Brace for impact! A thesis on medical care following an airplane crash
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Chapter 7

Radiological work-up after mass casualty incidents: are ATLS® guidelines applicable?

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Abstract

Objectives
In Mass Casualty Incidents (MCI) a large number of patients need to be evaluated and treated quickly. Well-designed radiological guidelines can save lives. The purpose of this study is to evaluate Advanced Trauma Life Support (ATLS®) radiological guidelines in the MCI of an airplane crash.

Methods
Medical data of all 126 survivors of an airplane crash were analysed. Data included type and body region of the radiological studies performed on the survivors, AIS and ISS codes and trauma care level of the hospitals.

Results
Ninety patients (72%) underwent one or more imaging studies: in total 297 radiographs, 148 CTs, and 18 ultrasounds were performed. Only 18% received diagnostic imaging of all four body regions as recommended by ATLS®. Compliance with ATLS® was highest (73.3%) in severely injured victims (ISS ≥16); this group underwent two thirds of the (near) total body CTs, all performed in Level I trauma centres.

Conclusion
Overall compliance with ATLS® radiological guidelines was low, although high in severely injured patients. Level I trauma centres, frequently used (near) total body CT. Deviation from ATLS® in radiological work-up in less severely injured patients can be safe and did not result in delayed diagnosis of serious injury.
Introduction

In disasters and Mass Casualty Incidents (MCI) a large number of trauma patients need to be screened for traumatic injuries, and treated within a relatively short time span, in difficult circumstances. Guidelines and protocols have been developed to enhance decision making and stabilisation of patients without wasting time on less critical injuries (1). The radiological work-up in trauma patients is an essential part of the diagnostic process but can be time-consuming. Well-designed radiological imaging guidelines can avoid unnecessary delay and save lives, especially in mass casualty incidents (2-4).

The initial care in trauma patients is based on Advanced Trauma Life Support (ATLS®), a system developed by the American College of Surgeons (1). ATLS® is based on the principle of “treat first what kills first”, following an ABCDE list of priorities. This ABCDE list also indicates necessary diagnostic imaging work-up. The ABCDE principle is designed to be applicable to all settings, e.g. no differentiation is made for highly or less developed trauma care systems or a high or low number of patients. No widely accepted protocol for radiological work-up in MCIs exists.

The Major Incident Medical Management and Support (MIMMS) provides triage protocols and decision schemes on transport priority, in order to make sure that in MCIs the most severely injured get access to in-hospital diagnostics and treatment as soon as possible (5). But the MIMMS does not hold protocols on radiological work-up in MCIs. Therefore ATLS® may be more appropriate. In the ABCDE of ATLS®, diagnostic priorities are injuries that cause airway, breathing, circulation and neurological disturbances respectively. If a trauma mechanism or clinical evaluation in the primary survey raises suspicion of injury to the chest, abdomen or pelvis, imaging studies are mandated (1; 6). Stabilisation of the cervical spine (C-spine) is mandated until imaging is deemed unnecessary (clinical evaluation) or until imaging is performed and the C-spine is cleared. With a stabilised C-spine, the imaging of the C-spine can be postponed until, for example, the secondary survey (1).

Radiographs of chest, C-spine and pelvis and a focused assessment with sonography for trauma (FAST) have long been the standard initial screening imaging studies of choice. Nowadays, these imaging studies are frequently replaced or supplemented by computed tomography (CT) in hemodynamically stable (and sometimes even hemodynamically unstable) patients. (Total body) CT is increasingly being used during trauma resuscitation, especially with fast multi-detector CT systems in the
emergency department or even in the trauma resuscitation room (7-9). In this way, faster and more accurate diagnosis of injuries can be achieved and morbidity and mortality reduced (10). Diagnostic pathways and treatment in the case of disasters and MCIs are highly dependent on the capacity of the emergency department and the department of radiology. Hospitals in the Netherlands are designated a trauma care “Level”, related to available capacity and resources to provide trauma care, ranging from I to III; Level I hospitals provide the full range of resuscitative and definitive trauma care (11).

