Brace for impact! A thesis on medical care following an airplane crash
Postma, Ingri

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Chapter 3

Mass casualty triage after an airplane crash near Amsterdam

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Abstract

Introduction
Triage is an important aspect of the management of mass casualty incidents. This study describes the triage after the Turkish Airlines Crash near Amsterdam in 2009. The results of the triage and the injuries of P3 casualties were evaluated. In addition, the role of the trauma mechanism and its effect on spinal immobilisation during transport was analysed.

Methods
Investigational reports, ambulance forms, and medical charts of survivors of the crash were retrospectively analysed. Outcomes were triage classification, type of injury, AIS, ISS, emergency interventions and the spinal immobilisation during transport.

Results
A minimal documentation of pre-hospital triage was found, and no exact numbers could be collected. During in-hospital triage, 28% was triaged as P1, 10% had an ISS ≥16 and 3% met the modified Baxt criteria for emergency intervention. Forty percent was triaged P3, 72% had an ISS ≤ 8 and 63% was discharged from the emergency department after evaluation. In-hospital over-triage was up to 89%. Critical mortality rate was 0%. Nine percent of P3 casualties and 17% of ‘walking’ casualties had serious injuries. Twenty-two percent of all casualties was transported with spinal immobilisation. Of the casualties diagnosed with spinal injury, 22% was not transported with spinal immobilisation.

Conclusion
After the Turkish Airlines Crash, documentation of pre-hospital triage was minimal. According to the Baxt criteria the over-triage was high. Injuries sustained by airplane crash survivors that seemed minimally harmed, must not be underestimated. Considering the high energy trauma mechanism, too little consideration was given to spinal immobilisation during transport.
Introduction

In a disaster or mass casualty incident (MCI), a rapid assessment and treatment of the injured is important. On February 25, 2009 a Turkish Airlines Boeing 737-800 crashed with 135 people aboard, nine people died at the scene. One hundred and twenty six casualties needed triage. Emergency services in the Netherlands have experience with MCIs, e.g. 245 casualties in the Volendam café fire in 2001 and 944 casualties in the Enschede fireworks explosion in 2000. (1-3) In previous MCIs difficulties with triage occurred, such as pre-hospital services employing different or inadequate triage methods (2-7) pp. 50–52. At the Volendam café fire, few triage scores were documented at the scene of the accident: the pre-hospital triage of the burns casualties was inadequate and did not lead to treatment and transport priorities. (2; 3)
The two-fold purpose of triage for trauma casualties is first to allocate casualties to the appropriate hospital, thus reducing the changes of secondary mortality and morbidity of individual casualties, and secondly to be as cost effective as possible. (8; 9) In an everyday situation there is no need to consider the ‘greatest good for the greatest number of people’. A difference with triage during disasters and large MCIs is that medical capacity is limited, resulting in a need for lower over-triage rates in order to prevent an overburdened medical system. (10; 11) In MCIs of bomb blasts, the critical mortality rate (number of critically injured casualties that die on the way to, or in hospital) has proven to be directly related to over-triage. (10; 12; 13)
The Triage Sieve and Sort Algorithm is a component of the Major Incident Medical Management and Support (MIMMS) course based on physiological parameters such as ability to walk, airway patency, breathing rate and pulse rate, and was (and still is) the practice used in MCIs in the Netherlands during the Turkish Airlines Crash (TAC) in 2009 (Figure 1). (14; 15) p. 53
The guidelines for field triage, as supposed by the American College of Surgeons, describe mechanisms of injury that might indicate a high energy impact. It is suggested that casualties of such an injury mechanism should be transported to a trauma centre for Advanced Trauma Life Support (ATLS®) resuscitation and subsequent treatment of their injuries. (8; 9) As an airplane crash deviates from regular trauma mechanisms, medical personnel might not be familiar with expected injuries in casualties of an airplane crash.
In this study several triage-related issues after the TAC are evaluated. The research questions were:
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Triage process:
1. What were the results of the pre-hospital and in-hospital triage process of the casualties of the TAC crash?
2. How did triage classifications relate to clinical criteria?

P3 and walking wounded:
3. What were the injuries of the P3 casualties and ‘walking’ casualties?
4. What was the expected severity of their injuries?

