Chapter 9

Delayed diagnosis of injury in survivors of the February 2009 crash of flight TK 1951

I.L.E. Postma resident orthopaedic surgery, AMC Amsterdam
J. Winkelhagen, traumasurgeon Westfriesgastuis, Hoorn
M.J. Heetveld, trauma surgeon Kennemerasthuis, Haarlem
T.S. Bijlsma, trauma surgeon, MCA Alkmaar
F.W. Bloemers, trauma surgeon, VuMC Amsterdam
J.C. Goslings, trauma surgeon, AMC Amsterdam

Based on
Delayed Diagnosis of Injury in survivors of the February 2009 crash of flight TK1951
Injury. 2012 Dec;43(12):2012-7
Abstract

Introduction
On 25 February 2009, a Boeing 737 crashed nearby Amsterdam, leaving 126 casualties. Some injuries in trauma patients initially escape detection. The aim of this study was to evaluate both the incidence of Delayed Diagnosis of Injury (DDI) and also the tertiary survey on the casualties of an airplane crash, and to evaluate the effect of ATLS® implementation on DDI incidence.

Patients and methods
Data from all casualties were analysed with respect to hospitalisation, DDI, tertiary survey, ISS, Glasgow Coma Score (GCS), injuries (number and type) and emergency intervention. Clinically significant injuries were separated from non-clinically significant injuries. The data were compared to an airplane crash in the UK (1989), which occurred before ATLS® became widely practiced.

Results
All 126 casualties of the Dutch crash were evaluated in a hospital; 66 were hospitalised, with a total of 171 clinically significant injuries. Twelve (7%) clinically significant DDIs were found in 8 patients (12%). In 65% of all patients, a tertiary survey was documented. The incidence of DDI in patients with an ISS ≥16 (n = 15*) was 27%*, compared to 9% in patients with ISS <16. Patients with >5 injuries had a DDI incidence of 25%, compared to 12% in patients with ≤5 injuries. Head injury patients had a DDI incidence of 19%, patients without a head injury 10%. Fifty percent of patients who needed an emergency intervention (n = 4) had a DDI; 3% of patients did not need emergency intervention. Eighty-one survivors of the UK crash had a total of 332 injuries. DDIs were found in 30.9% of the patients. Of all injuries, 9.6% was a DDI. The incidence of DDI in patients with >5 injuries was 5%, vs. 8% in those with ≤5 injuries.

Conclusion
DDI in trauma still happens. In this study, the incidence was 7% of the injuries in 12% of the population. In one third of the patients no tertiary survey was documented. A high ISS, head injury, more than 5 injuries and an emergency intervention were associated with DDI. The DDI incidence in our study was lower than in casualties of a previous airplane crashes prior to ATLS® implementation.
Introduction

On February 25, 2009, a commercial aircraft crashed nearby Amsterdam Airport Schiphol, in the Netherlands. One hundred and twenty six people survived the crash and nine people died. (1) This Mass Casualty Incident (MCI) warranted evaluation of medical treatment and other procedures. The diagnosis of all injuries in trauma patients can be a challenge, especially in large-scale accidents, with numerous multi-traumatised patients. Missed or delayed diagnosis of injuries may cause increased morbidity, a longer stay in hospital, higher costs, and can affect the patient–doctor relationship. (2-5)

Since the development of the Advanced Trauma Life Support (ATLS®) course by the American College of Surgeons, trauma resuscitation and care has been based on the principle of “treat first what kills first”, with a primary survey in order to detect immediate life-threatening injuries and a secondary survey consisting of a ‘head to toe’ examination. (6) However, primary and secondary surveys alone are not sufficient for detecting all injuries. In 1991, Enderson et al. reported an increase from 2% to 9% of injuries diagnosed late, when they actively looked for new diagnoses of injury in patients with blunt trauma, after the primary and secondary surveys. As a consequence, they introduced a tertiary survey, comprising a complete repetition of the physical examination performed during the previous surveys. (7; 8) This was later completed with a review of all diagnostic tests that had been carried out at a primary and secondary survey. (3; 5; 9)

The reported incidence of delayed diagnosis of injury (DDI) ranges from 1.3% to 65%. (2-5; 7-11) This wide range is attributable to heterogeneous study groups as well as the differences in definitions of DDI. Associated factors in the incidence of DDI are, for example, impaired consciousness, or a high Injury Severity Score (ISS). (3; 7; 9)

Although DDIs are now often discovered because of the introduction of the tertiary survey, DDIs are still common, even after tertiary survey. The effect of an MCI on the incidence of DDI is not clear.

