Prognostic significance of specific injury patterns in casualties of traffic-related accidents

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A R T I C L E   I N F O

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Fatal
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Injury pattern

A B S T R A C T

Aim: Fatal triad and ipsilateral dyad are patterns of pedestrian injuries related to significant mortality in traffic-related accidents. The aim of this research was to investigate the correlation between specific injury patterns and fatal outcome in other participants of traffic-related accidents.

Methods: This was a retrospective study of traffic-related accidents in the broader area of the city of Osijek in a five-year period from 1995 to 1999. Autopsy results from the Institute of Pathology and Forensic Medicine of the Clinical Hospital Centre Osijek were analysed of individuals who died after their accident. The total severity of injuries was measured using the ISS. Logistic regression analysis was used for assessing the correlation between specific injury patterns and an early outcome from the severe injury.

Results: There were 213 individuals included in the study: 72 pedestrians and 141 other participants (drivers, assistant drivers, passengers, cyclists and motorcyclists). A total of 129 individuals died on the spot and 84 died in the hospital during the first 48 h. Femoral and pelvic fracture, fatal triad and both variants of ipsilateral dyad were related to higher ISS values. Ipsilateral fracture of upper and lower extremities (ipsilateral dyad 1) was associated with a 4.59 times higher risk of an immediate fatal outcome in the total sample. In pedestrians, the risk was 5.99 higher, and in other participants, the risk was 4.11 times higher.

Conclusion: Specific skeletal injuries and injury patterns are a significant indicator for total injury severity and related poor prognosis for all participants of traffic-related injuries, not only for pedestrians. In this study, the ipsilateral fracture of upper and lower extremity was related to the largest total severity of injuries and the poorest prognosis.

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Introduction

A rapid diagnosis of all injuries that endanger the injured person is the basis for successful life saving, particularly during the “golden hour”. Knowledge of the type of collision (head-on, side, rear-end collision, turning over), and particularly the trends in injuries that occur in a certain type of collision, can be an important diagnostic aid for emergency departments because they indicate the possibility that behind the clinically obvious injury lies another, clinically hidden, injury of the same importance and severity [1]. For example, the direction of the collision and wearing a seatbelt are important factors in determining the type of injuries and identifying injured individuals with a high risk of severe injuries [2]. Therefore, while helping the injured in a traffic accident, it would be useful to have information about the collision: strength of the collision, location of the collision spot on the vehicle, usage of seat belts, and severity of vehicle damage. This information would give a better insight into the volume of the collision. Clinically evident skeletal injuries in these cases can be the indicators for searching for barely visible injuries of visceral organs. The injury pattern related to such skeletal injuries, e.g. femoral fracture, is an example of a useful tool for such purposes [3,4].

Pedestrians are the most exposed and vulnerable victims of traffic-related injuries and have the highest morbidity and mortality rate. While investigating the profile and pattern of injuries in pedestrians, Farley introduced the term “fatal triad”, which includes skull fracture associated with pelvic and femoral and/or tibia–fibula fractures, and is associated with a mortality...
rate of 25% [5]. Waddell later redefined this term as associated injuries on the level of the head, pelvis, and hip, and the leg, but he did not find a statistically significant correlation between these three levels [6]. In a study conducted in 1992, Brainard and his associates found two significant fracture patterns called “ipsilateral dyad”, which represents an associated fracture of an upper and lower extremity on the same side and a femoral fracture associated with a pelvic fracture [7]. The “ipsilateral” dyad is important because of the rare occurrence of an upper extremity fracture without a lower extremity fracture on the same side. The importance of the second pattern is related to the fact that a pelvic fracture often stays clinically hidden, but if there is a femoral fracture there should definitely be investigations to look for a pelvic fracture; i.e. pelvic radiography is absolutely indicated [7,8].

Subjects and methods

A total of 278 individuals (208 [75%] men and 70 [25%] women) died in traffic-related accidents in the broader area of the city of Osijek during a five-year period from 1995 to 1999. Autopsy results from the archive of the Institute of Pathology and Forensic Medicine of the Clinical Hospital Centre Osijek were used in this research. General data on casualties, including the time of fatal outcome after injury, and the list of all injuries the individuals suffered during the accident, were extracted from the documentation.

The total severity of injuries was measured using the ISS [7–10].

From the total 278 victims, 129 individuals who died on the spot immediately after the accident (Group A) and 84 individuals who died in hospital within the first 48 h after the accident (Group B) were included in this study. A total of 72 of the 213 individuals included in this study were pedestrians and the other 141 participants were drivers, assistant drivers, passengers, motorcyclists and cyclists.

Statistical analysis

The database into which all the obtained data were inserted was created in the computer programme Access from the MS Office package.

