Brace for impact! A thesis on medical care following an airplane crash
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Chapter 5

Preparing for mass casualty incidents and disasters Part 1: A proposal on how to determine hospitals’ critical treatment capacity

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Introduction

Definition of a Multiple Casualty Incident: A hazardous impact with as many casualties in which the available organizational and medical resources, or their management systems, are severely challenged. (1)

Triage Categories: In case of a Mass Casualty Incident (MCI), casualties are triaged at the scene following the critical/ immediate (P1), serious/urgent (P2), minor/ delayed (P3) triage classification according to the Triage Sieve and Sort system used by the MIMMS (Major Incident Medical Management and Support). (2)

Recent disasters such as the 2004 Madrid and 2005 London bombings, Hurricane Katrina in 2005, or the Japanese earthquake and tsunami in 2011, had a major impact and received worldwide attention. However besides these disasters, large scale accidents with multiple casualties happen more often. In 2013 at least 9 major railway accidents in Europe were reported that resulted in injuries to 6 to as many as 200 people at a time. (3) The World Health Organization’s regional office for Europe reported 636 major (man-made) accidents from 1990-2012; either industrial or transport accidents. In these accidents 17,910 people died and they affected 105,865 people. (4) Since 2000, the Netherlands has had an average of 13 major incidents (involving ≥10 injured casualties) a year, with a peak of 19 accidents in 2003 and a peak of 945 people injured and 21 deaths in one incident in 2001. (5) In the Netherlands multiple or mass casualty incidents (MCI’s) happen on a monthly basis.

Medical Management of MCI’s starts with triage of the injured, and their evacuation to medical facilities. When allocating casualties to the right medical facilities, it is important to know the number of casualties and the grade of injury a specific hospital can accommodate for diagnosis and treatment. Historically, triage and casualty distribution was based on the adage “the greatest good for the greatest number of people”. (6) Nowadays, in many MCI’s in the developed world, there is an abundance of highly specialised medical care. We may therefore expect the same high level care for MCI casualties as for those in daily medical care.

After the airplane crash near Amsterdam in 2009, the Medical Research Turkish Airlines Crash (MOTAC, Dutch acronym) study group investigated the triage and patient distribution in this MCI. We learned that pre-hospital personnel and commanding emergency service officers were not fully acquainted with the
patient distribution protocol (PDP), and found that the foundation of the PDP was inadequate. (7-9) The research into the events of this airplane MCI and the PDP in use (at the time of the crash) identified several questionable aspects. These aspect involved hospitals’ treatment capacity for MCI’s and the patient distribution principles (box 1).

**Box 1:** Issues of concern in patient distribution after the February 2009 airplane crash near Amsterdam

1. Different interpretations and definitions are used to indicate hospitals’ treatment capacity.
2. The hospitals’ capacity number is based on the outdated and irrelevant number of hospital beds.
3. The protocol allows hospitals to be utilized to their maximum capacity before allocating casualties to another hospital.
4. After the 2009 crash patients were distributed to too many different hospitals and over a large area. Some nearby hospitals (several of which had created extra capacity) were hardly or not utilized at all.
5. Pre-hospital personnel (medical officers, coordinators and ambulance personnel) were insufficiently or not acquainted with the patient distribution protocol.

In two chapters, a new concept for a PDP is presented. The concept is written from a medical point a view and is designed to support government and Emergency Services in their task to coordinate patient distribution after an MCI.