Figure 1. Imaging algorithm derived from ATLS principles

In February 2009, a commercial airplane crashed near Amsterdam, the Netherlands. Nine people did not survive the impact; all 126 survivors were evaluated for injury in several hospitals (12). ATLS® suggests that the mechanism of injury is essential in determining the index of suspicion of certain types of injury and type of diagnostic imaging required (1; 13). A high energy trauma, such as an airplane crash with large deceleration forces in both horizontal and vertical directions can cause a wide range of injuries, with a high probability of spine, chest, abdominal and pelvic injury. Therefore, according to ATLS® principles, in theory, imaging of the cervical spine, chest, abdomen and pelvis is appropriate in all patients of an airplane crash (1; 14). The algorithm of imaging, as it is widely used in ATLS® care of high energy trauma victims in the Netherlands, is illustrated in Figure 1.
To our knowledge, the appropriateness of ATLS® radiological imaging algorithm has not previously been investigated for an MCI.

In this study the application of ATLS® radiological imaging guidelines in an airplane crash mass casualty incident was evaluated.

The primary questions were:
1. Which types of radiological studies and how many were performed during trauma resuscitation?
2. Was the radiological work-up compliant with ATLS® guidelines?

The secondary aim was to answer the following questions:
3. Was radiological work-up different between centres with different designated trauma care levels?
4. Was there a difference in radiological work-up according to patient injury severity?
5. What were the injuries diagnosed in the radiological imaging of ATLS® body regions of C-spine, chest, abdomen and pelvis?
6. What was the role of CT?

Table 1. Type of imaging per body region

<table>
<thead>
<tr>
<th>Body region</th>
<th>X</th>
<th>CT</th>
<th>US</th>
<th>No of patients (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>-</td>
<td>26</td>
<td>-</td>
<td>24 (19.2)</td>
</tr>
<tr>
<td>Chest</td>
<td>85</td>
<td>16</td>
<td>-</td>
<td>76 (60.8)</td>
</tr>
<tr>
<td>Abdomen</td>
<td>-</td>
<td>14</td>
<td>18</td>
<td>29 (23.2)</td>
</tr>
<tr>
<td>Cervical spine</td>
<td>32</td>
<td>30</td>
<td>-</td>
<td>45 (36)</td>
</tr>
<tr>
<td>Thoracic Spine</td>
<td>30</td>
<td>21</td>
<td>-</td>
<td>40 (32)</td>
</tr>
<tr>
<td>Lumbar Spine</td>
<td>36</td>
<td>22</td>
<td>-</td>
<td>46 (36.8)</td>
</tr>
<tr>
<td>Pelvis</td>
<td>34</td>
<td>12</td>
<td>-</td>
<td>37 (29.6)</td>
</tr>
<tr>
<td>Extremities</td>
<td>62</td>
<td>6</td>
<td>-</td>
<td>31 (24.8)</td>
</tr>
<tr>
<td>Other</td>
<td>18</td>
<td>-</td>
<td>-</td>
<td>13 (10.4)</td>
</tr>
<tr>
<td>Total</td>
<td>297</td>
<td>147</td>
<td>18</td>
<td>90 (72)</td>
</tr>
</tbody>
</table>

All (near) total body CTs are counted per body region

US: ultrasound (focused abdominal sonography in trauma/ FAST)
Materials and methods

Medical data of all 126 survivors of the TK 1951 airplane crash were collected and retrospectively analysed. Specific data collected included: baseline characteristics such as gender, age, 1998 Abbreviated Injury Scale (AIS) codes, Injury Severity Score (ISS) (15; 16). The technique and body region of the radiological studies performed on the day of the crash (February 25th 2009), we collected per patient. Compliance with ATLS® was defined as the performance of radiological imaging of all four body regions as suggested by ATLS® guidelines (C-spine, chest, abdomen and pelvis), irrespective of the type of imaging (plain radiography, ultrasound, or CT). To assess compliance of radiological work-up with ATLS® protocol as defined above, we identified casualties in which all four body regions were imaged during radiological work-up and the full compliance group was defined as the percentage of the total group, including casualties in which no imaging was performed.