Mechanism of injury and spinal immobilisation:
5. Did trauma mechanism play part in this mass casualty triage?
6. If so, how did this affect spinal immobilisation rate during transport?

This retrospective study has been approved by the Institutional Review Board of the Academic Medical Centre Amsterdam.

Figure 1. The scene of the accident.
Setting
Turkish Airlines flight TK1951 crashed at 10:26 am in a field 1.5 km from the runway of Amsterdam Airport Schiphol (Figure 2). Nine people did not survive the impact of the crash. Casualties were transported to a total of 14 hospitals ranging from 5.8 km to 53.5 km from the crash site. The majority (86%) was transported to a hospital within a 25 km distance. (16)

Box 1. Triage Sieve classification according to MIMMS

<table>
<thead>
<tr>
<th>P1 (red): Immediate/ Critical</th>
<th>ABCD unstable, in need of immediate treatment because of either: A (airway), no open airway; B (breathing), respiratory rate &lt; 10 or &gt;30; C (circulation), pulse rate &gt;120; D (disability) GCS (Glasgow Coma Score) &lt;8.</th>
</tr>
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<tbody>
<tr>
<td>P2 (yellow): Urgent/ Severe</td>
<td>ABCD stable, but with possible life-threatening injuries if not treated within 6 hours.</td>
</tr>
<tr>
<td>P3 (green): Delayed/ Minor</td>
<td>ABCD stable, walking wounded.</td>
</tr>
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</table>

Methods

A retrospective analysis was carried out of available ambulance forms, the registered information of the 3 deployed Helicopter Emergency Medical Service (HEMS) teams and the present triage cards of the casualties. The collected data of the events, as described in investigational reports of the Dutch Health Inspectorate and Dutch Safety Board, were also used. (17-19) The pre-hospital data collected were: gender, age, vital signs and revised trauma score (RTS), triage classification, use of triage cards, time of transport and arrival at emergency department and medical interventions. In-hospital data included: trauma level of the receiving hospital, in-hospital triage classification, documented injuries, Abbreviated Injury Scale (AIS), Injury Severity Score (ISS) and medical procedures. The in-hospital triage classifications reported in the investigational reports of the Dutch Health Inspectorate and Dutch Safety
Board were utilised for the study purposes. These data were not documented per individual casualty but only as a group and therefore no comparison with individual diagnosis or ISS was possible. The data consisted of estimations reported during evaluation interviews by the hospitals involved and cross-checked with the collection of individual injuries and ISS scores in our own database.

An indicator of the performance of triage is the critical mortality rate, representing the number of critical casualties (P1) that died on the way to or in the hospital. (4; 10; 12; 20)

**Triage classification**

The triage classifications with 2 clinical criteria; Injury Severity Score (ISS) and the modified Baxt criteria were compared. (21-23) For the comparison with ISS we analysed how the P1 category correlated with an ISS ≥16, P2 with an ISS 9–15, and P3 with an ISS ≤ 8. Secondly, we used the modified Baxt criteria (from now on called ‘Baxt criteria’) and hospital admission shown in Figure 3. The Baxt criteria consist of emergency interventions patients have undergone in order to treat acute life threatening injuries. Patients who met the Baxt criteria were considered P1. Patients who did not meet Baxt criteria but were admitted to hospital for at least 24 h were considered P2. Patients that did not meet Baxt criteria and were discharged within 24 h were considered P3. (21; 22; 23) We evaluated the processes of triage and different outcomes from pre-hospital and in-hospital triage. Over-triage was calculated by dividing the number of non-critical casualties triaged as P1, by the total number of P1 triaged casualties. (12; 20; 22) Under-triage was calculated as the ratio of critically injured casualties, and casualties with an ISS ≥16 that were not transported to a level one trauma centre. (9; 24)
Box 2. Modified Baxt criteria.

**Modified Baxt criteria**

- Chest decompression (needle or tube thoracostomy)
- Intravenous fluid for a systolic blood pressure <90 mmHg, or absence radial pulse
- Blood transfusion
- Assisted ventilation or open airway procedure
- Invasive central nervous system monitoring with brain imaging or other evidence of increased cranial pressure
- Non-orthopaedic operation (or pelvis stabilization) with positive findings within 6 hours

P1: ISS ≥ 16: One of more modified Baxt criteria apply within 6 hours of the crash.
P2: ISS 9-15: No Baxt criteria but admission > 24 hours.
P3: ISS ≤ 8: No Baxt criteria and discharged < 24 hours.

