Severe Injuries in Passenger Cars – Development of a Software Tool for Emergency Diagnostics

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Abstract

In Germany averagely two million traffic accidents happen each year and emergency medical services are called to more than 400 000 patients. Even though this number is decreasing continuously (due to improvements in the fields of vehicle safety, road construction, and accident prevention) every case is yet a challenge for the rescuers and requires improvements in emergency medicine as well. Especially during diagnostics right at the accident scene, there are only limited instruments available to gain the necessary knowledge of the injuries suffered, to come to essential decisions about treatment or transport. To provide an additional diagnostic aid by scouting and estimating the situation, a software-tool calculating the likeliness of the most frequent severe injuries (AIS 3-6) of front occupants in passenger cars has been developed to deliver this necessary information about particular accident scenarios. To achieve this, logistic likelihood functions have been calculated in a multivariate regression analysis analysing all AIS 3+ injuries in the GIDAS database of the years 1999-2006 that happened more than four times.

Introduction

Especially after traffic accidents, that make up 25% and thus the largest portion of all trauma fatalities [18], it is often difficult to comprehend all injuries immediately and weight them regarding their urgency of treatment. On one side there is often the problem that the patient is not easily accessible right away and on the other side slighter superficial injuries may distract from severe inner trauma. In addition to that the confrontation with a severely injured crash victim always embodies a critical situation, especially for less experienced emergency physicians. It is then particularly essential to use all hints and information available for the diagnostic investigation. Due to the fact that the treatment of crash victims requires crucial decisions regarding necessary forces, on-spot treatment, transportation and appropriate hospitals, a thorough comprehension of all threatening single injuries is absolutely vital.

Using a software-based calculation of the most likely injuries on the basis of a few easily accessible parameters at the accident scene, these analyses offer an aid for thorough diagnostics. The tool can point out expected injuries and already call attention to important diagnostic steps before the actual examination. Beside the analysis of injuries that are only obvious if the patient is freely accessible, both inner traumata that can even slip the attention of a thorough initial examination, and brain injuries that can always lead to "talk and die" situations due to delayed manifestation, are considered.

Used Data

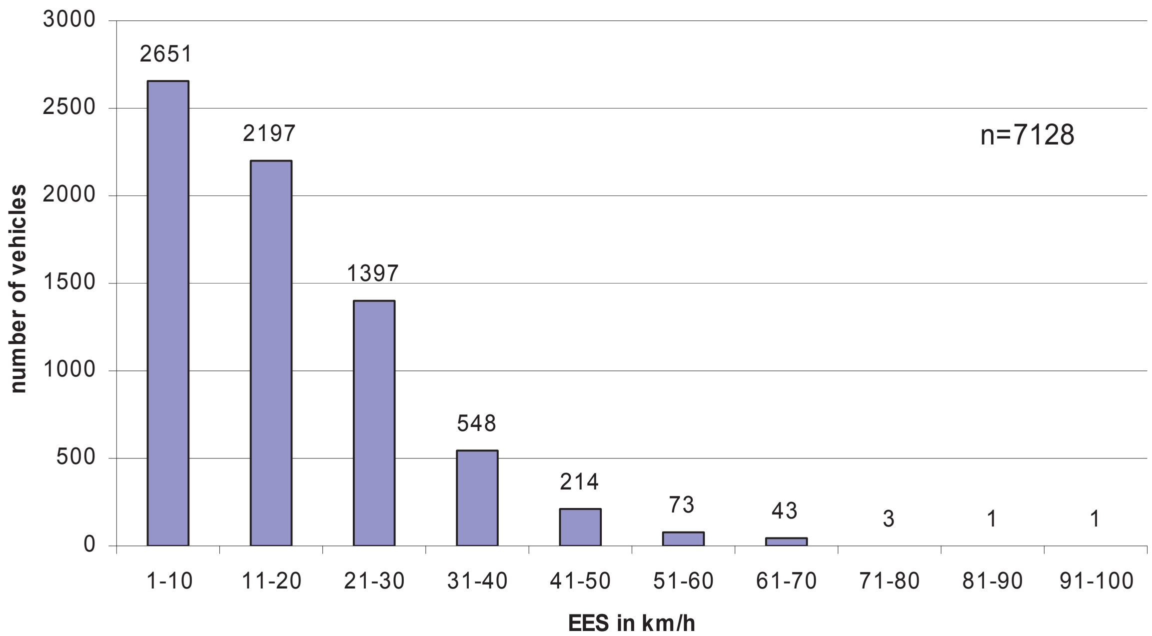
For this study the GIDAS database of the years 1999-2006 was used, using data from Dresden as well as Hanover. The used data base copy from 15 May 2006 included 8839 reconstructed cases with 22768 involved persons. Since only passenger car occupants are considered in this study, only automobiles and limousines were included. In addition to that only front occupants were considered, because from experience [10] there are only enough cases for those. Accidents with a rollover were also excluded.

The master dataset does now include 5010 accidents involving 7128 vehicles and 9106 drivers or front-seat passengers. In these accidents 342 people suffered 768 AIS 3+ injuries and injuries of unknown severity. These injuries were available for the analyses.