To research the questions about the differences between hospitals and injury severity of the patient and compliance with the ATLS®, the patients and their radiological work-up were analysed in groups. The first three groups to be compared were patients who were initially treated in Level I, Level II and Level III hospitals respectively, according to the designated trauma care level of the hospitals. The next three groups to be compared were patients classified as minor (ISS 1–8), moderate (ISS 9–16) and severely (ISS≥16) injured.

We analysed which injuries were diagnosed in the four ATLS® body regions, by collecting all AIS codes of the injuries of each patient that corresponded with one of the ATLS® body regions. To research the consequences of not imaging the four ATLS® body regions, we looked at the injuries that were missed or diagnosed late in this MCI. The delayed diagnosis of injury in this MCI has been previously reported by this study group (17).

To determine the role of CT in this study group, CTs were first analysed to determine which body regions were completely imaged. The following body regions were defined: head, chest, abdomen, pelvis, C-spine, thoracic spine, lumbar spine and extremities. All different body regions were counted as a separate CT. Also the number of (near) total body CTs was registered. A total body CT included CT imaging of the head and all four ATLS® regions (C-spine, chest, abdomen and pelvis) with multi-planar reformations of the thoracic and lumbar spine. (9) A near total body CT included CT imaging of all except one body region. The collected data about CTs were analysed in groups. The groups to be compared were the same as
those used in previous research questions based on the designated trauma level of the hospital (Levels I, II, and III) and ISS classification (minor, moderate and severe). Approval for this study was obtained from the ethics board of the Amsterdam Academic Medical Centre (AMC).

Results

Of the 126 survivors of the airplane crash, 124 were allocated to 14 hospitals for evaluation (4 Level I, 6 Level II and 4 Level III hospitals, responsible for the evaluation of 52, 51 and 21 casualties, respectively), one reported to hospital himself, later that day (Level II) and one the next day (Level III) (12). On the basis of triage in the field (pre-hospital triage) patients were given priority for transport. The most severely injured patients were transported to Level I hospitals, but exact data on pre-hospital triage was scarce (18; 19).

As we only assessed data from the day of the crash, the survivor who presented himself to a hospital 1 day after the crash was excluded from this study. The remaining study population of 125 comprised 83 men and 42 women, with an average age of 38 (range 11 months to 76 years). The mean ISS was 6.7 with a range from 0 to 66 and median of 4. Six survivors (5%) had no physical injuries. Because of the need for specialised care for spinal injury, secondary transfer to a Level I trauma
centre was needed for 2 survivors. They were initially presented at a Level II hospital and a Level III hospital (12; 18).

On the day of the crash 90 of the 125 patients (72%) underwent one or more radiological study: a total of 297 radiographs, 147 CTs of specific body regions and 18 FAST ultrasounds were performed. In 87 patients (70%), at least one radiograph and in 41 (33%), at least one CT was performed. In Table 1 imaging types and imaged body regions are presented. The compliance with the ATLS® guidelines is presented in Figure. 2.

In Table 2 the number of radiological studies performed per group of hospitals with the same designated trauma level and ISS group is presented.

With the imaging of the ATLS® body regions 47 injuries were diagnosed in 28 patients, 20 of these had an AIS ≥ 3. Injury types are presented in Table 3.

Nine patients (7.2%) underwent a total body CT; their mean ISS was 27 (range 9–66). Three patients (2.4%) received a near total body CT in which either the head or pelvis was not (completely) imaged; their mean ISS was 15 (range 9–24). Patients receiving either total or near total body CTs comprised 9.6% of all 125 patients and 13.3% of those underwent diagnostic imaging. Eight of the 15 severely injured patients (53.3%; ISS ≥16) received a (near) total body CT; all were initially admitted to a Level I trauma centre. The remaining 7 patients with an ISS ≥16 underwent at least one CT of the region of their most severe injury (highest AIS). One patient with an ISS ≥16 was at first not admitted to a Level I hospital.