Pre-hospital P3 and ‘walking’ casualties

Casualties triaged as P3 (delayed) were determined by either a documented P3 triage classification on the ambulance form or on the triage tag. Another sub-group of P3 casualties was determined by documentation of their presence in the last casualty clearing station. In this casualty clearing station, casualties triaged P3 were initially gathered in order to be reunited with their families. Later it was decided that these casualties also needed in-hospital evaluation because of the high energy trauma mechanism. (19; 18) Duplicates within both groups were filtered out and the subgroups were analysed together as one. The injuries and treatment of this group were analysed.

In the Triage Sieve algorithm the first determination is done by noting whether the casualty is walking. (15) When walking, casualties are triaged as either P3 (if injured) or uninjured. We identified casualties that were reported (by documentation on ambulance form) to have come ‘walking’ from the aircraft wreckage or crash site. We also made calculations for these groups (P3 and walking wounded) combined (taken out duplicates) in order to study the value of estimation of the injuries of this category. To be able to see if the frequently used triage term ‘walking wounded’ is accurate in excluding major injuries, their injuries and treatments (operative or non-operative) were analysed.

In order to report the extent of the injuries and possible need for hospital evaluation, the highest AIS score of each of the P3 casualties and each of the walking wounded was determined.
Trauma mechanism and spinal immobilisation

All casualties were eventually considered to have been subjected to a high energy trauma mechanism, during the triage process. Documentation from the ambulance forms of spinal immobilisation during transport and diagnosis of spinal injury and the in-hospital treatment, were gathered.

The data were collected, stored and analysed using SPSS® 16.0 (SPSS® for Windows® version 16.0, IBM® corporation, U.S.A.).

<table>
<thead>
<tr>
<th>Table 1. Triage disposition according to location and injury criteria</th>
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<tr>
<td>Pre-hospital triage*</td>
</tr>
<tr>
<td>In-hospital triage</td>
</tr>
<tr>
<td>ISS</td>
</tr>
<tr>
<td>Baxt [see also figure 3]</td>
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</tbody>
</table>

*From the pre-hospital triage, documentation of 36 casualties(2P2, 34 P3) was found.
Results

Events
A house and 2 barns next to the crash site functioned as improvised casualty clearing stations (CCS). About 20 of the most severely injured casualties (in the investigational reports called P1) were taken to the house, and about 70–75 of the less severely and minimally injured (in the investigational reports referred to as P2 and P3) were assigned to the 2 barns. (19; 18) Some casualties were trapped in debris. At least 37 minimally injured casualties (in the investigational reports referred to as P3) were later transported to a third CCS in a sports centre, which was the pre-assigned CCS in the MCI protocols. This CCS is supposed to be mainly used for P3 casualties. Here during re-triage, 2 casualties were found to be critically injured (P1) and 17 to have severe injuries (P2). It was then decided, that because all casualties had suffered a high energy trauma, they should all be evaluated in hospital according to ATLS® principles.

Two casualties left the crash site by themselves and were not triaged but reported to a hospital later that day and the day after the crash. They are not accounted for in the results. The other 124 occupants were transported to 14 different hospitals within a median time of 3.5 h after the crash. Ambulance forms of 91 patients, which contained heterogeneous and incomplete data were retrieved.

In this article, the crash site, the house and two barns, which were the first improvised CCS, together are referred to as ‘the scene of the accident’. The third CCS, being the pre-assigned sports centre, is referred to as the CCS. The means of transport are summarised in Figure 2.

Triage classification
Documentation of a pre-hospital triage classification was found on 27 of the 91 ambulance forms (30%, 2 P2 and 25 P3). Few triage tags were used and only 11 were retrieved. (19; 18) The result of the triage classification, ISS and Baxt criteria are shown in Table 1. It was reported at the scene that there were 20 P1 casualties. (19; 18) When considering an ISS ≥16 as a measure of P1 casualties, 7 (35%) of those 20 casualties should not have been triaged P1. Using the Baxt criteria the pre-hospital over-triage was 80%. The in-hospital over-triage would have been 63% if it had been calculated with ISS and 89% with the Baxt criteria. All casualties were evaluated in a hospital, and all casualties who needed emergency intervention (Baxt criteria) were transported to a level 1 trauma centre. Eighty nine percent of
the casualties with triaged P1 in-hospital and 92% of casualties with ISS ≥16 were transported to a level 1 trauma centre, giving an under-triage rate of 11% and 8% respectively. No casualties died on the way to or in hospital; therefore the critical mortality rate was 0%.