In this chapter we propose a model to calculate the capacity of hospitals to receive, diagnose and treat trauma victims in MCI’s. This number is called the Critical Care Capacity (CCC). Although many national and international documents can be found on hospitals’ preparation for MCI and disasters, we could not find protocols on how Critical Care Capacity is calculated. (10-13)

The next chapter proposes a design of a patient distribution plan for a high risk area, allocating the right number of patients to the right hospitals. Although the location of an MCI or disaster cannot be predicted, some areas can be appointed as high risk. These are for example airports, train stations, business complexes, and chemical industry locations. With pre-designed patient distribution plans for these areas, ad hoc decision making can be reduced.
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Principles of patient distribution

These principles are derived from the research literature and experiences from previous MCI’s or disasters. (7-9;14-18)

1. The Critical Care Capacity (CCC) of a hospital should be calculated using the same formula in every hospital, considering, among other things, numbers of trained personnel, and the presence of adequate facilities and sufficient equipment.

2. During the patient distribution phase of an MCI, distribution of casualties among several hospitals must be performed from the start.

3. P1 casualties (casualties triaged as critical with first transport/treatment priority) should preferably only be distributed to trauma centres (in the Netherlands, Level I and II hospitals). Only when there is a threat of exceeding the Critical Care Capacity (CCC) in the region and the other trauma centres are too far, can Level III hospitals (basic trauma care) be considered for the resuscitation and stabilization of P1 casualties.

4. Secondary transfers should preferably be minimised by taking the hospital’s designated trauma care level (Level I, II, III) and specialisation (e.g. burns, neuro-trauma) into account in the first patient distribution phases.

5. Under-triage among P3 casualties is to be expected. Certain types of incidents can result in such trauma mechanisms that everyone who has been involved is entitled to be screened at the hospital for injury. When the incidence is of such a magnitude that all relatively close hospitals are in danger of being overwhelmed, minimally injured casualties can be screened and treated for their injuries by less specialised and less equipped medical facilities; e.g. a general practitioners’ post or a casualty clearing station set up near the accident site.

6. Ambulance personnel are expected to be back at the incident site as soon as possible to pick up the next casualty. However transportation should not be solely to the nearest hospital. It is the task of a (pre-assigned) Patient Distribution co-ordinator (PDC) to manage adequate patient allocation among the appointed hospitals.

7. Recurrent training and drills among all professionals involved in MCI’s are necessary to maintain experience and knowledge.
Phases in Mass Casualty Incidents

In MCI trauma care, rapid stabilisation and evacuation of the patient to the right medical facility is seen as essential, but the exact maximum allowed pre-hospital time is subject to debate. (19) Systems and protocols should be designed in order to achieve in hospital treatment of P1 and P2 casualties as soon as possible. In case of a large MCI, hospitals will be asked to create extra treatment capacity, e.g. by activating their MCI/disaster protocol. This ‘up-scaling’ takes time; with a good protocol and training this may take about an hour. In this first hour some casualties will already arrive at the hospital. Ideally this should mainly be P1 casualties, but will probably involve ‘walking wounded’ arriving by themselves (not by ambulance).

After preparation, most casualties will be arriving in hospital. At the end there is time to treat minor injuries and redistribute casualties if necessary. Based on our principles of trauma care in MCI’s we have designed 3 phases of casualty management in MCI’s.

**Phase 1**

Phase 1 starts when the incident is reported to the Emergency Services Centre (ECS) and the level of response is defined. The level of response is based on incident type and an estimated number of casualties. It refers to the number of ambulances and Helicopter Emergency Services (HEMS, Dutch acronym MMT) that need to be sent to the incident side, and the number of hospitals that need to be asked to activate their disaster protocol in order to create extra capacity (“up-scale”). Phase 1 ends after the appointed hospitals have up-scaled their capacity. This will be after approximately 1 hour. If a hospital experiences trouble in activating its hospital disaster protocol this is reported to commanding officer in charge. This will be the patient distribution co-ordinator (PDC).