The aim of this study was to examine the incidence of DDI and a tertiary survey in the casualties of the 2009 Turkish Airlines airplane crash in the Netherlands. We were interested in associated factors such as ISS, number of injuries, type of injury, GCS and emergency interventions. We were also interested in the effects of 20 years of ATLS® doctrine and evolving trauma care on this incidence and comparing these to a similar airplane crash in the UK in 1989, that happened shortly before ATLS® became widely practiced.
This study was approved by the Medical Ethical Committee of the Academic Medical Centre, Amsterdam.

Figure 1. Documentation of a tertiary survey in relation to DDI in patients admitted following the Dutch crash.

Patients and methods

Setting Turkish Airlines crash 2009, in the Netherlands
On February 25 2009, at 10:26 a.m., a Turkish Airlines Boeing 737-800 crashed in a field approximately 1.5 km short of the runway of Amsterdam Airport Schiphol. The aircraft broke into 3 sections and both engines ended up dozens of meters away. Amsterdam Airport Schiphol is situated in a densely populated area of the Netherlands, where everybody lives less than 10 minutes from a hospital. (12) Fifteen different hospitals received one or more patients, resulting in all 126 survivors being evaluated in a hospital.

Data collection and outcomes
The demographic and medical data of all patients, at each of the 15 receiving hospitals, were collected retrospectively; using a Microsoft Access® database. The medical charts of the hospitalised patients were reviewed for documentation of a tertiary survey and for DDI, as primary outcomes.
Delayed diagnosis of injury

DDI was defined as an injury diagnosed after a primary and secondary survey, meaning this injury could be found at a tertiary survey, or later. Secondary outcomes were possible risk factors for DDI, including a high ISS, number of injuries, head injury, Glasgow Coma Score (GCS) on arrival at the Emergency Department (ED) and an emergency intervention. An emergency intervention was defined as an intervention such as an operation, angiography, or intubation; for any acutely life-threatening injury, within 6 hours after the trauma. A distinction was made between clinically significant injuries and DDIs, and clinically non-significant injuries and DDIs. Clinically significant was defined as an injury that, if unnoticed, would possibly lead to delayed or poor healing, and could have consequences for a patient's recovery and return to daily activities. Thus, this definition is not based on severity as a threat to life, but more as a chance of disability or impairment. This therefore means, any injury that needs treatment, or at least one check-up after diagnosis. In our results we have only considered clinically significant injuries, unless stated otherwise.

Statistical analysis
Because of the small study population, only descriptive statistics are calculated using SPSS 16® for Windows®.

Comparison with UK crash 1989

Setting
On January 8 1989, at 08:30 p.m., a Boeing 737-400 crashed on the M1 motorway about 900 m short of the threshold of the runway of East Midlands Airport, near Kegworth, Great Britain. The aircraft broke into 3 sections and came to rest on the embankment of the M1 motorway. The nearest hospital was approximately 16 km from the crash site and two other hospitals were approximately 19 km and 32 km from the crash site. (13)

Data collection
The Nottingham, Leicester, Derby, Belfast Study group published the data of this crash in several articles and a book. (13-20) We collected the demographic and medical data from the published articles and compared the relevant data to the outcome measures of the Dutch crash, as described above. The data from the UK
crash only consider ‘major injuries’, the definition of which is comparable to the one we used as ‘clinically significant injury’. (19)

Table 1. Patients with and without DDI in Dutch crash.