Table 2. Results of P3 and ‘walking’ casualties

<table>
<thead>
<tr>
<th></th>
<th>P3 and walking (n=50)</th>
</tr>
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<tbody>
<tr>
<td>Mean ISS (median; IQR; range)</td>
<td>4.1 (2; IQR 1/5; 0-22)</td>
</tr>
<tr>
<td>Hospitalised</td>
<td>17 (34%)</td>
</tr>
<tr>
<td>Mean number of days in hospital</td>
<td>7 days (3; 2/10; 1-17)</td>
</tr>
<tr>
<td>Fracture</td>
<td>11 (22%)</td>
</tr>
<tr>
<td>Spinal fracture</td>
<td>7 (14%)</td>
</tr>
<tr>
<td>Surgery</td>
<td>7 (14%)</td>
</tr>
<tr>
<td>Surgery for spinal fracture</td>
<td>5</td>
</tr>
<tr>
<td>At least 1 moderate injury (AIS ≥2)</td>
<td>22 (44%)</td>
</tr>
<tr>
<td>At least 1 serious injury (AIS≥3)</td>
<td>6 (12%)</td>
</tr>
</tbody>
</table>

P3 and walking wounded

Thirty-three casualties were identified as P3 either by documentation on their ambulance form or because they went through the CCS. Among those were several victims that were later re-triaged as P2 or P1, because of an existing injury, not because of clinical deterioration (information by word of mouth). We could not identify those casualties that were upgraded in triage classification. One P3 patient was later diagnosed with a bilateral lung contusion, a spinal fracture, and an ankle fracture, resulting in an ISS of 22.

On the ambulance forms of 23 casualties it was reported that they came walking from the wreckage by themselves. One of those ‘walking’ casualties was later diagnosed with a tibia fracture, 2 spinal fractures, and a kidney contusion (ISS 17). Combining these two groups and extracting duplicates 50 casualties were identified within this category. The results of clinical outcomes in this category are in Table 2. The injuries with an AIS ≥3 that were diagnosed in this group were a fracture of the odontoid of the 2nd cervical vertebra, 5 thoracolumbar spine fractures (in 3 casualties), a fracture of the sternum, 2 tibia fractures (bilateral in 1 patient), 2 cerebral contusions and 1 retina laceration.
Spinal immobilisation

Documentation on transport with or without spinal immobilisation was found for 83 casualties. It can be assumed (and it was reported verbally to the author) that the 17 patients transported together in a bus had no spinal immobilisation. Of the 126 survivors, 23 had a spinal injury, 4 of whom we determined received no immobilisation on transport. Ten patients needed surgical treatment for their spinal injury 1 of whom was not immobilised during initial transport. The data on spinal immobilisation during transport are shown in Table 3.

Two (6%) of the P3 casualties were later diagnosed with spinal injury, but were not immobilised during transport. Apart from these 2, there were also 2 (9%) of the ‘walking’ casualties with a spinal fracture that were not immobilised. One of them needed operative treatment for the spinal injury.

Discussion

Before beginning the discussion on the individual topics, it should be noted that this paper is in no way intended to criticise the individual work of the emergency responders all who contributed to saving lives and minimising harmful results of the crash. This evaluation is performed mostly by hospital professionals and might therefore insufficiently capture the complexity of pre-hospital work-flow.