**Phase 2**

Most of the P1, and P2 casualties will arrive at the hospitals after the first hour. This is phase 2. The goal is to end phase 2 within a maximum of 6 hours. This is based upon the widespread belief that P1 and P2 casualties benefit the most from treatment as quickly as possible, within a maximum of 1 hour for P1 and 6 hours for P2 casualties. (20-23) After 6 to 8 hours research literature reports that the quality of medical care in hospitals will decrease, since supplies run out and personnel fatigue sets in. (23) There is a maximum time that people can deliver good quality care under extreme pressure of both quantity and high level complexity. The patient
distribution coordinator (PDC), will keep track of the reported numbers of P1, P2 and P3 injured casualties that are (still) at the incident site. When the P1 and P2 casualties have been transported from the incident site to the hospital, the PDC will declare the end of phase 2 and the start of phase 3.

**Phase 3**

At this point there is time to treat the (minor) injuries of the P3 casualties and, if needed, perform secondary transfer of stabilised casualties to other hospitals. Secondary transfers should be minimised by taking hospitals’ specialisation into account in the first 2 patient distribution phases. Examples, these specialisations are traumatic brain injury, pelvic and spinal fractures, and extensive burn injuries. P1 casualties should ideally only be transported to trauma centres. Another reason for secondary transfer is to re-distribute the burden of definitive care. The Summary of the phases are presented in Box 2.

**Box 2. Phases of patient distribution in MCI’s**

- **Phase 1:** **Start:** directly after declaration of an MCI; **Duration:** 1 hour (from time of declaration of an MCI until the moment hospitals have fully activated their disaster protocol to create extra capacity).
- **Phase 2:** **Start:** after 1 hour; **Duration:** maximum 5 hours (from the 2nd hour after declaration of an MCI until all P1 and P2 casualties have arrived for treatment at a hospital).
- **Phase 3:** **Start:** when P1 and P2 casualties have arrived at hospital; **Duration:** indeterminate (Until all casualties (P1, 2, 3) have been screened and treated for injuries at the hospitals and are at the right facility for definitive care).

**Calculation of Critical Care Capacity**

In the preparation for major accidents and disasters it is important that hospitals identify beforehand how many critically and severely injured victims (P1 and P2) they can receive and treat. In this part a method is presented to calculate this capacity. The time needed to perform a primary and secondary survey on 1 casualty is called the Critical Stabilisation Time (CST).
1. **During or after office hours.**
   For phase 1 it is important the make a difference between time during office hours, where most of the personnel is already at work, or after office hours. During phase 2 and 3 the hospital will up-scale and extra personnel will become available. It makes no difference when phase 2 or 3 occurs, since maximum capacity is made available regardless of the time of day.

2. **Composition of Critical Care Teams for P1 victims**
   To be able to calculate the Critical Care Capacity (CCC) it is important to know how many P1 resuscitation beds/rooms are available at the Emergency Department (ED). After up-scaling, different rooms can be equipped to become P1 resuscitation rooms.
   Secondly, medical trauma teams need to be formed to resuscitate critically and severely injured victims. (16; 25) Together this corresponds with the Emergency Department Capacity (EDC$_{P1}$). Medical personnel must be the best trained and most experienced available.
   The composition of a P1 resuscitation team:
   * 2 ATLS trained doctors; (at least one trauma surgeon/anaesthesiologist, or senior resident)
   * 2 nurses (ER and/or anaesthesiology nurse)
   * 1 radiologist (or resident)
   * 1 radiology laboratory assistant/radiology technician.

   One team can perform ATLS work-up (primary and secondary survey) on 1 to 2 P1 casualties in an hour (0.75 hours per casualty, = Critical Stabilisation Time, CST$_{P1}$), and hand them over to either an operating team or the Intensive care. This time is an estimation based on the Dutch situation and research literature, taking into account that in an MCI setting, only major injuries need to be diagnosed in the resuscitation phase. (25) In a high stress situation, deviation from daily practice can lead to confusion and inferior quality of care. Therefore normal logistics/working routine should be preserved as much as possible, keeping everybody in the environment they are used to working in and where they have the most routine.
   Once it is decided how many P1 teams and beds can be created, a cross check is performed for availability of enough equipment and enough secondary facilities available to resuscitate 1 to 2 P1 casualties per team. Examples are: (mobile) x-ray and ultrasound equipment, CT-scanners, ventilation machines, surgical capacity.
(50% of all P1 casualties), laboratory capacity, blood bank capacity, splints or casts for extremity fractures, intervention radiologists, etc. (26)