<table>
<thead>
<tr>
<th>Admissions</th>
<th>Hospitalised Pt with DDI (n=8, 12%)*</th>
<th>Hospitalised Pt without DDI (n=58, 88%)*</th>
<th>Total Pt hospitalised (n=66)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean ISS (range, median)</td>
<td>21.9 (5-66; 13.5)</td>
<td>9 (1-34, 5)</td>
<td>10.5 (1-66, 5)</td>
</tr>
<tr>
<td>ISS ≥16</td>
<td>4 (50%)</td>
<td>9 (15.5%)</td>
<td>15</td>
</tr>
<tr>
<td>No. of injuries*</td>
<td>39</td>
<td>132</td>
<td>171</td>
</tr>
<tr>
<td>Mean no. of injuries (range, median)</td>
<td>4.5* (1-11, 2)</td>
<td>2.3* (0-11, 1)</td>
<td>2.6 (0-11, 2)</td>
</tr>
<tr>
<td>&gt;5 injuries</td>
<td>2 (25%)</td>
<td>6 (10%)</td>
<td>8</td>
</tr>
<tr>
<td>Mean GCS at admission (median)</td>
<td>14 (15)</td>
<td>15 (15)</td>
<td>14.9 (15)</td>
</tr>
<tr>
<td>Head injury (AIS≥2)</td>
<td>3 (19%)</td>
<td>13 (81%)</td>
<td>16</td>
</tr>
<tr>
<td>Emergency intervention</td>
<td>2 (25%)</td>
<td>2 (3.4%)</td>
<td>4 (6.1%)</td>
</tr>
<tr>
<td>Mean hospital stay (days) (range, median)</td>
<td>29.3 (2-104, 10)</td>
<td>6.9 (1-35 4)</td>
<td>8.9 (2-104, 4.5)</td>
</tr>
</tbody>
</table>

* Only clinically significant injuries.

Results

Demographic data
Nine of the 135 occupants died at the scene of the Dutch crash. There were no later deaths on the way to, or in hospital. Sixty-six percent were male and the mean age was 38 (range 11 months to 76 years). A total of 66 patients (range 1–19) were admitted to 13 hospitals (Figure 1). The Academic Medical Centre (AMC) in Amsterdam and VU Medical Centre (VUMC) in Amsterdam, both major trauma centres, hospitalised most patients, 19 and 18 respectively.

Outcomes
The population and documentation of a tertiary survey is shown in Figure 1. All clinically significant DDIs were found in the 2 trauma centres receiving the largest number of patients and in the most severely injured patients (mean ISS 13.2* compared to 10.5*, of admitted patients). One patient was severely injured, with an ISS of 66*, and in need of several immediate emergency interventions. Non-lifesaving diagnostic studies were deliberately postponed. This patient suffered 5
Delayed diagnosis of injury

DDIs and needed operative treatment for 4 of them. The results of patients with and without DDI are in shown Table 1. The types of clinically significant DDIs and their treatment are shown in Table 2.

The results of the associated factors in patients with and without DDI are shown in Figure 2. The mean time to diagnosis of clinically significant DDI was 4.5 days (range 1–10 days, median 5 days). None of the DDIs had been imaged radiographically during the primary and secondary survey (Figure 3).

**Table 2. Type of Delayed Diagnosis of Injury**

<table>
<thead>
<tr>
<th>Type of Injury</th>
<th>Number</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distal Radius fracture</td>
<td>1</td>
<td>Surgery</td>
</tr>
<tr>
<td>Metacarpal fracture</td>
<td>1</td>
<td>Plaster cast</td>
</tr>
<tr>
<td>Interphalangeal dislocation</td>
<td>1</td>
<td>Closed reduction and plaster cast</td>
</tr>
<tr>
<td>Lumbar vertebral fracture</td>
<td>1</td>
<td>Conservative</td>
</tr>
<tr>
<td>Meniscal tear</td>
<td>1</td>
<td>Conservative</td>
</tr>
<tr>
<td>Tibial plateau fracture</td>
<td>2</td>
<td>Surgery</td>
</tr>
<tr>
<td>Tibial shaft fracture</td>
<td>2</td>
<td>1 surgery, 1 plaster cast</td>
</tr>
<tr>
<td>Ankle sprain</td>
<td>1</td>
<td>cast</td>
</tr>
<tr>
<td>Kidney contusion</td>
<td>2</td>
<td>expectative</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>12</strong></td>
<td></td>
</tr>
</tbody>
</table>

**Comparison with UK crash 1989**

**Demographics**

Thirty nine of the 126 occupants of the UK aircraft died at the scene, 4 on their way to hospital, leaving 83 who were transported to 4 different hospitals, which received 37, 24, 20 and 2 patients respectively. One of the 4 hospitals reported not to have hospitalised 2 patients because of minor or no injury. We assume that the other hospitals hospitalised all the casualties that they received, even though 6 of the casualties had an ISS of 1, and 4 had an ISS of 2. A report of the ‘Air Accidents Investigation Branch’ of the British Department of Transport states there were only 5 casualties with just minor injuries. (21) Of the patients that were hospitalised, another 4 died at 12 hours, and 11, 15 and 22 days after the accident, ultimately leaving 79 surviving casualties.