Triage

The evaluation of the triage process after the TAC was difficult because there was a small amount of individualised data on pre-hospital and in-hospital triage. It is remarkable how few triage tags were used, namely in 12% of casualties for whom we found pre-hospital data. Evaluations of other MCI's around the world have shown
the same. (25; 26) The National Protocol Ambulance Care does prescribe the use of casualty/triage tags (15)p.20. There has been criticism on the layout of triage tags themselves and also on the fact that ambulance personnel are unfamiliar with the use in daily practice. In the management of an MCI, deviation from daily routine has shown to be difficult. (18; 25) This has been mentioned as an explanation for why the tags were not used in the TAC. In the TAC only’126 casualties needed evaluation. In larger incidents, with greater numbers of casualties (e.g. Madrid bombing 2004 with more than 2000 casualties) practical sorting methods of triaged casualties are indispensable. Some plead for geographical triage instead of using triage tags, because in MCIs with >20–25, casualties triage tags could be impractical. (27) In a way this was done at the TAC for most of the P3 casualties who were transferred to a separate CCS. The use of triage tags and feasibility of implementation in daily practice should be investigated. This asks for a casualty/triage tag with enough space for identification information, medical information and triage category which can be altered during the process. The goal should be to create a tag/card (maybe digital) that can be used during day to day casualty management and is also applicable in MCIs.

In the research of the TAC we focused on the possible over-triage of P1 casualties and the possible underestimation of the injuries of P3 casualties. In an MCI where there is no shortage of medical care, non-life threatening injuries have a greater importance than in disasters, especially in developed countries with high standards of medical care.

Over-triage was not defined by the designated trauma care level of trauma of the hospital to which casualties were transported, because ambulance personnel could have chosen to transport casualties with minor or moderate injuries to a level 1 trauma centre because of its large capacity rather than because of the specialised care. (9; 28) Because all casualties were eventually evaluated in a hospital, no under-triage was present in that way. Therefore under-triage was evaluated to standards of daily practice, not MCIs, which determines whether critically injured casualties are transported to the highest level of care in the region. (9) Over-triage rates are high (80–89%) when considering the Baxt criteria, but when using the ISS as a measure, the rates were lower (35–63%). However, an ISS ≥16 can consist of all none (acutely) life-threatening injuries and ISS should not be used as a sole means to define critically injured casualties as in the P1 triage classification. (21; 22)

In daily practice, a certain amount of over-triage is accepted, as a way to reduce under triage. It has been stated that in MCIs and disasters, an over-triage rate of
50% must be accepted, to produce an under-triage rate of zero. (12) However, the American College of Surgeons states that in daily practice an under-triage of 5% is acceptable with an associated over-triage rate of 25–50%. (9; 27) The over-triage rate of P1 casualties in TAC of up to 89% is high, as is the under-triage rate of P1 casualties of up to 12%. This was not reflected in the critical mortality rate (0%), which could be due to the large availability of medical resources in this setting. (29) In descriptions of other MCIs the under-triage rates are mostly not evaluated. Our 12% under-triage is calculated from a daily practice standard, and can be considered low for an MCI.

The high in-hospital over-triage rates could be due to inaccurate use of the P1 triage classification. In an evaluation report, a major trauma centre mentions to having received '5 P1 casualties of whom 2 had acute life threatening injuries. (30) According to the MIMMS Triage Sieve, the 3 casualties without acute life threatening injuries should not have been triaged P1.

**P3 and ‘walking’ casualties**

In the TAC medical management, it appears to have been unclear how to manage casualties triaged as P3, as 37 P3 casualties were almost sent home, but were later assigned entitlement to in-hospital evaluation. In the patient distribution plan of the region it is stated that in-hospital treatment only applies to major injuries (P1 and P2). Casualties with less serious injuries (P3) are only seen as a hindrance at the scene of the accident and at the hospital entrance. (31; 32) The investigational report of the Dutch Health Care Inspectorate mentions that ‘P3 casualties can be treated at the scene by medical assistance teams. (19) In our opinion, this is an incorrect interpretation of the MIMMS triage method, which determines that P3 casualties have no transport priority and need not necessarily be initially transported by ambulance. MIMMS does not advocate that in-hospital evaluation of P3 casualties should be withheld (14).

Our data show that casualties from an airplane crash who are walking and/or triaged as P3 can still have major injuries, including spinal fractures. Some casualties might not immediately experience the physical pain caused by these injuries because of high levels of stress hormones released directly after the survival of such an accident. Repeated evaluation of casualties (re-triage), as was done in the CCS, is therefore necessary.

