a prospective, standardized method to evaluate a hospitals major incident response from the patient's perspective. The protocol was then tested in a second exercise for its feasibility.

Results: New insights were gained after review of the footage; the traditional observer did not note some of the evaluation points. The information gained from the patient's perspective proved to be implementable into the evaluation protocol.

Conclusion: The use of point of view camera recordings from mock patient's perspective has shown to be a feasible addition to traditional evaluation of trauma drills and trauma care. Protocols should be designed to optimize and objectify the judgement of such footage.

Introduction

Evaluation of patient care is one of the most important elements in medical training for individual care, education and large-scale major incident exercises. Various methods are used to evaluate exercises and disaster preparedness of a medical institution.[1] Traditionally the evaluation is based on input from three dimensions; surveys, direct live observation and video analysis.[2] Data from registration systems and observational cameras can also be reviewed to judge the performance of a hospital during the response to a major incident. However, these observation techniques only show a part of the process the patients are put through and most data can't be reproduced or is subject to personal interpretation. To create a true insight in the patient's process through the medical system in case of a disaster, we propose, as an addition to the traditional methods, to equip mock victims with point of view cameras. This additional fourth dimension provides the evaluator with footage that can illustrate the course of the patient during trauma care. Furthermore, the performance of the medical care given to the patient can be analysed based on treatments and time. The Major Incident Hospital (MIH) in Utrecht, the Netherlands, organizes large trauma drills with mock victims on a yearly basis in order to test and optimize the response to future major incidents. The MIH serves as stand-by, highly prepared, hospital, which can deploy 200 additional beds, within 30 minutes, to the Dutch medical system in case of major incidents.[3, 4] The aim of this concept study was to test the feasibility of patient perspective video evaluation and to develop a prospective standardized method to evaluate exercises of hospitals major incident response with the use of this video footage.

Methods

During the trauma drill in 2014, two mock patients were equipped with the point of view camera to gain a first experience with the new system. (Figure 1) The drill involved 100 mock victims with traumatic injuries and additional need for decontamination, caused by the crash of a train transporting hazardous substances.

The footage from the point of view camera gave insight in the patient's experience of the decontamination process and the primary survey in the shock room of the Major Incident Hospital. (Figure 2)

The gained footage from the patient's perspective during the major incident drill was analysed by the principal investigator and the information extracted from the images was used to create a protocol to measure the performance of medical care during a hospitals major incident response.

During the second trauma drill, in 2015, two mock victims were again equipped with point of view cameras. The drill was set up as a major traffic crash that resulted in 120 victims of whom some needed decontamination due to hazardous substance contamination from a transport wagon. The drill served as a basis to test the protocol prospectively and determine the feasibility of the patient perspective video evaluation.

Results

Feasibility: During the first drill two mock patients were successfully equipped with point of view cameras. The audiovisual results were of adequate quality for evaluation. The obtained camera results showed to be a good addition to the observers' feedback and offered new insights that were not gained in the traditional methods. The information was used to set up the evaluation protocol, which is shown in figure 3. In a second trauma drill, the evaluation protocol was tested live for the first time. The resulting footage was reviewed and could successfully be implemented into the evaluation protocol. Registration of all subfields was possible including a judgement as to the time effectiveness and completeness of the trauma care and decontamination process.

Outcome: The implementation of the point of view cameras and the protocol in the 2015 major trauma drill was successful and review of the footage provided new insights in addition to the traditional methods. During the drill in 2015, one observer was constantly present in the decontamination facilities; the feedback had focused on the medical process and the communication within the medical team. The footage from the patient's perspective has taught us that the non-medical aspects of decontamination needed improvement. Particularly the routing to the decontamination unit was confusing and communication with the mock victim upon the arrival at the decontamination unit was insufficient. The traditional observer did not note these observations. Further, the footage gave insight in adherence to the lead times set for the primary survey within the trauma bay. In general footage from the patient's perspective could serve two purposes in training of medical staff. Firstly

Figure 1. One of the mock patients wearing the action camera during a trauma drill.

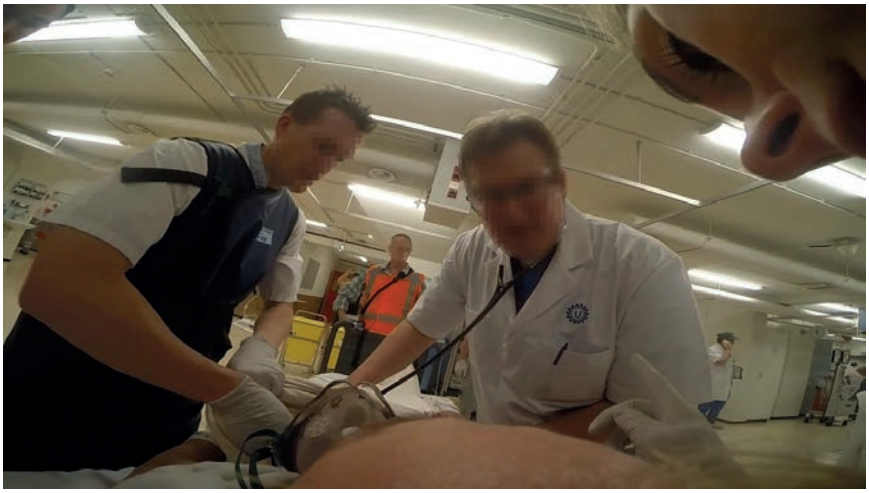

Figure 2. The patient's perspective in the trauma bay, during primary survey.

it can improve patient communication through review by the involved personnel and secondly it can illustrate how a treatment is experienced from a patient's point of view.

Discussion

This concept study introduces a fourth evaluation dimension for medical training, in addition to the traditional methods. By using action cameras, footage was taken from the patient's perspective to capture the patient's experience and judge the performance of a medical system during trauma drills. Based on the experiences from one major trauma drill a protocol was designed and it was tested in a second trauma drill. The evaluation method provided additional, new, insights to the traditional methods. The protocol proposed is designed to be generic and widely usable without adaptation. It is a new type of evaluation tool that can be extended to many types of training including communications training for medical students. Most literature on disaster education and training is based on reporting of lessons learned and other mostly subjective measures.[1, 5] Various efforts have been done to create and promote standardized and objective tools, implementation however has been minimal.[1, 6-8] Video evaluation has the benefit of reproducibility, the exact same footage can be studied several times by any number of people, making it a method open to objectification.[9] The added value of video registration in trauma care has been described in the literature, it can serve three main goals. Firstly, educational purposes by the reviewed tapes of trauma care, secondly to assess quality such as guideline adherence and lastly for research purposes.[9, 10] To remove the subjective assessment, guidelines should be written and followed by reviewers in the analysing process.[11] Video analysis has shown to be useful in assessment of teamwork and leadership as well, assessment of communication with the patients can be further improved by the patient perspective.[10] Video review has further proven to assist with rapid and sustained learning, it was more effective in behavioural improvement than purely verbal feedback.[12] This study is a limited first experience with a new approach to drill evaluation. Although for evaluation purposes multiple exercise observers had been using the images, the principal investigator was the only one to analyse the footage entirely to set up the evaluation protocol. Further work should be done to validate the protocol and the use of evaluation from the patient's perspective.