The demographics were comparable to the Dutch crash.
Outcomes
The comparison of DDI in these 2 airplane accidents is shown in Table 3. In the UK crash, all DDIs occurred in the 3 hospitals receiving the most patients. We could not extract data such as ISS, GCS, or number of injuries per patient, patients with or without DDI, from the UK data. The Nottingham, Leicester, Derby, Belfast Study group found no significant difference in the incidence of DDI between patients with ≤5 injuries, or the group with >5 injuries, 8% and 5% respectively. (19) The DDIs consisted of 8 fractures and 1 soft tissue injury of the upper limb, 9 fractures of the lower limb and 14 spinal injuries (13 fractures and 1 prolapsed thoracic vertebral disc). Five DDIs required operative treatment. (19) The cause of DDI in 14 cases was misinterpretations of X-rays, in 8 due to failed clinical investigation and 10 injuries were not radiographed. (19)

Discussion
The incidence of DDI in the Dutch airplane crash was 7% of all injuries and in 12% of the hospitalised patients. This is comparable to DDI incidence in trauma patients in literature. (2; 9; 22-24) All DDIs were found in the 2 hospitals receiving the largest
numbers of casualties, with the highest severity of injuries. An unpublished study of delayed diagnosis in 1124 trauma patients in the same two hospitals showed a DDI incidence of 8.2% of the study population. (25) The higher incidence in our study might be due to the large number of casualties presenting in such a short period of time. The fact that all DDIs were found in the major trauma centres could mean that smaller (level 2 and level 3) hospitals could have less complete documentation, i.e. not a standard tertiary survey form.

In 65% of the admitted patients in the Dutch crash, there was documentation of a tertiary survey. This should ideally be 100%. The absence of documentation of a tertiary survey does not necessarily mean that no tertiary survey was performed, and not all DDIs were discovered during a tertiary survey. Nevertheless, all DDIs were found in patients in whom a tertiary survey was documented, so it is possible that, in the remaining 35% (without a tertiary survey), some DDIs were missed.

Table 3. Comparison of Dutch vs. UK data.

<table>
<thead>
<tr>
<th></th>
<th>Dutch</th>
<th>UK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortality</td>
<td>9 (7%)</td>
<td>43 (34%)</td>
</tr>
<tr>
<td>Survivors</td>
<td>126</td>
<td>79</td>
</tr>
<tr>
<td>No. of DDIs</td>
<td>12* (7%)</td>
<td>32* (10%)</td>
</tr>
<tr>
<td>No. of patients with DDI</td>
<td>8 (12%)</td>
<td>25 (30%)</td>
</tr>
<tr>
<td>Mean time to diagnosis of DDI (days, median)</td>
<td>5.3* (1-10, 6)</td>
<td>44* (1-132)</td>
</tr>
<tr>
<td>Mean ISS (range, median)</td>
<td>6.3 (1-57, 4)</td>
<td>15.2 (1-50, 11)</td>
</tr>
<tr>
<td>ISS≥15</td>
<td>13 (10%)</td>
<td>30 (37%)</td>
</tr>
<tr>
<td>Number of injuries</td>
<td>305 (171*)</td>
<td>332 (major injuries)</td>
</tr>
<tr>
<td>Head injury (AIS≥2)</td>
<td>21 (17%)</td>
<td>34 (41%)</td>
</tr>
</tbody>
</table>

* Only clinically significant Delayed Diagnosis of Injury

Our definition of clinically significant injury was chosen based on the risk of disability or impairment and not on the basis of AIS score, because injuries with an AIS severity of 1 can have important consequences to a patient if they are missed and left untreated. For example, an interphalangeal dislocation, or rupture of multiple tendons in the hand, has AIS of 1, but if diagnosed late or completely missed, they can be disabling for the patient. In practice, this meant that injuries not accounted for were only minor ones like, superficial lacerations, abrasions and contusion of skin, or joints. These comprised 52 injuries in the hospitalised patients.

A total of four patients needed one, or more, emergency intervention because of acute life-threatening injury. According to the ATLS® principle, the imperative is to “treat first what kills first”. (6) In the Dutch crash 2 patients needed immediate
surgery because of acute life-threatening injuries. The delay in diagnosing some non-life-threatening injuries caused by this immediate surgery can therefore be seen as functional. Excluding these DDIs, the incidence becomes lower at 3.5% of the injuries in 9% of the patients. It should be noted that all DDIs were non-life-threatening injuries, which is consistent with the application of ATLS® principles. Another debatable DDI is that of a meniscal tear. This DDI was suspected at the end of this patient’s hospital stay. The MRI confirming the diagnosis was made a few weeks later. In daily practice a meniscal tear is hard to diagnose through physical examination directly after trauma, because of extensive swelling and pain. An MRI to confirm a meniscal tear is not routinely performed shortly after the trauma.