3. Composition of Critical Care Teams for P2 victims

P2 casualties are not vitally threatened. First, the number of P2 resuscitation beds/rooms need to be assessed, and second, the number of P2 teams. This is the Emergency Department Capacity (EDC_{P2}). Experiences of earlier mass casualty incidents and disasters have taught us to expect more over-triage (P2 casualties being triaged and presented to hospitals as P1) than under-triage. (7)

The composition of a P2 resuscitation team:
* 1 ATLS trained doctor
* 2 nurses (ER or anaesthesiology)
* 1 radiology laboratory assistant/ radiology technician

One team can perform ATLS work-up (primary and secondary survey) at 2 P2 beds (next to each other) at one time (0.5 hours per P2 casualty per team, is Critical Stabilization Time, CST_{P2}). This time is an estimation based on the Dutch situation and research literature taking, into account that in an MCI setting, only major injuries need to be diagnosed in the resuscitation phase. (25) Then another cross-check needs to be performed to confirm there are enough secondary facilities available to give primary treatment to the victims’ injuries. There is no need for equipment to support vital organ systems but examples of equipment needed are casts or splints, bandages, laboratory availability, and a radiologist and trauma surgeon for supervision (one each for 6-8 casualties an hour).

4. Total number of P1 and P2 Casualties

Following the method explained below, the total number of P1 and P2 casualties for both phase 1 and 2 (total of 6 hours) must be calculated.

5. P3 casualties

P3 casualties need to be checked and treated for injury. They can receive their primary care either at casualty clearing stations, at a general practitioners’ office or at the hospitals once the emergency there has subsided. After they have been checked at other treatment stations, casualties can be sent to hospital for definitive treatment if needed. The P3 casualties are at risk of a certain type of under-triage. Even though their injuries may not be life threatening, they can sustain injuries
that can eventually give (secondary) morbidity. (7) Nevertheless their injuries can be treated at a later stage, sometimes even with a delay of some days. At the end of phase 2 the PDC checks how many P3 casualties are in need of hospital care. Then the PDC checks if the hospitals are still able to receive P3 casualties. It might be necessary to allocate these P3 casualties to hospitals further away.

**Formula to calculate Critical Care Capacity (CCC)**

Once the number of teams and resuscitation beds (mostly at the Emergency Department) for P1 and P2 casualties (Emergency Department Capacity, EDC) are defined, the exact CCC can be calculated. The estimated rate for P1: P2 casualties is in general 1:3. (27)

**Box 3. Formula to calculate Critical Care Capacity (20)**

- Critical Care Capacity = Emergency Department Capacity : Critical Stabilisation Time.
  
  \[ \text{CCC} = \frac{\text{EDC}}{\text{CST}} \]

- Critical Care Capacity of the first hour = \( \text{CCC}_1 \)
  
  \[ \text{CCC}_1 = \frac{\text{EDC}_1}{\text{CST}_1} \]

- Critical Care Capacity after the hospital is up-scaled = \( \text{CCC}_{\text{up-scaled}} \)
  
  \[ \text{CCC}_{\text{up-scaled}} = \frac{\text{EDC}_{\text{up-scaled}}}{\text{CST}_{\text{up-scaled}}} \text{ (per hour)} \]

- Critical Care Capacity of 1st hour and after up-scaling combined = \( \text{CCC}_{\text{total}} \)
  
  \[ \text{CCC}_{\text{total}} = \text{CCC}_1 + (\text{CCC}_{\text{up-scaled}}) \times 5 \]

**Example**

We provide an example based on a Level I trauma centre in the Netherlands. The numbers provided are the ones calculated for this hospital but have not been tested yet in a real MCI or training. Table 1 presents the Emergency Department Capacity (EDC) for P1 and P2 casualties. Table 2. Shows the formula to calculate Total Critical Care Capacity (Phase 1 and 2, total 6 hours, in a Level I hospital).