In conclusion, evaluation can be extended into a fourth dimension by using point of view cameras to capture the patient's perspective during trauma care exercises and major incident drills. Based on first experiences a protocol was developed to evaluate the medical system during a major incident exercise and tested in a consecutive exercise. New insights have been gained from this perspective that were not obtained through traditional surveys, observers and traditional video footage. The use of video evaluation can be a valuable addition to medical training and other goals involving the patient's experience of the medical system.

Protocol for patient perspective video evaluation during major incident exercises

Guidelines for the user

The evaluation should be written and structured following the headings below. Starting with a summary of the scenario and ending with the admittance to an operating theatre, intensive care unit, other ward or discharge of the patient. Commentaries should be short and cover the heading only.

General outline of the exercise

1. Short summary of the scenario
   Provide a short overview of the training scenario, where does the event take place, how many victims are involved, what is their triage category.

2. Training goals
   What are the goals of the major incident drill, are specific observations necessary.

3. Hazards causing and involved in the Major Incident
   Describe the type of incident and the risks involved. Is the incident man-made or natural, predominantly sharp or blunt trauma? Is a chemical, biochemical, nuclear, radioactive or explosive (CBRN-E) agent involved and does that have any consequences for the scenario.

4. Description of circumstances
   Under which circumstances is care provided, what is the time of day, weather conditions and how is the availability of resources?

Patient perspective video evaluation of hospital response

5. Routing to hospital
   How does the patient arrive at the hospital, by self-referral or ambulance services? Describe the quality of the routing for self-referral patients and if triage is performed in case of a queue at the hospital entrance.

   a. Self-referral, ambulance services
   b. Triage performed in routing
   c. Routing quality

Figure 3.

6. Decontamination (if applicable)
   Describe how decontamination patients are recognized and routed to the facilities. When does triage start and how is communication with the staff in personal protective equipment. Are patients divided in supine or walking decontamination and describe the time taken for the process of decontami-nation.

   d. Routing to decontamination
   e. Triage between walking and supine decontamination performed
   f. Time necessary for decontamination process

7. Triage
   Describe the triage modality at the first triage station and its registration. Is the priority of the patient recognized in due time.

   g. Time taken for triage
   h. Registration of triage category

8. Registration
   Describe when and where patients are first registered; note the amount of time the process takes. Include a description of innovative solutions for registration, i.e. photographs or patient tracking systems.

   i. Registration of patient details
   j. Time taken
   k. Photograph made for identification

9. Trauma bay – primary survey
   Describe the time taken to arrive at the trauma bay and the time spent in the trauma bay for resuscitation. Note the availability of trauma teams and resources, as well as the completeness of ATLS procedures.

   l. Time between triage and arrival in trauma bay
   m. Full trauma team available
   n. ATLS performed
   o. Time needed in trauma bay

Figure 3. Continued

10. Imaging
    Describe the imaging which is performed, the time taken to perform it and the limitations to imaging in a disaster situation.

    p. Imaging performed
    q. Imaging limited to the critically necessary

11. OR / ICU / Ward
    Discuss the final destination of the patient and the time taken from initial in-hospital triage to arrival at the OR, ICU or wards.

    r. Time from triage to OR/ ICU / Ward

12. Discharge
    In case of discharge describe the time taken from triage to finishing the medical treatment in the trauma bay; include the time spent for discharge procedures under the scenario.

    s. Time form triage to discharge
    t. Time taken for discharge procedures

Figure 3. Continued

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Chapter 10

Regional disaster medicine preparedness training; is the knowledge consolidated for the professional?

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Submitted

Abstract

Introduction: To enhance crisis preparedness in the Dutch healthcare system, in 2008 the Dutch government introduced the OTO project, a temporary project to stimulate the healthcare sector's crisis and disaster preparedness. We hypothesize that 50% of these key players will have remained in function several years after their training, making a temporary stimulus package unsuited to achieve a stable consolidation of knowledge.

Methods: To evaluate the consolidation of knowledge gained through the OTO project, a short questionnaire was designed and sent to 650 participants in OTO project-funded activities in the region of Utrecht.

Results: An effective response rate of 29% was reached, consisting of 190 persons involved in 292 OTO activities. The OTO project-funded activities had enhanced the participants' knowledge in crisis management (79%), 18 persons (9%) had switched their position and five had found employment outside of the Utrecht trauma region.

Conclusion: The consolidation of knowledge, based on the position of trained staff, has been shown to be sufficient. Only nine percent of participants had changed employment position. However, in the longer term, investment is required to develop a consolidation program to retain knowledge and skills for the individual and the system. Furthermore, centralized registration should be performed.

Introduction

Preparedness and its integration in disaster medicine has been of growing importance in the last 20 years, both in the Netherlands and worldwide.[1, 2] Training of staff for disaster response is challenging, since it is time consuming, costly and requires regular repetition to maintain the level of competence.[3, 4] In the case of a major incident or disaster, hospitals need to respond at short notice with an upscaling of their resources (including staff members) and activities. From 2006 to 2008, an initial government campaign with a financial support package was organized to raise awareness of the need for hospital disaster plans. An evaluation was held for the first care package, which showed that 74% of the Dutch hospitals participated and started a structure to maintain the hospital disaster plan and crisis organization.[5] However, there was room for improvement and on October 16th, 2008, a voluntary agreement was drafted between the Minister of Health, Welfare and Sports and the national umbrella organizations in healthcare on the provision of subsidies for OTO. OTO is the Dutch acronym for "Educate, Train and Simulate": educate to enhance knowledge, train to improve skills, and simulate to use the knowledge and training.[6]

This temporary support package project is funded by the national government to support the healthcare sector's crisis and disaster preparedness training and awareness, with a special emphasis on hospital disaster plans and preparedness. The 2008 covenant divides a total of 10 million euros per year between the 11 leading trauma centres in the Netherlands, which will have the responsibility of managing the budget and allocating it to the other centres within their respective trauma regions.[7] Under Dutch law, institutions in the healthcare sector are responsible for their own crisis preparedness and also for the associated infrastructure. Delivering a responsible level of care in special circumstances requires additional and specialized skills that may differ from those required in the regular function. The stimulus project focuses on these additional and specialized skills.

In the trauma region of Utrecht, the Netherlands, the daily duties are taken as a basis to build the disaster-response structure.[8] For medical staff, there is little difference in their tasks during upscaled care. However, at the tactical and strategical levels officers need specific training to fulfil their crisis management roles, which differ from their day to day activities. Tactical and strategic training is difficult; prior to the introduction of the support packages, disaster management has not been the focus. Staff are encouraged to take up a position in the crisis organization that is in line with their daily job, and at the same time, a number of carefully selected key

players are regularly trained to gain the right skills to deal with crises and disasters. Suffering from limited resources and a lack of exposure to crisis situations, it seems more effective to develop a small number of key players thoroughly than entire organizations superficially.

In 2011, a status report was published describing the advancements of the 2008 package.[9] It was concluded that there was an improvement in the overall awareness of hospital disaster plans and crisis management; however, not all key players had been equally trained.[9] Following the 2011 status report, guidelines for quality control and audit procedures have been developed to set indicators for quality and create uniformity between the different regions.[10]

The 2008 plan described the planned training of key players; the future final evaluation of this plan will be based on the number of trained key players in the crisis organization. One of the most important factors for future success is the need to consolidate the knowledge and training made possible with the support package, previously judged by qualitative assessment of the organization put in place to maintain hospital disaster plans. The reality of people changing jobs and functions was not accounted for in the evaluation of the first campaign, nor in the plan for the 2008 project.