Statistical programme packages STATISTICA (data analysis software system), version 7 (StatSoft, Inc. 2004) and SPSS for Windows 9.0.0 were used for statistical analysis of the data.

Differences in frequency of certain injuries and injury patterns in particular groups of casualties were tested using the Chi-squared test.

Differences in the ISS values as measures of the total injury severity among certain groups of casualties were analysed using the Mann–Whitney U-test and Kruskal–Wallis test.

The significance of correlations between specific injury patterns (fatal triad, ipsilateral dyad) and early outcomes of severe trauma (which is defined as an immediate fatal outcome or death within the first 48 h) was investigated using binary logistic regression analysis.

Results

There were a total of 213 casualties included this study: 27.7% of these casualties suffered a femoral fracture (ipsilateral or bilateral), 38.5% a pelvic fracture, 12.7% a fatal triad (skull fracture together with pelvic and lower extremity fracture), 21.1% an ipsilateral dyad 1 (concomitant fractures of upper and lower extremity on the same side), and 15.9% an ipsilateral dyad 2 (femoral fracture associated with a pelvic fracture).

A between-group comparison of the occurrence of such injuries and injury patterns showed that femoral fracture was more common in group A (immediately deceased) than in group B (died within the first 48 h) (p = 0.0037). Fatal triad (p = 0.0066) and ipsilateral dyad 1 (p = 0.0004) were also more common in group A compared with group B. There were no significant differences in the occurrence of isolated pelvic fracture and ipsilateral dyad 2 between the two groups (Table 1).

An investigation into the frequency of these injuries between groups, separately for pedestrians and other participants (pattern of injury), revealed similar results for pedestrians: femoral fracture, fatal triad and ipsilateral dyad 1 were more common injuries in pedestrians who died on the spot immediately after the accident compared with those who died within the first 48 h (p = 0.0308, p = 0.0339 and p = 0.0339, respectively). In other participants, femoral fracture and ipsilateral dyad 1 were more common in those who died immediately compared with those who died within 48 h (p = 0.0168 and p = 0.0098, respectively), whereas

<table>
<thead>
<tr>
<th>Table 1</th>
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</thead>
<tbody>
<tr>
<td>Frequency of specific injury patterns in casualties who immediately deceased (Group A) and those who died within the first 48 h (Group B).</td>
</tr>
<tr>
<td>Total (N=213)</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>Femoral fracture</td>
</tr>
<tr>
<td>Pelvic fracture</td>
</tr>
<tr>
<td>Fatal triad</td>
</tr>
<tr>
<td>Ipsilateral dyad 1</td>
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<tr>
<td>Ipsilateral dyad 2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pedestrians (N=72)</th>
<th>Immediately deceased (N=41)</th>
<th>Deceased within the first 48 h (N=31)</th>
<th>Chi-squared test (df=1)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Femoral fracture</td>
<td>12 (29.27%)</td>
<td>5 (16.13%)</td>
<td>1.04</td>
<td>0.308</td>
</tr>
<tr>
<td>Pelvic fracture</td>
<td>18 (43.90%)</td>
<td>15 (48.39%)</td>
<td>0.02</td>
<td>0.8892</td>
</tr>
<tr>
<td>Fatal triad</td>
<td>12 (29.27%)</td>
<td>2 (6.45%)</td>
<td>4.50</td>
<td>0.0339</td>
</tr>
<tr>
<td>Ipsilateral dyad 1</td>
<td>12 (29.27%)</td>
<td>2 (6.45%)</td>
<td>4.50</td>
<td>0.0339</td>
</tr>
<tr>
<td>Ipsilateral dyad 2</td>
<td>8 (19.51%)</td>
<td>4 (12.90%)</td>
<td>0.18</td>
<td>0.6703</td>
</tr>
<tr>
<td>Other (N=141)</td>
<td>Immediately deceased (N=88)</td>
<td>Deceased within the first 48 h (N=53)</td>
<td>Chi-squared test (df=1)</td>
<td>p</td>
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</tr>
<tr>
<td>Femoral fracture</td>
<td>33 (37.50%)</td>
<td>9 (16.98%)</td>
<td>5.71</td>
<td>0.0168</td>
</tr>
<tr>
<td>Pelvic fracture</td>
<td>31 (35.23%)</td>
<td>18 (33.96%)</td>
<td>0.02</td>
<td>0.8786</td>
</tr>
<tr>
<td>Fatal triad</td>
<td>11 (12.50%)</td>
<td>2 (3.77%)</td>
<td>2.06</td>
<td>0.1515</td>
</tr>
<tr>
<td>Ipsilateral dyad 1</td>
<td>26 (29.53%)</td>
<td>5 (9.43%)</td>
<td>6.67</td>
<td>0.0098</td>
</tr>
<tr>
<td>Ipsilateral dyad 2</td>
<td>17 (19.32%)</td>
<td>5 (9.43%)</td>
<td>1.76</td>
<td>0.1845</td>
</tr>
</tbody>
</table>

* Yates’ correction.
the frequency of fatal triad did not prove significantly higher. There were no significant differences in the occurrence of isolated pelvic fracture and ipsilateral dyad 2 between groups A and B in any of the analyses conducted (Table 1).