**P1 CCC**: \[ 5 \div 0.75 = 6 \text{ P1/hour} \]

There will be more P1 teams than beds, so while delivering one casualty to ICU or operating theatre the next team can take care of the next casualty at the same bed.
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The fact that it takes some time to clear the room and prepare it again for the next casualty, must also be taken into consideration.

\[ P2 \text{ CCC}; 9 \div 0.5 = 18 \text{ P2/hour} \]

One team will be taking care of 2 beds so just 4 to 5 teams are needed.

Table 3 gives an example of how these CCC numbers can be displayed in a PDP. The capacity should never be intended to be used to the maximum and a reserve of about 25% must be calculated in. Table 4 gives an overview of CCC’s of Level I-III hospitals.

**Table 1. Emergency Department Capacity, EDC**

<table>
<thead>
<tr>
<th>First hour</th>
<th>P1 beds</th>
<th>P1 teams</th>
<th>P2 beds</th>
<th>P2 teams</th>
</tr>
</thead>
<tbody>
<tr>
<td>During office hours</td>
<td>4</td>
<td>4</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>After office hours</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>After up-scaling</td>
<td>5</td>
<td>&gt;8</td>
<td>9</td>
<td>&gt;5</td>
</tr>
</tbody>
</table>

**Table 2. Total Critical Care Capacity (Phase 1 and 2, total 6 hours, in a Level I hospital)**

<table>
<thead>
<tr>
<th>During office hours</th>
<th>After office hours</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>P1 CCC</strong>&lt;sub&gt;total&lt;/sub&gt;; 4 + 33 = 37</td>
<td><strong>P1 CCC</strong>&lt;sub&gt;total&lt;/sub&gt;; 2 + 33 = 35</td>
</tr>
<tr>
<td><strong>P2 CCC</strong>&lt;sub&gt;total&lt;/sub&gt;; 10 + 90 = 100</td>
<td><strong>P2 CCC</strong>&lt;sub&gt;total&lt;/sub&gt;; 6 + 90 = 96</td>
</tr>
<tr>
<td>137 P1/P2 casualties</td>
<td>131 P1/P2 casualties</td>
</tr>
<tr>
<td><strong>P1 CCC</strong>&lt;sub&gt;5&lt;/sub&gt;; ([5 \div 0.75] \times 5 \text{ hours}= 33 \text{ T1})</td>
<td></td>
</tr>
<tr>
<td><strong>P2 CCC</strong>&lt;sub&gt;5&lt;/sub&gt;; ([9 \div 0.5] \times 5 \text{ hours}= 90 \text{ T2})</td>
<td></td>
</tr>
</tbody>
</table>

**Discussion**

To verify our numbers of CCC we compared them to the limited available literature. The ratio of P1 : P2 is 1:3 in the MCI literature. (27) In the example above, the Level I hospital, we calculated the numbers for, has an estimated total bed capacity of 650 (in daily practice); our total CCC is 21% of this total bed capacity and if the 75% maximum is kept, 16%. Literature reports suggest that the CCC should be between 10-20%. (20; 28; 29)

According to the de Boer et al. the CCC per hour should be 0,5-1 casualties per 100 beds before up-scaling, and 2-3 casualties per 100 beds after up-scaling. (30) In our example of a 650 bed hospital, this would add up to 3.25-6.5 casualties in the first hour and 13-19.5 casualties per hour for the next 5 hours. This adds up to
68.25 to 104 casualties in total in 6 hours. De Boer et al. consider a total mean MCI time of 8 hours, giving a maximum CCC of a Level I hospital of 94.25 to 143 P1 and P2 casualties in total. Our calculations lie within this range.