In our opinion, the migration of these key players into different functions and organizations should also be taken into account. We hypothesize that 50% of these key players will have remained in function several years after their training. We will further reflect on the adequacy of a temporary support package for long-lasting consolidation of knowledge in disaster preparedness and crisis management.

Methods

In order to perform an evaluation of knowledge consolidation gained within the OTO project, a short questionnaire was designed and disseminated amongst the recipients of the OTO project-funded training in the trauma region of Utrecht (including prehospital, hospital and municipality officers). First, the function of the responder was assessed, i.e. medical, administrative or policy officer, followed by registration of the OTO activities that the responder participated in. Secondly, the questionnaire focused on assessing the consolidation of knowledge in the region by asking whether the participant still held the same professional position as they did during their

participation in the OTO activities. If this was not the case, two other questions were made available. The first enquired whether the gained skills and knowledge were still applicable within their new job and the second whether their new job was in the same trauma region as their previous job. The consolidation of knowledge will be primarily based on the number of people remaining in the same position as they held during their training. Additionally, we will review the number of people that switched positions within the trauma region, but still apply their gained knowledge in their new positions. Finally, the number of people who have left the trauma region of Utrecht will also be collated.

The questionnaire was sent out through the sub-coordinators of the OTO project in the trauma region of Utrecht. Altogether, 650 participants of activities financed by the OTO funds received the survey. Respondents were often involved in several OTO activities over the years, but the questionnaire offered them the possibility to comment on each activity they attended separately.

Results

A total of 301 (46%) people responded to the questionnaire, but 111 (17%) respondents had not participated in OTO activities and were therefore excluded. These 111 respondents were in the OTO projects potential target group at some sub-centres and received the survey erroneously. With this group excluded, 190 surveys were included in this study, resulting in an effective response rate of 29%. This group of 190 people had participated in a total of 292 activities and the results are outlined in Table 1. Most activities were focused on medical/nursing staff (44%) and policy makers (43%), while the remaining 13% consisted of staff in administrative and supportive functions (i.e. communication officers and security officers). The majority (60%) of staff worked in hospitals or for government and prehospital organizations (34%), while a small group worked in primary care (6%). Overall, the different activities funded by the OTO have enhanced the participants' knowledge in crisis management (79%) and the activities were useful for the usual job of the participant in more than half of the cases (58%). In 32% of cases, the activities were not useful for the participants' usual job; however, participants did indicate that the knowledge would be useful for their role in the crisis organization.

Of the 190 people who participated in activities funded by the OTO budget, 18 (9%) had switched their employment position since being trained. Five of these 18

Table 1. Overview of participants and activities

Background of trainee *	
Medical	84 (44%)
Administrative / Supportive	25 (13%)
Policy Maker	81 (43%)
Field of work *	
Government / Prehospital	65 (34%)
Hospital	113 (60%)
Primary care	12 (6%)
Did the course(s) enhance you knowledge in crisis management? **	
Yes	79%
Neutral	15%
No	6%
Was/were the course(s) usefull for your daily job at that time? **	
Yes	58%
Neutral	10%
No	32%
Is your current position different from your position when you took the course(s)? ***	
Yes	172 (91%)
No	18 (9%)
Is your new position still in the trauma OTO region of Utrecht? ***	
Yes	13 (72%)
No	5 (28%)
"When was the course / training followed?	
<1 year ago	123 (42%)
1 - 3 years ago	122 (42%)
3 - 5 years ago	29 (10 %)
>5 years ago	18 (6%)

* N=190 persons
** N= 292 courses
*** N=18, of the people who have changed positions

individuals had found employment outside of the Utrecht trauma region; therefore the knowledge gained by participation in the OTO activities had been lost to the region. Table 2 shows the difference in the applicability of the crisis management skills gained by OTO activities in the 18 persons who had switched their job; they had engaged in a total of 33 different activities. A decline of over one-third (39%) can be seen in the applicability of the OTO-funded activities in this group.

245 from a total of 292 activities were participated in within the last 3 years and the remaining 47 were undertaken more than 3 years ago (Figure 1). The short follow-up of this study may have contributed to the finding that a large proportion of people are still working in the same job as when they engaged in training.

Table 2. Subgroup people who switched working position

n = 33 courses in 18 people	**Previous position**	**Current position**
Is the course applicable to your position		
Yes	91%	52%
Neutral	6%	18%
No	3%	30%

Figure 1. Time between the survey and the participation in the OTO funded activity

Discussion

To enhance crisis preparedness in the Dutch safety regions, the Dutch government introduced the OTO project in 2008, a temporary project to stimulate the healthcare sector's crisis and disaster preparedness. The consolidation of this knowledge, based on the employment position of the trained staff, has been shown to be sufficient. Currently, over 90% of those who attended activities funded by the OTO project still work in the same position as they did during the training. Of the 18 persons who have left their position, only five people no longer work within the region of Utrecht.

No literature is available regarding the consolidation of knowledge and skills gained by temporary support packages in disaster medicine. The focus is put entirely on how to build the framework for disaster preparedness and crisis management organization. Other countries, such as Sweden and the United States of America, have also implemented government supported programs, but the evaluations did not describe the follow-up performed to maintain the level of disaster preparedness.[4, 11] The available literature on the consolidation of basic life support skills suggest that retention of these skills decreases significantly shortly after training, but is still above pre-training levels at 6–12 months. It should therefore be frequently repeated within this timeframe.[12-14] Medical personnel not frequently involved in resuscitation lost their skills as rapidly as laymen.[15] As with basic life support, training for skills that are required to aid in disaster relief and overall crisis management is frequently required because real life exposure is limited. This supports the need for frequent repetitions and continuous training to consolidate the gained expertise. Analysis of the Advanced Trauma Life Support courses has led to a 4-year repetition cycle to maintain the required level of knowledge and skills. In this study it was shown that knowledge deteriorated by 6 months after the course; the most important principles, however, were retained for some 6 years.[16, 17] Cognitive knowledge was lost more quickly than practical skills and exposure to the subject on a daily basis has been shown to have a positive effect on knowledge retention.[18, 19] The experiences from basic life support and advanced trauma life support underline the importance of a consolidation program to retain the level of knowledge and skills.

Due to the decentralized and therefore occasionally incorrect registration of individuals following activities from the OTO budget, some selection bias can be expected. The program has been in place for over 8 years, however 84 percent of the responders had attended their activities in the last 5 years and our data is therefore based mostly on this group. If a larger response rate from the 5–10-year group was

received, one would expect more participants to have moved to new positions, possibly in different trauma regions or organizations. A factor not accounted for in this study is the number of trained people who have already participated in OTO activities in another region and migrated into the Utrecht trauma region. Not all crisis management activities take place using OTO funding; organizations are requested to invest in activities to guarantee continuity after the eventual stopping of the OTO project.

Future endeavours would benefit from a uniform registration and follow-up of the individuals participating in OTO-funded activities. Correct registration of participants would enable future evaluation to be more effectively organized. The value of registration to support quality improvement programs has been extensively described.[20,21] A fully centralized registry of the OTO activities, including a corresponding centralized database, should be put in place. The centralized registration will not only give a basis for the evaluation of the program, but will also improve adequate repetition of training and keep a continuous track of the state of preparedness and training for crisis management. Since 2014, all individuals taking part in OTO activities are registered.