Table 2. Total number of radiological studies performed per trauma level and Injury Severity Score (ISS) group

<table>
<thead>
<tr>
<th>ISS Group</th>
<th>X (mean/patient)</th>
<th>CT (mean/patient)</th>
<th>US (FAST) (mean/patient)</th>
<th>Total body CT</th>
<th>Near Total body CT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1 (mean/patient)</td>
<td>146 (2.8)</td>
<td>123 (2.4)</td>
<td>11 (0.2)</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td>Level 2 (mean/patient)</td>
<td>105 (2.0)</td>
<td>19 (0.4)</td>
<td>2 (0.0)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Level 3 (mean/patient)</td>
<td>46 (2.2)</td>
<td>5 (0.2)</td>
<td>5 (0.2)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total (125)</td>
<td>297 (2.4)</td>
<td>147 (1.2)</td>
<td>18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ISS 0 (6)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ISS 1-8 (83)</td>
<td>160</td>
<td>34</td>
<td>11</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>ISS 9-15 (21)</td>
<td>70</td>
<td>37</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>ISS ≥16 (15)</td>
<td>67</td>
<td>76</td>
<td>5</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>297</td>
<td>147</td>
<td>18</td>
<td>9</td>
<td>3</td>
</tr>
</tbody>
</table>
Discussion

In this study of 125 airplane crash survivors, 72% underwent some form of diagnostic imaging. An average of 3.6 imaging studies (2.4 radiographs and 1.2 CTs) were performed per patient. According to the available literature on Level I trauma centres, fewer radiographs and a comparable number of CTs were performed in our study. In our study in the Level I trauma centres, the mean ISS in this MCI was 11 (median 9, range 1–66), the mean number of radiographs per patient 2.8 and CTs 2.4. In 2 studies (in regular trauma care) performed at a Level I trauma centre (mean ISS 8.6 and median 14), the mean number of plain radiographs was 6.2–9.5 and CTs 1.8–3 (20; 21). Most literature on radiological imaging in MCIs concerns (terrorist) bombings and reports a wide range of use of radiographs (45–81%) and CTs (7–90%) (22-25).

Table 3. Injuries in ATLS body regions. (28 patients)

<table>
<thead>
<tr>
<th>Region</th>
<th>Type of Injury</th>
<th>No of patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest</td>
<td>Rib fractures (AIS 1 or 2)</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Rib fractures (AIS 3 or 4)</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Sternum fracture (AIS 2)</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Flail chest (AIS 5)</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Pulmonary contusion unilateral (AIS 3)</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Pulmonary contusion bilateral (AIS 4)</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Myocardium contusion (AIS 3)</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Trachea laceration (AIS 4)</td>
<td>1</td>
</tr>
<tr>
<td>Cervical Spine</td>
<td>Odontoid fracture (AIS 3)</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Cervical spine fracture (AIS 2)</td>
<td>3</td>
</tr>
<tr>
<td>Abdomen</td>
<td>Kidney contusion (AIS 2)</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Spleen laceration (AIS 4)</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Liver laceration (AIS 3)</td>
<td>1</td>
</tr>
<tr>
<td>Pelvis</td>
<td>Pelvic fracture (AIS 2)</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Pelvic / Sacrum fracture (AIS 3)</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Pelvic fracture (AIS 4)</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>47</strong></td>
</tr>
</tbody>
</table>

Only 18% of all victims received diagnostic imaging studies of all four body regions as recommended by ATLS®. Compliance with ATLS® guidelines was higher in Level I trauma centres than in Level II or III hospitals (36.5% vs. 2% and 14.3% respectively) but can still be considered low. Compliance was highest in the severely injured patients (ISS ≥16; 73.3%), who received two thirds of the (near) total body CTs, all performed in a Level I trauma centre.
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Most of the severely injured patients did receive imaging in compliance with ATLS® guidelines. In the present study, selective compliance with ATLS® guidelines regarding imaging seemed safe, provided that clinical evaluation and trauma mechanism played a vital role in the decision making. Over the years ATLS® guidelines have evolved towards a greater emphasis on the role of clinical evaluation.