In the Dutch crash, a high ISS, the number of injuries per patient, a head injury AIS ≥2 and the need for an emergency intervention were associated with a higher chance of a DDI, as shown in Figure 2. Although these factors can be correlated to each other, association with DDI has been shown in previous studies. (3; 7; 9; 26) The Nottingham, Leicester, Derby, Belfast Study group concluded that the incidence of DDI is not related to overall patient condition. Perhaps the difference of 7% compared to 10% (or 12% compared to 31% in population) in DDI incidence between the UK and Dutch findings can also be explained by the fact that more casualties from the UK crash were severely injured than in the Dutch crash (ISS ≥16 of 30.7% compared to 11.9%). Since we could not correct the data for the severity of the crashes, in terms of the extent of the injuries per patient, statistical analysis of the comparison was not possible.

From the UK data, we could not extract GCS scores per patient with, or without, DDI. However, with the high numbers of significant head injuries and casualties who had no recollection of the crash (55%), it can be presumed that in the UK there was a large number of casualties with a lowered state of consciousness. (18; 27) This could also be a factor related to the higher DDI rate.

Comparison with the UK crash is difficult because the UK crash was more severe, resulting in more initial deaths and more survivors with an ISS≥16. As mentioned earlier this might be an explanation as to why the incidence of DDI was higher in the UK crash. In the Dutch crash only the DDIs found during initial hospital stay were reported. This means that we might have underestimated our DDI incidence in comparison to the UK. On the other hand, according to the published literature, not admitting all patients just because of the high energy trauma mechanism, cannot be presumed to lead to a significantly higher DDI rate. (28)
The UK crash happened before ATLS® was fully adopted in the UK and thus also before a tertiary survey was introduced in daily practice. (7; 8; 20) The first ATLS® courses had only just started in the UK so few doctors were ATLS® certified, and ATLS® principles were not yet protocolled. The Nottingham, Leicester, Derby, Belfast Study group does mention that all patients were carefully re-examined the morning following the crash and every morning thereafter, but a large number of diagnoses were initially missed, due to failure of clinical examination and misinterpretation of X-rays. There was a long delay until some DDIs were found. This might have been (partially) prevented by the structured methods of ATLS® and a tertiary survey.

It is remarkable in the UK crash that so many spinal injuries were initially missed, being 4.2% of all injuries compared to 0.6% of all injuries in the Dutch crash. Tait et al. and the NLDB study group state that this might be explained by an incomplete understanding or realisation of the trauma mechanism, with high G forces (higher than in the Dutch crash) creating a large vertical load. (19) They advised that all casualties of high energy trauma should receive a full spinal radiological examination. In the study of the UK crash, only delayed bony injuries were considered. If this had been done for our study, the DDI incidence would have been 6% of the injuries in 9% of the patients.

This study has several limitations. Studying incidence rates in an isolated event, such as an aircraft crash, carries the disadvantage of a rather small study population. Also, the trauma mechanism and the conditions are unique. Therefore, these data cannot be extrapolated to the general trauma population. The differences between the two airplane crashes described, and the differences in the specification of the data, preclude a direct comparison.
Conclusion

DDI incidence in the casualties of the Turkish Airlines crash in Amsterdam was 7% and affected 12% of the study population. This is comparable to the published literature, so it must be concluded that in mass casualty incidents as in any other trauma casualties, some injuries are initially missed.

This study showed a sub-optimal documentation of a tertiary survey in airplane crash casualties. The performance of structured trauma resuscitation with a primary, secondary and tertiary survey is vital in finding DDI. A high ISS, head injury with AIS ≥2, the need for an emergency intervention and >5 injuries/patient should raise the suspicion of a DDI. The implementation of ATLS® may have led to a low number and earlier discovery of DDIs.

*During the process of the several studies, certain calculations of the ISS scores needed to be revised. The injuries and AIS scores were correct but some ISS scores had been miscalculated. This has led to minor revisions of some results, which did not lead to different conclusions. In this chapter the correct results are displayed and therefore there are some numbers that differ from the published article. These numbers are indicated with an *asterisk. The whole dataset of revised results is displayed in a table in chapter 12.
Delayed diagnosis of injury

References