The optimal situation would be for the crisis management activities to become part of the regular tasks for staff and be incorporated into their job descriptions, with dedicated crisis management budgeting in the human resources process. Future research should focus on the effectiveness and sustainability after 10 or more years of a limited one-time-funded activity as opposed to multiple or frequent training activities. Additionally, future research should identify how to design update courses and activities to account for changing concepts and refreshing old knowledge.
In conclusion, the Dutch OTO project to promote crisis management training has proven to be successful in consolidating knowledge in 91% of the individuals invested in. The 8-year investment program has promoted knowledge, which has mostly remained available to this trauma region. Apart from a temporary care project to improve knowledge, a consolidation program including regular repetition of training activities to retain knowledge and skills is required. Finally, a more detailed registration should be performed in one centralized database to guarantee adequate repetition of training and to keep a continuous overview of the state of preparedness and training for crisis management.

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Chapter 11
Summary and future perspectives

J.J. Mark Haverkort

Summary and future perspective

Major incidents and disasters have occurred since the beginning of time, and will continue to occur in the future. In today's world, with efficiency-driven medical systems and the increasing concern of terrorist threats on urban areas, major incidents, natural disasters, and epidemics, it is necessary to prepare for incidents that can impose a disruptive claim on the emergency response system. The term "preparedness" signifies the level of preparation to cater for the high surge of patients resulting from major incidents and disasters. This calls for a paradigm shift wherein medical professionals are required to do the most for the benefit of the greatest number of patients with limited resources, instead of focusing on the best possible care for a single patient with nearly unlimited resources.

To guarantee an organized response to these injury events, planning, training, and education are of the utmost importance. To improve preparedness, training and the sharing of new concepts and of lessons learned are of great value.

This thesis has focused on the lessons learned and methods to improve preparedness from a hospital viewpoint.

The development of Disaster Medicine as a medical specialty and the importance of preparedness is outlined in **Chapter 1**. It describes the threats that can cause major incidents and disasters, and outlines the challenges for the healthcare system caused by the high surge of victims. In this chapter, the MIH is introduced, which is the basis for most of the research in this thesis.

Part 1 describes new concepts and on-going developments to promote preparedness.

Chapter 2 discusses the preparedness of the healthcare system in Utrecht, The Netherlands. The scenario of a bomb explosion at Utrecht Central Station, the busiest railway station in the Netherlands, is presented and the plans for casualty distribution are discussed. The chapter concludes that a great deal of training, education and simulation is in place in preparation for such an incident. Preparedness is increased by the development of a regional hospital disaster plan and a patient-distribution plan. Furthermore, with the presence of the MIH, the region as well as the nation is equipped with an additional capacity for 200 patients needing immediate care.

Chapter 3 describes the development of "dedicated Mass Casualty Incident (MCI) hospitals." These facilities are built to provide additional stand-by capacity for the healthcare system, and are designed to optimize the registration and treatment of large groups of patients at the same time. The latter remains a challenge, given the lessons learned from various terrorist MCIs in Europe and the USA. Furthermore, the design of different facilities situated in The Netherlands, Italy, and Israel is presented. The functioning of the facilities has to be adapted to local circumstances, likely MCI scenarios, and threats faced. The MCI hospitals described range from providing solutions for short-term surge capacity to catering for long-term hospital under-siege scenarios. However, they all emphasize the need to create similar working practices for medical professionals by keeping procedures and equipment similar to routinely-used resources.

Chapter 4 describes the Patient Barcode Registration System (PBRS) and its 20 years of on-going development. The tool has proven to be a usable, feasible, and sustainable system for patient registration, tracking, and tracing over time. With the help of this system, the MIH is able to provide much-needed information on victims from MCIs to both internal and external parties. The tool can help prevent additional suffering caused by a lack of information about patients and their locations, leading to suboptimal use of resources and uncertainty among relatives. Furthermore, it provides management possibilities with real-time overviews of hospital capacity and patient characteristics. The data gathered by the system can be used to evaluate in detail a hospital's response to patient surge.

Chapter 5 describes a concept study to improve registration of triage categories and enable all medical staff to perform triage sort through a triage registration form to be used in the ambulance bay of hospitals in times of MCI response. The form has been designed in cooperation with involved professionals and has been implemented on four occasions. In staff surveys on such occasions, the form was judged to be clear, easy to use, and of added value during MCI circumstances.

Chapter 6 extends the design of registration forms to a pilot Disaster Medical Record (pDMR). The results confirm the lack of documentation during MCIs. Although patient documentation is secondary to treatment of the wounded, it is essential to ensure correct continued care; in addition, such documentation constitutes an important legal document. A one-page pDMR was developed as an alternative to the over-complicated and extensive primary survey form. The pDMR was tested during a MCI drill and compared to the regular record-keeping during a MCI. The pDMR has led to

significantly increased registrations of primary survey data (p = 0.001). It was noted that 89% of the pDMR forms contained information, whereas the previous medical records only contained information on the primary survey in 61% of the forms. In subgroup analyses of the patient categories, the new pDMR form was significantly more frequently used in T1 (p = 0.013) and T2 (p = 0.000) patients. A golden rule concerning MCI is to keep it simple and concise and do not change the daily routine for medical staff. This concept study underlines that this golden rule should also be applied to medical-record keeping. Following these results, a complete Disaster Medical Record was developed for the MIH. Future studies involving larger sample sizes should now be undertaken using this record.

Part 2 evaluates several deployments and preparations for disaster relief.

Chapter 7 describes the way the crisis organization of the MIH increased preparedness for an infectious disease scenario. The Ebola virus outbreak in Western Africa was reason for the MIH to prepare itself to receive international military and healthcare personnel who worked in the affected area. Within 3 months an extensive training program was set up for staff and necessary adaptations to infrastructure were made. In December 2014 an international soldier with confirmed Ebola Virus Disease was treated in the MIH. The preparations made prior to and the lessons learned during the admission of this patient confirmed the necessity of clear and practical protocols, a buddy system and intensive staff training, all of which increase the safety of healthcare workers. The demand on resources to treat viral haemorrhagic fever, such as Ebola virus disease, infected patients proved high and could lead to understaffing of other departments at the expense of other patients. The availability of a dedicated major incident hospital has greatly increased the resources and preparedness of our medical centre.

Chapter 8 evaluates three events wherein a hospital was fully or partially evacuated to the MIH. Two of these events concerned true deployments; the other was a MCI drill. These events were evaluated based on a standardized protocol, and the real events were compared to the MCI drill to judge the adequateness of our training. The MCI exercise proved a great benchmark for medical response in the acute phase of medical relief. However, it is difficult to train and measure the performance after the acute phase. Moreover, IT systems should be tested in their regular production modes. In our experience, a successful operation in test environments does not guarantee a successful use during live events. The MIH demonstrated to be highly prepared to admit an entire evacuating hospital or large groups of patients in such

a scenario. The legal implications to allow staff of an evacuating hospital to work in another hospital need to be protocolled in advance.