### Table 3. CCC table like in PDP (for a Level I hospital)

<table>
<thead>
<tr>
<th>Phase</th>
<th>1st hour</th>
<th>1st hour</th>
<th>Phase 2 (after up-scaling, regardless of time of day)</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>P2</td>
<td>P1</td>
<td>P2</td>
<td>P1</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>2</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>6</td>
<td>18</td>
<td>37</td>
<td>100</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100</td>
</tr>
</tbody>
</table>

### Table 4. Example of CCC of Level I, II and III hospitals

<table>
<thead>
<tr>
<th>Hospital (trauma level)</th>
<th>Phase 1 (day)</th>
<th>Phase 1 (night)</th>
<th>Phase 2 maximum</th>
<th>Maximum 75%</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (I)</td>
<td>4</td>
<td>10</td>
<td>6</td>
<td>37</td>
</tr>
<tr>
<td>B (II)</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>16</td>
</tr>
<tr>
<td>C (III)</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>33</td>
</tr>
</tbody>
</table>

Estimation of the number of casualties at the scene of the accident is vital for execution of medical management of an MCI. The number of ambulances, Helicopter Emergency Medical Services and hospitals that need to be (immediately) alerted is dependent on it. Regular updates of the estimation of the number of casualties should therefore be given throughout the entire time of MCI management. The rationale behind a maximum duration of phase 1 and 2 (together) of 6 hours, has already been explained earlier. Taking into account the maximum capacity of a Level I hospital for P1 and P2 casualties calculated above, we believe that exceeding this number is not realistic for the provision of a high level of care. We also think that extending the time frame of phases 1 and 2 beyond 6 hours would put an even higher strain on the daily care, which will be postponed even further. In these cases it will not be possible to provide the high level of care we expect to be able to meet during MCI’s, and the incident might become a disaster instead.

If all hospitals calculate their CCC based on the formula proposed here, an accurate view of the capacity needed for the medical management of an MCI can be provided. This should, of course, be checked in an MCI drill. All regional and national PDP’s should be based on this same principle, providing clear terminology. An accurate view of CCC limits the chance of inadequate utilisation of care capacity as happened after the 2009 airplane crash.
Specific protocols should be prepared for the management of fire disasters. The trauma teams in the hospital should have a ventilation specialist and the availability of ventilation equipment should be the key point in the preparation of a large number of burn victims. The new CCC numbers should be checked regularly and updated, and the protocol should be studied and drilled frequently by all professionals involved.
References


Checklist

Regional or national government in charge of the preparation and protocol for MCI’s and disasters need to ask hospitals for the following numbers:

Phase 1: (1st hour) **during office hours** (08:00-17:00)
1. a How many P1 casualties can be stabilized in this hour?
   b How many P2 casualties can be stabilized in this hour?

Phase 1: (1st hour) **after office hours** (evening/night weekend)
2. a How many P1 casualties can be stabilized in this hour?
   b How many P2 casualties can be stabilized in this hour?

Phase 2. (up-scaled situation 2nd, 3rd hour, etc.)
3. a How many P1 casualties can be stabilized in these hours per hour?
   b How many P2 casualties can be stabilized in these hours per hour?

Phase 1 + 2
4. a What is the maximum number of P1 casualties that can be stabilized and receive primary treatment in this hospital?
   b What is the maximum number of P2 casualties that can be stabilized and receive primary treatment in this hospital?

Phase 3 (all P1 and P2 casualties are stabilized at the hospitals).
5. How many P3 casualties can you receive and treat?

Phase 4 definitive care (This phase goes beyond the MCI and disaster protocol for local/national government)
6. a What is the ventilation bed capacity?
   b What is the high care (no ventilation) bed capacity?
   c How many minor to moderate trauma casualties can be admitted?