Casualties in the total sample who had femoral fracture, pelvic fracture, fatal triad or ipsilateral dyad 1 had a significantly higher ISS, whereas casualties who had injuries according to ipsilateral dyad 2 did not differentiate significantly in overall ISS. Similar differences in total injury severity were seen when the group of pedestrians and other participants were analysed separately (Table 2).

As shown in Tables 1 and 2, ipsilateral dyad 1 was associated with the lowest p-values in the analysis of frequency differences with the Chi-squared test and in the analysis of differences in the total ISS measured with the Mann–Whitney U-test; therefore, further analyses were conducted for only this pattern of injuries.

The Kruskal–Wallis test was used to assess the differences in total ISS between groups A and B in those with or without ipsilateral dyad 1 (associated fractures of an upper and lower extremity on the same side). The total ISS in group A (those who died immediately after the accident) in patients who had sustained head injuries that meet the criteria of the ipsilateral dyad 1 was significantly higher than in those whose injuries did not meet these criteria regardless of the time of fatal outcome (i.e. immediately or within the first 48 h) (Table 3).

Hence, the ipsilateral dyad 1 is a criterion that has successfully restricted two groups of casualties according to the total injury severity measured with ISS even in the group of individuals who died immediately: individuals who had injuries that met the criteria of this pattern had the highest ISS values. This pattern was therefore inserted into the binary logistic regression analysis as an independent categorical value to investigate the risk of an individual who has these injuries having a fatal outcome immediately after being injured. This analysis was conducted separately for all examinees and separately for pedestrians and for other participants (drivers, assistant drivers, passengers, cyclists and motorcyclists).

The results indicate that the risk of immediate fatal outcome in the total sample was 4.59 times higher in individuals with associated ipsilateral fracture of an upper and lower extremity (ipsilateral dyad 1). The 95% reliability interval showed that the risk growth was moving between 1.94 and 10.87 times. The same analysis showed that the immediate fatal outcome risk for the pedestrian group was 5.99 times higher (95% reliability interval from 1.23 to 29.15 times), and in the group of other participants, the risk was 4.11 times higher (95% reliability interval from 1.33 to 12.71 times) (Table 4).

Discussion

Bone fractures of the skull, pelvis and other skeletal bones indicate the high kinetic energy that is transmitted to the body in traffic-related traumas. Such large amounts of kinetic energy on the body also increase the risk of associated soft tissue injury and subsequent haemorrhage, which directly and indirectly threaten the life of the casualty during the first minutes after trauma [11,12].

The presence of bone fractures, which are often visible on clinical examination, can be an important diagnostic aid in the pre-hospital treatment of individuals injured in traffic-related accidents: clinically-visible skeletal fractures can be an extra criterion in diagnosing a severely injured individual.

Fatal triad and both variants of ipsilateral dyad (associated fracture of an upper and lower extremity on the same side [dyad 1] and femoral fracture associated with pelvic fracture [dyad 2]) are injury patterns that are related to high mortality; the significance of these injury patterns is investigated primarily in pedestrians.

Brandar and associates conducted a study in 1992 that comprised 115 deceased pedestrians after a motor vehicle collision and found no significant correlation between skull fractures, pelvic fractures and lower extremity fractures (fatal triad) [7]. Conversely, they found a statistically significant correlation between the ipsilateral upper and lower extremity fracture (ipsilateral dyad 1) and lower extremity fracture associated with pelvic fracture (ipsilateral dyad 2) [7].

Table 3

<table>
<thead>
<tr>
<th>Total injury severity measured with ISS Kruskal–Wallis test (p)</th>
<th>Immediately deceased (N=129)</th>
<th>Deceased within the first 48 h (N=84)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>With ipsilateral dyad 1 (N=38)</td>
<td>Without ipsilateral dyad 1 (N=91)</td>
</tr>
<tr>
<td>Immediately deceased</td>
<td>0.0266</td>
<td>0.0685</td>
</tr>
<tr>
<td>Deceased within the first 48 h</td>
<td>0.0685</td>
<td>&gt;0.9999</td>
</tr>
</tbody>
</table>

* Kruskal–Wallis test (H (3, N=213)=69.69795; p < 0.0001).