Chapter 9 introduces a novel concept for evaluation. Currently, evaluation is performed three-dimensionally: by means of surveys, external video images, and observers. Through the use of point of view cameras filming from mock patients' heads, we aimed to add a fourth dimension to capture the patient's perspective during a MCI drill. After an initial drill, a protocol was designed to judge the hospital system's performance during MCI drills, based on footage from the patients' perspectives. During a second drill, the feasibility of the technique as an adjunct to the traditional evaluation methods was studied. New insights were gained from this perspective, which were not obtained through traditional surveys, observers, and video footage. The use of point of view video evaluation can be a valuable addition to medical training. Protocols should be used to judge footage, and future studies should expand on additional possibilities.

Chapter 10 discusses the suitability of a temporary stimulus package to promote the preparedness of the healthcare sector under extraordinary circumstances. The Dutch government implemented such a stimulus package in 2008. In this study, we questioned whether a temporary package would be effective in promoting preparedness, owing to job migration of trained personnel; however, our survey showed that only 9% of the respondents had switched work positions and only 5% had migrated out of the trauma region which catered for the training activities. The eight-year investment program has thus promoted knowledge, which has mostly stayed available to the trauma region. However, in the long run, there needs to be investment in a consolidation program to retain the knowledge and skills of both the individual and the response system. Furthermore, centralized registration should be performed in order to guarantee adequate repetition of training and keep track of the state of preparedness and training of crisis management.

Future perspectives

The threat of disasters has always existed and will continue to do so in the future; in particular, MCIs in urban areas, though still rare, are of increasing concern worldwide.[1-3] Since its establishment as a medical specialty, Disaster Medicine has gained expertise and enhanced knowledge over a number of years; experiences are shared and lessons learned are implemented worldwide. With the increasing frequency of terrorist attacks on major cities, the development of new strategies as well as the optimization of existing strategies is of great importance in order to be

able to handle the patient surge emanating from these incidents. The paradigm shift in which the care is focused on the benefit to the greatest number of people instead of to the individual has now been well established. Preparedness has to start before an actual incident occurs.[4] Careful planning, with design of new systems, training programs, and education, needs to be integrated into daily practice. The challenge is to continuously optimize preparedness and to engage healthcare professionals, despite the infrequent exposure to MCIs.

The challenges that healthcare systems face from major incidents and disasters have changed. Due to the advancement of cost-effectiveness in care, the reserve capacity needed to handle the patient surge from an incident no longer exists. This poses the question of whether there should still be a difference in approach between multiple casualty events and MCIs. Considering the number of victims from the 2015 Paris terrorist attacks, the incident could be classified as a multiple casualty event. However, considering the disruption to and suffering of the healthcare system and society, it was unarguably a MCI. The Nepalese and Haitian earthquakes were MCIs or disasters, given the lack of advanced healthcare systems in these countries. The global definitions in Disaster Medicine are applicable to all countries of the world. However, judgment is greatly dependent on a country's preparedness for such incidents. Through the introduction of the Sendai framework, the United Nations has taken an important role in international disaster reduction and in the global improvement of preparedness.[3]

Different countries face different threats. However, the lessons learned from incidents are applicable to other healthcare systems. The construction of dedicated MCI hospitals has been based on the problems that arise during an MCI response. These hospitals are equipped with an extra stand-by capacity to handle the number of patients involved during a patient surge. Furthermore, they have optimized resources such as ventilators and operating theatres, the critical resources required for an MCI response.[5] The main difference in the missions of individual MCI hospitals is whether they tend to respond to the acute phase of isolated incidents or act as a longer-term hospital during under-siege scenarios.

One of these MCI hospitals is the MIH in the Netherlands, which has been optimizing preparedness for incidents during the past 25 years, based on a unique civilian–military cooperation.[6] This cooperation, combined with the partnership with the National Poison and Information Centre, guarantees a high level of expertise to respond to different types of incidents and trauma mechanisms, including chemical, biological, radiological, and nuclear incidents, in addition to blast injuries.

With the MIH, the resilience of the Dutch healthcare system is greatly improved. The optimization of the operating procedures of the MIH has increased preparedness to a level wherein after a 30-minutes deployment time, a surge of 200 patients can be dealt with. The development of the MIH does not stop here; the centre is a focus of expertise with the experience of 25 years of preparing for such incidents. The civilian–military knowledge, combined with the expertise of other partners, is the basis for further developments to optimize preparedness.

In the chaos of an MCI, official information is generally available at a slower rate than is demanded by society at large. The internet provides information much more quickly, but at the cost of reliability. During the attacks in Paris and Brussels, social media provided a platform for people located close to the scenes; with the press of a single button, they could confirm that they were unharmed in the incident.[7] However, information on the victims emerged slowly, partially due to lack of registration. Government agencies should be able to receive updates on the numbers of victims and their corresponding injuries, to keep the public better informed. Future developments in MCI preparedness should include additional integration of information systems in order to optimize registration and tracking of patients both pre-hospital and in-hospital. The PBRS has already been proven to aid considerably in these efforts. Further development of systems using uniform normalized barcodes both pre-hospital and in-hospital would further assist significantly in these achievements. One single uniform system to trace, register, and document patients can promote preparedness in multiple respects. Such a system could be designed as a cell phone application and made easily and widely available to the professionals. With the availability of smartphones and widespread cellular data services, no further dedicated devices will be needed. An easy-to-use application could also aid in the triage of patients by staff other than medically-trained professionals.

Working under MCI conditions is very demanding on healthcare professionals. To help healthcare professionals to function at an optimal level, work should be as similar as possible to their daily routines. This is, by design, the policy of the MIH. All supplies, machines, and procedures are the same as in the UMC Utrecht. Therefore, the medical professionals work according to routine principles, though under special circumstances. Consequently, the majority of medical staff can carry out duties that are as similar as possible to their daily routines in medicine, nursing, or other supporting functions. Additionally, a number of carefully selected key-players are regularly trained in order to gain the right skills to assume coordinating functions during deployment.
Due to the lack of adequate exposure to MCIs, it is of great importance to maintain

knowledge and skills up-to-date at both the operational and strategic levels. Because engaging personnel has previously proven difficult, a targeted stimulus package has been introduced in the Netherlands to promote training and awareness. In order to successfully engage staff, they should be encouraged to take up a position in the crisis-organization that is in line with their daily activities and responsibilities. Adequate training through simulation tools and international courses such as the Medical Response to Major Incidents (MRMI) course has shown to increase awareness and knowledge among personnel.[8] The benefit of the MRMI doctrine is that the whole medical chain is trained together, instead of there being separate training for individual components in separate courses. In the end, no chain is stronger than its weakest link; and this emphasizes the importance of large-scale training with every discipline involved, so that interdisciplinary perspectives are shared and understood effectively.

In conclusion, the threat of natural and manmade MCIs will continue to exist. Knowledge from civilian and military organizations needs to be combined so as to guarantee expertise in Disaster Medicine. Preparedness for MCIs is a necessary and dynamic process of continued optimization based on research, training, and lessons learned. Integration of systems must be performed across the entire medical chain, and staff should be encouraged to participate in preparedness. In order to promote preparedness, training and education is essential and should be kept up-to-date.

Disaster Medicine is the medical specialty developed to cope with manmade and natural disasters that involve a large number of victims. The Utrecht MIH is the centre of expertise in the Netherlands and the facility that guarantees "Preparedness" and optimized care in the event of major incidents and disasters.