If all P3 and walking wounded in the TAC had not been evaluated in hospital an increase in morbidity and possibly mortality could have resulted. Use of
contradictory terms and protocols must be avoided in managing MCIs. It must also be clear to everyone in the field what the definition of terms used in these protocols is. For example ‘walking wounded’ should not be explained as ‘not injured’ or ‘not entitled to hospital evaluation.’

**Trauma mechanism and spinal immobilisation**

According to the field triage rules by the American College of Surgeons, all casualties of a high energy impact should be considered for evaluation in a major trauma centre rather than a level II or III trauma centre, based on the expected severity of the injuries. (9) In everyday practice in the Netherlands, if expected injuries are less severe, high energy trauma casualties can also be transported to level II hospitals. (15) The criteria of high energy impact are defined for more common trauma mechanisms such as falls from a high height or motor vehicle accidents, but not for rare accidents such as airplane crashes. (9) The one criterion most applicable for this airplane crash was ‘death in the same passenger compartment,’ as 6 people who were seated in the passenger compartment did not survive the impact of the crash. The decision that all casualties should be evaluated in hospital on the basis of the high energy trauma criteria was therefore justifiable.

In the TAC, 75% of the casualties had no spinal immobilisation during transport to hospital, and 22% of the casualties eventually diagnosed with spinal injury were not transported with immobilisation. The MIMMS states that ‘full spinal immobilisation is impractical for all casualties of, for example, a rail crash, even though they are exposed to the same mechanism of injury. Clinical judgement must be exercised to a greater extent than in a single casualty blunt trauma incident. (14) The trauma mechanism of this airplane crash put several parts of the spinal column at risk of injury. Ninety-two of the 126 survivors had a head or facial injury, probably due to a blow to the head by flying loose objects or by hitting the head itself against the airplane’s interior, putting the cervical spine at risk. (33) The crash could have been assumed to have been accompanied by horizontal and vertical deceleration forces. (17) This might have resulted in a blow to the thorax by hitting the seat in front compressing the thorax and/or flailing over the seatbelt compromising the lumbar spine in the horizontal deceleration force. Considering a possible vertical deceleration, a direct compression force is applied to the entire spine especially in a sitting position. For decision making about cervical spine immobilisation, the NEXUS criteria are the basis of the Dutch ambulance protocol. (15) In this type of trauma, the NEXUS criteria seem to be incomplete. In the TAC, availability of medical
resources such as ambulances and immobilisation material was not sparse, so more casualties could have been transported with spinal immobilisation. In hindsight the Dutch ambulance protocol also appears to be insufficient to clear the spine as a whole. The mechanism of injury must be accompanied by symptoms such as pain in the spine, being unalert (GCS < 15 or intoxication), distracting injury, neurological deficit, facial (not head) injury or suspicion of basilar skull fracture, in order for the ambulance personnel to immobilise the spine. (15) If the trauma mechanism had been considered at an earlier stage, emergency medical personnel at the scene probably would have immobilised more casualties.

In conclusion the TAC was not a disaster, since there was enough medical capacity to manage all casualties with high standards of care. This is reflected in the critical mortality rate of 0%. When a crash like this happens, the magnitude cannot fully be predicted in the first moments of pre-hospital care. Therefore it is sensible to start triaging as if it is a disaster where a lack of capacity is expected. This means that at first (all) P1 casualties should be identified by physiological parameters as with the Triage Sieve. The rest, being P2 and P3 casualties can wait. Later, when the scale of the incident is clear, and it can be assumed that there is enough capacity for high standards of care to be delivered to every casualty, the incident should be downgraded to an MCI where normal triage and standards of care can be applied. This takes into account not only physiological parameters and injury type, but also mechanism of injury. In hindsight, this is in fact what happened at the management of the TAC.

**Conclusion**

After the Turkish Airlines Crash, documentation of triage was minimal. According to the Baxt criteria there was a high percentage of over-triage (up to 89%), which is acceptable in daily practice to minimise under-triage, but is less desirable in MCIs and disasters. Over- and under-triage did not result in an increase of mortality, since the critical mortality rate was 0%. The possible injuries sustained by the P3 casualties should not be underestimated, as major injuries were diagnosed in this group. In an airplane accident, such as described in this study, spinal immobilisation for transport should be considered for all survivors.
Chapter 3

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