Table 4

<table>
<thead>
<tr>
<th>Samples</th>
<th>β coefficient</th>
<th>Standard error of β</th>
<th>Odds ratio</th>
<th>95% Confidence interval</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedestrians (N=72)</td>
<td>1.7912</td>
<td>0.8075</td>
<td>5.9952</td>
<td>1.2301–29.1545</td>
<td>0.0265</td>
</tr>
<tr>
<td>Non-pedestrians (N=141)</td>
<td>1.4142</td>
<td>0.5755</td>
<td>4.1130</td>
<td>1.3312–29.1545</td>
<td>0.0140</td>
</tr>
<tr>
<td>Total (N=213)</td>
<td>1.5243</td>
<td>0.4394</td>
<td>4.5921</td>
<td>1.9407–10.8660</td>
<td>0.0005</td>
</tr>
</tbody>
</table>

β—explanatory variable coefficient.
In the current study, a total of 213 fatal casualties were analysed: 72 were pedestrians and 141 were other participants (drivers, assistant drivers, passengers, cyclists and motorcyclists). The casualties were divided into those who died immediately (Group A = 129) and those who died after medical treatment, pre-hospital or in hospital, within the first 48 h (Group B = 84).

Ndiaye and associates [13] reported that the ratio of those who died on the spot immediately after trauma made up three-quarters of the total number of deceased.

Nikolić and associates [14], in their 2001 study, described a sample of deceased individuals after traffic-related accidents in which 50% were pedestrians.

The aim of this research was to determine whether specific skeletal injury patterns can be used as parameters to signify extremely heavy trauma in pedestrians and other participants and to indicate risk of immediate fatal outcome.

In this study, separate analysis of the whole pattern for pedestrians and other participants showed that the frequency of pelvic fractures and ipsilateral dyad 2 (femoral fracture associated with a pelvic fracture) was not significantly different between individuals who died immediately and those who died within the first 48 h after trauma.

In their 2011 study, Papadopoulos and associates showed that deceased individuals with pelvic fracture had a significantly higher number of associated injuries, a significantly higher total severity of injuries measured using ISS, and a significantly lower survival time compared with deceased individuals with no pelvic fracture [15].

The fatal triad was more common in those who died immediately in the overall sample and in pedestrians, whereas in other participants, the fatal triad was not common in those who died immediately. Femoral fracture and ipsilateral dyad 1 were more common in those who died immediately in each of three separate analyses: total sample, pedestrians, and other participants.

Analysis of the difference in total injury severity (ISS) showed that individuals who suffered injuries that met the criteria for ipsilateral dyad 1 had a significantly higher total injury severity regardless of the type of participant involved (total sample, pedestrians, and other participants).

Other injuries and injury patterns did not show a significant differentiation between those who immediately deceased and those who died within the first 48 h.

Brainard and associates also emphasised the ipsilateral dyad 1 as a sample of injuries that requires special attention because it is related to more associated injuries, a higher total injury severity and a poorer prognosis [7].

In contrast, Landy and associates claim in their 2010 study that no correlation was found between upper and lower extremity fractures, or between upper and lower extremity fractures with vertebral fractures [4]; however, these findings were limited by the lower representation of severe trauma cases in their study [4].

Only the ipsilateral dyad 1 was included in the current paper because of the strong significance in previous analyses: the difference in total injury severity was measured in individuals with or without ipsilateral dyad 1 who died immediately and those who died within the first 48 h, also with or without the ipsilateral dyad 1. Individuals who died immediately with injuries according to the ipsilateral dyad 1 had a significantly higher total injury severity than those who died immediately without the ipsilateral dyad 1 and than those who died within the first 48 h without this pattern. It is interesting that individuals who died immediately with ipsilateral dyad did not differentiate significantly in total injury severity (ISS) from persons who did not die on the spot and had injuries that meet the criteria of this pattern.

Finally, the impact of ipsilateral dyad 1 (among the other injuries sustained) on relative risk of immediate fatal outcome was assessed in the total sample, in pedestrians and in other participants.

In the total sample of casualties, individuals with injuries that met the criteria of ipsilateral dyad 1 had a 4.59 times higher risk of immediate fatal outcome compared with individuals without the ipsilateral dyad 1. In separate analyses, for the pedestrian group this risk was almost 6 times higher and for the other participants group it was 4.11 times higher.

**Conclusion**

Data from this study indirectly confirm that individuals who are involved in traffic-related accidents sustain injuries according to the type of specific patterns, and have a high total amount of injuries that directly threaten their lives. The ipsilateral upper and lower extremity fracture is particularly important: polytrauma-tised individuals who have these injuries, among others, require special attention and emergency treatment.

**References**