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Summary and future perspectives in Dutch (Samenvatting en toekomstvisie)

11

Grootschalige incidenten en rampen vinden plaats sinds het begin der tijden en zullen ook in de toekomst blijven plaatsvinden. De huidige medische systemen zijn gebaseerd op efficiënte zorg met slechts beperkte reservecapaciteit voor niet geplande zorg. Het is noodzakelijk om voorbereid te zijn op de stijgende dreiging van grootschalige incidenten welke een zorgsysteem ernstig kunnen verstoren, zoals terroristische aanslagen op steden, natuurrampen en epidemieën. "Paraatheid" duidt het niveau van voorbereidheid aan om een groot aanbod van patiënten van grootschalige incidenten en rampen op te kunnen vangen. Een verandering van paradigma is hierbij noodzakelijk, waarbij medici en paramedici zo veel mogelijk moeten doen, met beperkte middelen, voor de grootste groep slachtoffers in plaats van de focus te leggen op de beste zorg voor het individu met een ongelimiteerde hoeveelheid middelen.

Om zeker te zijn van een goed georganiseerde respons op zulke incidenten zijn planning, training en educatie noodzakelijk. Om paraatheid te bevorderen zijn training en informatie uitwisseling op het gebied van nieuwe concepten en verworven inzichten van het grootste belang.

Dit proefschrift legt de focus op de nieuwe inzichten en methoden om de paraatheid voor grootschalige incidenten en rampen van ziekenhuizen te bevorderen.

De ontwikkeling van de rampenopvang als medische discipline en het belang van paraatheid worden beschreven in **Hoofdstuk 1**. Waarbij ook de uitdagingen voor het zorgsysteem worden benoemd die ontstaan door de grote en acute toestroom van slachtoffers. Het Calamiteitenhospitaal, waar de basis is gelegd voor het grootste deel van dit proefschrift, wordt beschreven.

Deel 1 beschrijft nieuwe concepten en lopende ontwikkelingen om paraatheid te optimaliseren.

Hoofdstuk 2 richt zich op de paraatheid van het zorgsysteem in de regio Utrecht. Aan de hand van een scenario met een bomaanslag op het Centraal Station van Utrecht worden de respons en het principe van gewondenspreiding beschreven. Opleiding, training en oefening zijn noodzakelijk ter voorbereiding op een dergelijk incident. De paraatheid in de regio Utrecht is verhoogd door de introductie van een regionaal ziekenhuis rampen opvang plan en gewondenspreidingsplannen. Daarnaast beschikt Nederland, met het Calamiteitenhospitaal, over een extra reservecapaciteit voor 200 patiënten welke binnen 30 minuten beschikbaar is.

Hoofdstuk 3 beschrijft de ontwikkeling van speciale ziekenhuizen die enkel ingezet worden voor grootschalige incidenten, de zogenoemde calamiteitenhospitalen. Deze faciliteiten worden gebouwd om extra stand-by capaciteit te garanderen voor een zorgsysteem en zijn ontworpen om grote groepen patiënten te registeren en behandelen in een korte tijd. Dit laatste blijft een uitdaging, zo blijkt uit verworven inzichten na diverse terroristische aanslagen in Europa en de Verenigde Staten van Amerika. Het verschil in ontwerp van calamiteitenhospitalen uit Nederland, Italië en Israël wordt beschreven. Het ontwerp en de functionaliteit van deze calamiteitenhospitalen dienen te worden aangepast aan de lokale omstandigheden en de te verwachten dreiging van grootschalige incidenten. De beschreven calamiteitenhospitalen verschillen van korte termijn oplossingen voor acute toestroom van grote groepen patiënten, tot lange termijn oplossingen voor langdurige conflicten en oorlogssituaties. In alle centra worden de werkzaamheden zo veel mogelijk gelijkgesteld aan de dagelijkse praktijk. Door middel van overeenkomstige procedures en apparatuur kunnen de medische professionals zo veel mogelijk routineus blijven werken.

Hoofdstuk 4 stelt het Patiënten Barcode Registratie Systeem (PBRS) en de voortdurende ontwikkeling van het systeem in de afgelopen 20 jaar centraal. Het PBRS heeft over de jaren bewezen een bruikbaar en duurzaam systeem te zijn als slachtoffervolgsysteem en garandeert een goede registratie van patiënten. Met behulp van dit systeem kunnen interne en externe partners effectief voorzien van belangrijke informatie over slachtoffers. Deze informatievoorziening helpt bovendien middelen effectiever in te zetten en voorkomt onduidelijkheid bij familieleden over de locatie van hun naasten. Daarnaast levert het systeem belangrijke informatie voor interne coördinatoren door middel van real-time overzichten van de ziekenhuiscapaciteit en overzichten van slachtoffer karakteristieken. Evaluatie van de respons op een incident worden verricht middels analyse van de data uit dit systeem.

Hoofstuk 5 beschrijft de ontwikkeling van een triage registratieformulier voor patiënten bij een grootschalig incident. Het formulier stelt iedere medicus in staat om *triage sort* uit te voeren, ook zonder scholing. Het formulier bestaat uit één pagina en is ontwikkeld in samenspraak met betrokken professionals en tijdens vier gelegenheden gebruikt en geëvalueerd. Uit een enquête onder de medische staf is gebleken dat het formulier helder, gebruiksvriendelijk en van toegevoegde waarde is tijdens de opvang van grote groepen slachtoffers.

In **Hoofdstuk 6** wordt het ontwerp van registratieformulieren verder besproken aan de hand van een pilotstudie ter ontwikkeling van een patiënten status specifiek voor rampenopvang, het "pilot Disaster Medical Record" (pDMR). De resultaten tonen een evident gebrek aan documentatie van medische gegevens tijdens de rampenopvang. Hoewel statusvoering secundair is aan de behandeling van de slachtoffers, is het van essentieel belang voor goede zorg en een wettelijke verplichting. Het pDMR van één pagina is ontwikkeld om gebruikt te worden tijdens de traumaopvang en vergeleken met de bestaande, gecompliceerde en uitgebreide status. Het pDMR is getest tijdens een grootschalige oefening in het Calamiteitenhospitaal en vergeleken met de reguliere status tijdens een daadwerkelijke openstelling. Op het pDMR is significant meer data van de trauma opvang genoteerd ($p = 0.001$). In 89% van de gevallen bevatte het pDMR informatie, tegen 61% in de reguliere status. Subgroep analyse toont aan dat met name bij de T1 ($p = 0.013$) en T2 ($p = 0.000$) patiënten significant meer werd geregistreerd in de status. Tijdens rampenopvang geldt de norm dat alles zo eenvoudig mogelijk gemaakt moet worden. Dit blijkt ook van toepassing op medische statusvoering. Op basis van deze resultaten is een volledig "Disaster Medical Record" ontworpen voor alle stadia van de rampenopvang in het Calamiteitenhospitaal. Verdere studies met grotere groepen moeten worden gedaan om deze specifieke status te valideren.

Deel 2 evalueert verschillende inzetten van het Calamiteitenhospitaal en de voorbereidingen voor de rampenopvang.