The most frequently imaged body region in our study was the chest, which is to be expected according to ATLS® ABC priorities. The next most frequently imaged body region was the lumbar spine and third was the cervical spine. In airplane crashes in particular, a large number of spinal injuries are observed, as in our study population, i.e. 35 injuries in 23 survivors (12; 17; 26). On the basis of a high level of suspicion of spinal injury, given the mechanism of trauma in this MCI, a relatively large number of spinal imaging studies can be expected. Several authors have stated that all victims of a dangerous trauma mechanism should receive at least some C-spine imaging, as is the case in the Canadian C-spine rules (13; 14). The cervical spine is part of the primary survey in the ATLS®, and has some priority in radiological work-up. A third of our crash victims received C-spine imaging with 4 patients positive for C-spine injury (3.2% of total, 10% of the ones with C-spine imaging). This could mean that clinical evaluation played an important role in spinal imaging of the survivors of this MCI. No C-spine injuries were diagnosed late; one day or more after the trauma (17).

A total of 47 injuries were diagnosed in the ATLS® body regions, of which 20 were significant (AIS≥3). In victims admitted to a hospital for longer than 24 hours, 8 injuries were diagnosed with late radiographic imaging (at least 1 day after the crash) (17). Only 2 of the delayed diagnoses were in 1 of the 4 ATLS® body regions. These were both kidney contusions (AIS 2) which are considered to be of little clinical significance in the resuscitation phase.

In our study an average of 1.2 body regions per victim underwent CT. Because all the different body regions were counted as separate CTs, this might have led to a higher number of CTs. For example, in a chest CT the thoracic spine can also be fully represented. Half of the CTs were of the spine and the next most frequently imaged body region was the head. These body regions can be considered more difficult to assess with clinical investigation and plain radiographs. All (near) total body CTs were performed in Level I hospitals. A high case load of severely injured patients and high compliance with ATLS® algorithms in Level I trauma centres might have caused the installation of CT systems near the trauma resuscitation rooms before this MCI. This might explain the increased use of (near) total body CT in these
Level I centres. Another reason is the higher index of suspicion of injury in an ATLS® body region in severely injured patients. Of note, 5 of the 7 severely injured patients (ISS ≥ 16) who did not receive a (near) total body CT, were treated in the one Level I trauma centre that has a CT system in the resuscitation room. The placement of this CT equipment in the resuscitation room is the subject of multiple studies, and may lead to more strict indication for the use of CT imaging (7-9). Otherwise, it could have been the character of the MCI, with multiple casualties arriving within a short amount of time that led to strict indications for primarily CT imaging being used only for life-threatening injuries. Nevertheless using total body CT in an MCI as a triage tool as well as a diagnostic tool, can be feasible as well (27; 28). We were unable to retrieve exact time information on the performed diagnostic imaging. Therefore we cannot comment on the effect of CT-scanning on the time till diagnosis. A study on the optimisation of trauma workflow using CT scanning shows a significantly longer work-up time in trauma patients that did receive CT compared to those that did not (7). It was not corrected, though, for ISS. A systematic review on total body CT in trauma patients found 3 studies that registered work-up time. These showed no difference in work-up time or even significantly shorter work-up times in trauma patients receiving total body CT compared to those that received conventional radiological work-up (28). The effect of total body CT on the efficiency of trauma resuscitation in high energy trauma patients is the subject of a current international prospective randomised trial in 5 Level I hospitals, including the 2 Level I hospitals that received most of the critically injured patients in our study. (9)

Conclusion

This study of the radiological work-up of trauma resuscitation of survivors of a very serious airplane crash, showed that the overall compliance with ATLS® guidelines was generally low, although it was high (73%) in severely injured patients. Body regions with the highest priority in the ATLS® guidelines were most frequently imaged. Level I trauma centres, which received the most severely injured patients, frequently used (near) total body CT. With skilled clinical triage it is safe to deviate from the ATLS® guidelines in the radiological work-up of less severely injured patients and in our study this did not result in the delayed diagnosis of serious injury. In Mass Casualty Incidents, an optimised diagnostic imaging strategy is important for maximum survival of the most severely injured.
References


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