Hoofdstuk 7 beschrijft hoe de crisisorganisatie van het Calamiteitenhospitaal de paraatheid heeft verhoogd voor het infectieziekten scenario. Na de uitbraak van het Ebola virus in West-Afrika heeft het Calamiteitenhospitaal zich voorbereid om internationaal militair en medisch personeel uit het aangedane gebied op te kunnen vangen in Nederland. Binnen drie maanden is een uitgebreid trainingsprogramma opgezet voor personeel en zijn noodzakelijke aanpassingen aan de infrastructuur gerealiseerd. In december 2014 werd een internationale militair met een bevestigde besmetting met het Ebola virus behandeld in het Calamiteitenhospitaal. De voorbereidingen op deze casus en de verworven inzichten naderhand bevestigen de noodzaak van praktische protocollen, een buddy systeem en intensieve training van personeel, om de veiligheid van zorgpersoneel te garanderen. De behoefte aan middelen om patiënten met een virale hemorragische koorts, zoals besmetting met het Ebola virus, te behandelen is hoog gebleken en zou kunnen leiden tot personeelstekorten op andere afdelingen. Dat zou ten koste gaan van de reguliere patiëntenzorg. De beschikbaarheid van een volledig geëquipeerd

calamiteitenhospitaal heeft sterk bijgedragen aan de beschikbaarheid van middelen en paraatheid van dit medisch centrum.

Hoofdstuk 8 evalueert drie situaties waarbij een ziekenhuis geheel of gedeeltelijk naar het Calamiteitenhospitaal is geëvacueerd. In twee gevallen betrof het een daadwerkelijke openstelling, in één geval een grootschalige oefening. Middels een gestandaardiseerd protocol zijn de inzetten geëvalueerd en vergeleken met de grootschalige oefening om de adequaatheid van de training te evalueren. De grootschalige oefening bewees een goede referentie te zijn voor de acute fase van de rampenopvang. Het is echter moeilijk om het functioneren na de acute fase te trainen en te meten. Daarnaast moeten IT-systemen in de reguliere productieomgevingen worden getest. In onze ervaring is een succesvolle werking in testomgevingen geen garantie voor een goede werking tijdens daadwerkelijke inzetten. De juridische procedure om personeel uit een evacuerend ziekenhuis te laten werken in het ontvangende ziekenhuis dient vooraf te worden vastgelegd. Het Calamiteitenhospitaal heeft aangetoond goed voorbereid te zijn om een geheel ziekenhuis of grote groepen patiënten te ontvangen tijdens een evacuatie scenario.

Hoofdstuk 9 introduceert een nieuw concept voor evaluatie van grootschalige incidenten. Evaluatie omvat doorgaans drie dimensies: middels enquêtes, externe videobeelden en observatoren. Door middel van het gebruik van actie camera's, filmend vanaf het hoofd van de patiënt, werd een vierde dimensie hieraan toegevoegd: het perspectief van de patiënt. Na een eerste inzet tijdens een grootschalige oefening is een protocol opgesteld om het functioneren van het ziekenhuis systeem te meten door gebruik van de beelden uit het perspectief van de patiënt. Gedurende een tweede oefening is de uitvoerbaarheid en haalbaarheid van de techniek als toevoeging aan de traditionele evaluatiemethoden bestudeerd. Nieuwe inzichten, welke niet middels traditionele evaluatiemethoden zijn opgemerkt, werden verkregen uit het beeld vanuit het patiënten perspectief. Het gebruik van deze actie camera's kan dus een waardevolle aanvulling zijn bij medische training. Toekomstige studies zouden zich moeten richten op aanvullende mogelijkheden voor de inzet van deze evaluatietechniek buiten de rampenopvang.

Hoofdstuk 10 bediscussieert de geschiktheid van een tijdelijk financieel stimuleringspakket ter bevordering van de paraatheid voor crises in de gezondheidszorg. In 2008 heeft de Nederlandse overheid het Opleiden, Trainen, Oefenen (OTO) project hiertoe geïmplementeerd in de Nederlandse veiligheidsregio's. In deze studie is beoordeeld of een tijdelijk financieel stimuleringsproject effectief is

in het duurzaam verhogen van de crisis paraatheid, gezien mogelijke uitstroom van getraind personeel. Uit een enquête onder deelnemers aan activiteiten gefinancierd uit het stimuleringspakket bleek dat slechts 9% van de deelnemers van baan is veranderd, 5% van de deelnemers heeft werk gevonden buiten de veiligheidsregio waarin de opleiding heeft plaatsgevonden. Het acht jaar durende investeringsprogramma heeft de kennis in de regio bevorderd en deze kennis is grotendeels beschikbaar gebleven in de veiligheidsregio. Op de lange termijn moet er echter gewerkt worden aan de consolidatie van de kennis en vaardigheden. Gecentraliseerde registratie dient plaats te vinden om adequate herhaling van training te garanderen en om een overzicht te houden van de paraatheid en training in de crisisbeheersing.

Toekomstperspectieven

De dreiging van rampen heeft altijd bestaan en zal in de toekomst voortduren. Grootschalige incidenten in stedelijke gebieden, hoewel zeldzaam, vormen wereldwijd een groeiende reden van bezorgdheid.[1-3] De rampenopvang heeft in de afgelopen jaren kennis en expertise opgedaan; ervaringen en verworven inzichten worden wereldwijd gedeeld en geïmplementeerd. Met de toenemende frequentie van terroristische aanslagen op grote steden, is zowel de ontwikkeling van nieuwe als de optimalisatie van bestaande strategieën van groot belang om de patiëntenstroom te kunnen verwerken. De verandering van paradigma waarbij de zorg zich tijdens deze gebeurtenissen richt op het welzijn van het grootste aantal patiënten in plaats van het individu is inmiddels vastgesteld. Paraatheid moet geoptimaliseerd zijn voor een incident plaatsvindt.[4] Zorvuldige voorbereiding, middels ontwikkeling van nieuwe systemen, trainingsprogramma's en educatie moeten geïntegreerd worden in de dagelijkse praktijk. De uitdaging is om voortdurend de paraatheid te optimaliseren en de zorgprofessionals daarin te blijven betrekken, ondanks de zeldzame blootstelling aan grootschalige incidenten.

De voorbereiding op rampen en grootschalige incidenten is door de jaren heen veranderd. Door de toename van kosteneffectiviteit in de zorg is de reservecapaciteit, waarmee een plotselinge toename in zorgvraag kan worden opgevangen, niet langer beschikbaar. Hiermee is de scheiding tussen incidenten met enerzijds een grote of anderzijds een massale toestroom van patiënten geleidelijk verdwenen. Gezien de patiënten aantallen kunnen de aanslagen in Parijs van 2015 omschreven worden als grootschalige incidenten met grote toestroom van slachtoffers, een massale toestroom van slachtoffers is echter uitgebleven. Indien echter de impact op het zorgsysteem in Parijs in beschouwing wordt genomen, moet de respons geclassificeerd worden als een massale toestroom van slachtoffers. De aardbevingen in Nepal en Haïti hebben

de impact van een ramp gehad door het ontbreken van geavanceerde zorgsystemen. Hierbij zijn de definities uit de rampenopvang wereldwijd van toepassing, echter de benaming is afhankelijk van de paraatheid van een land en haar zorgsysteem voor incidenten. Door middel van de introductie van het *Sendai framework* hebben de Verenigde Naties internationaal een belangrijke stap gezet in de bestrijding van rampen en de globale paraatheid.[3]

Met het verschil in dreiging van rampen en incidenten, verschilt ook de voorbereiding hierop per land. Verworven inzichten na een ramp kunnen echter op ieder zorgsysteem worden toegepast. Het ontwerp van calamiteitenhospitalen is gebaseerd op de belangrijkste knelpunten in de behandeling van patiënten bij grootschalige incidenten. Deze ziekenhuizen beschikken over extra stand-by capaciteit om een grote toestroom van patiënten te kunnen verwerken. Daarnaast zijn kritische middelen, zoals beademingsapparatuur en operatiekamers, optimaal beschikbaar.[5] Het grootste verschil tussen de diverse calamiteitenhospitalen is of zij zijn ontworpen voor de acute fase van geïsoleerde incidenten of dat zij een rol dienen voor lange termijn conflict scenarios.

Het Calamiteitenhospitaal in Utrecht, een civiel-militaire samenwerking, heeft over de afgelopen 25 jaar voortdurend haar paraatheid geoptimaliseerd.[6] Deze samenwerking, in combinatie met het partnerschap met het Nationaal Vergiftigingen Informatie Centrum, garandeert beschikbare expertise. Conventionele traumamechanismen, maar ook blast letsels en Chemisch, Biologisch, Radioactieve en Nucleaire (CBRN) mechanismen behoren tot de domeinen van paraatheid. Middels de beschikbaarheid van het Calamiteitenhospitaal is het Nederlandse zorgstelsel extra weerbaar tegen deze scenarios. De optimalisatie van de procedures binnen het Calamiteitenhospitaal hebben de paraatheid dusdanig verhoogd dat het ziekenhuis 30 minuten na alarmering beschikbaar is om 200 patiënten te ontvangen. De ontwikkeling van het Calamiteitenhospitaal gaat echter verder, het is een expertise centrum op basis van de 25 jaar ervaring in rampenopvang en optimalisatie van paraatheid. De civiel-militaire kennis en samenwerking, gecombineerd met de expertise van overige partners is de basis waarop paraatheid in de toekomst voortdurend verder zal worden uitgebouwd.

De informatievoorziening via officiële kanalen komt langzaam op gang tijdens een grootschalig incident, terwijl de samenleving deze steeds sneller eist. Het internet voorziet in deze informatiebehoefte, vaak ten koste van de betrouwbaarheid. Tijdens de aanslagen in Parijs en Brussel hebben de sociale media echter een belangrijke rol vervuld. Op basis van hun locatie kregen mensen, in de nabijheid van het

incident, via hun smartphone de mogelijkheid om aan te geven dat ze veilig waren.[7] Informatievoorziening met betrekking tot de slachtoffers verliep echter traag, mede door het gebrek aan registratie. Overheidsinstanties zouden de beschikking moeten hebben over gegevens van aantallen slachtoffers en hun verwondingen om de samenleving snel en correct te informeren. Toekomstige ontwikkeling op het gebied van paraatheid dient zich te richten op systemen ter bevordering van registratie en het volgen van slachtoffers en de integratie hiervan zowel pre- als in-hospitaal. Het Patienten Barcode Registratie Systeem heeft bewezen bij te dragen aan dergelijke ontwikkelingen. Ook verdere toepassing van systemen op basis van geüniformeerde barcodes over de gehele medische keten zou significant bijdragen. Een centraal en uniform systeem om patienten te registreren, volgen en documenteren is een waardevolle toevoeging aan de paraatheid. Met de beschikbaarheid van smartphones en mobiele data netwerken is het mogelijk om systemen als mobiele applicaties toe te gaan passen. Hierdoor vervalt de noodzaak voor extra apparatuur. Een simpele applicatie welke niet-medici begeleidt in de triage kan het proces verder bevorderen.

Goed functioneren tijdens een grootschalig incident vergt veel van zorgverleners. Om deze impact te minimaliseren moet het werk tijdens een grootschalig incident zo veel mogelijk aansluiten bij de dagelijkse praktijk. Het ontwerp van het Calamiteitenhospitaal is hierop gebaseerd. Alle middelen, apparatuur en procedures zijn gelijk aan het UMC Utrecht. Een selecte groep medewerkers wordt regelmatig getraind om een coördinerende sleutelrol te vervullen tijdens een openstelling. Hierdoor kan de grote groep zorgprofessionals routineus werken onder bijzondere omstandigheden.

Gezien de geringe blootstelling aan grootschalige incidenten is het van groot belang om op operationeel en strategisch niveau kennis en kunde te onderhouden. In het verleden is het engageren van personeel een kritisch punt gebleken. Een gericht financieel steunpakket werd reeds opgezet door de Nederlandse regering om het bewustzijn aangaande en de training in de crisisbeheersing te verbeteren. Professionals moeten worden gestimuleerd om een rol in de crisisbeheersing op zich te nemen welke aansluit bij hun dagelijkse activiteiten en verantwoordelijkheden. Goede training door middel van simulatiemiddelen en internationaal gecertificeerde cursussen, zoals de "Medical Response to Major Incidents" (MRMI), hebben bewezen de bewustwording en de kennis onder professionals te doen toenemen.[8] De MRMI doctrine traint de gehele medische keten tezamen, in plaats van de conventionele aanpak waarbij ieder onderdeel apart traint of getraind wordt. Uiteindelijk is geen enkele keten sterker dan de zwakste schakel. Hetgeen eens te meer benadrukt dat

training grootschalig en met iedere betrokken discipline plaats dient te vinden, opdat perspectieven effectief en interdisciplinair worden gedeeld en begrepen.

Concluderend zal de dreiging van antropogene en natuurrampen blijven bestaan. Kennis en kunde van civiele en militaire organisaties dienen gebundeld te worden om de expertise in de rampenopvang te optimaliseren. Paraatheid in de rampenopvang is een noodzakelijk en dynamisch proces van voortdurende optimalisatie gebaseerd op onderzoek, training en verworven inzichten. Integratie van systemen en procedures dient plaats te vinden in de gehele medische keten en staf moet worden geëngageerd om deel te nemen in de voorbereidingen en paraatheid. Om paraatheid te optimaliseren zijn training en educatie van essentieel belang, evenals het bijhouden van vaardigheden, kennis en kunde.

De rampenopvang is een medische discipline, ontwikkeld om optimaal te reageren op antropogene en natuurrampen waarbij veel slachtoffers betrokken zijn. Het Calamiteitenhospitaal in Utrecht is het Nederlandse expertisecentrum en een faciliteit welke paraatheid en geoptimaliseerde zorg garandeert in het geval van een grootschalig incident of ramp.

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Curriculum Vitae Auctoris

Johan Joseph Mark Haverkort was born in Harderwijk on the 11th of March 1987. After graduating from Praedinius Gymnasium college (Groningen, the Netherlands) he moved to Italy to study Italian Language and Culture at the Università per Stranieri in Perugia. The next year he attended Law school at the University of Groningen. In 2011 he was enrolled in the Medical School at the University of Groningen, the Netherlands. For the final year of his studies he went to the University Medical Centre in Utrecht under supervision of dr. K.J.P. van Wessem and prof.dr. L.P.H Leenen. In September 2014, he started his PhD with the subject of mass casualty incident preparedness under the supervision of prof.dr. L.P.H. Leenen. During his research he became licensed instructor of the International Medical Response to Major Incidents and Hospital Major Incident Management and Support courses. From January 2017, Mark will start his surgical training at the Jeroen Bosch Hospital 's-Hertogenbosch under the supervision of dr. K. Bosscha and the University Medical Centre Utrecht under the supervision of prof.dr. M.R. Vriens.