Descriptive Analyses

EES Distribution in the Dataset

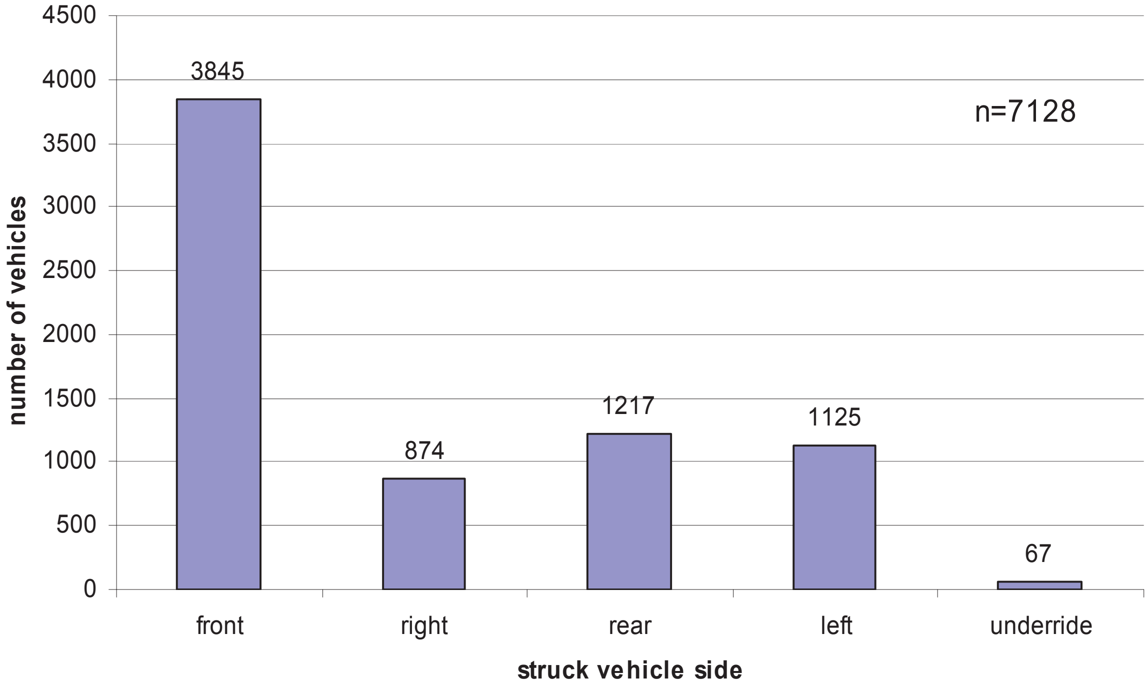
Since slight accidents do of course happen more often than severe collisions at high speeds, the number of GIDAS cases reduces considerably for higher EES values [picture 1]. Due to that fact a statistical evaluation with a univariate analysis can be rather difficult, because after a classification there are only smallest sample sized left.



Picture 1 - EES Distribution in Dataset [Source: GIDAS]

Struck Side Distribution in the Dataset

The distribution of the struck vehicle side [picture 2] shows that collisions on the vehicle front are expectedly most frequent. This fact has been shown in several studies before [6,16,22] and can partly be derived from the usual forward driving direction. Collisions on the left vehicle side were 1.3 times more frequent than collisions on the right vehicle side.



Picture 2 – Struck Side Distribution in Dataset [Source: GIDAS]

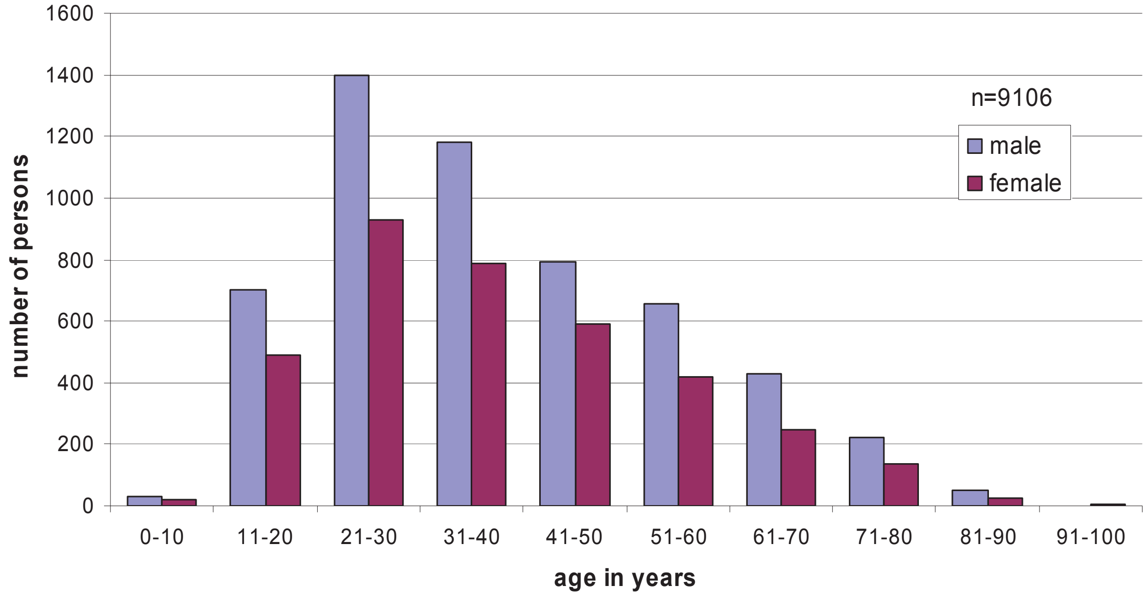
Seat Belt Usage Rate in the Dataset

The analysis of the seat belt usage rate showed that 96% of all front occupants used their seatbelts during the collision. This portion is consistent with the official belt usage rates of the German federal road research institute. Here the total belt usage rates of adult passenger car occupants indicates 97% average in 2006, 96% in 2005, and 93%-95% for the years 1999-2004. [5]

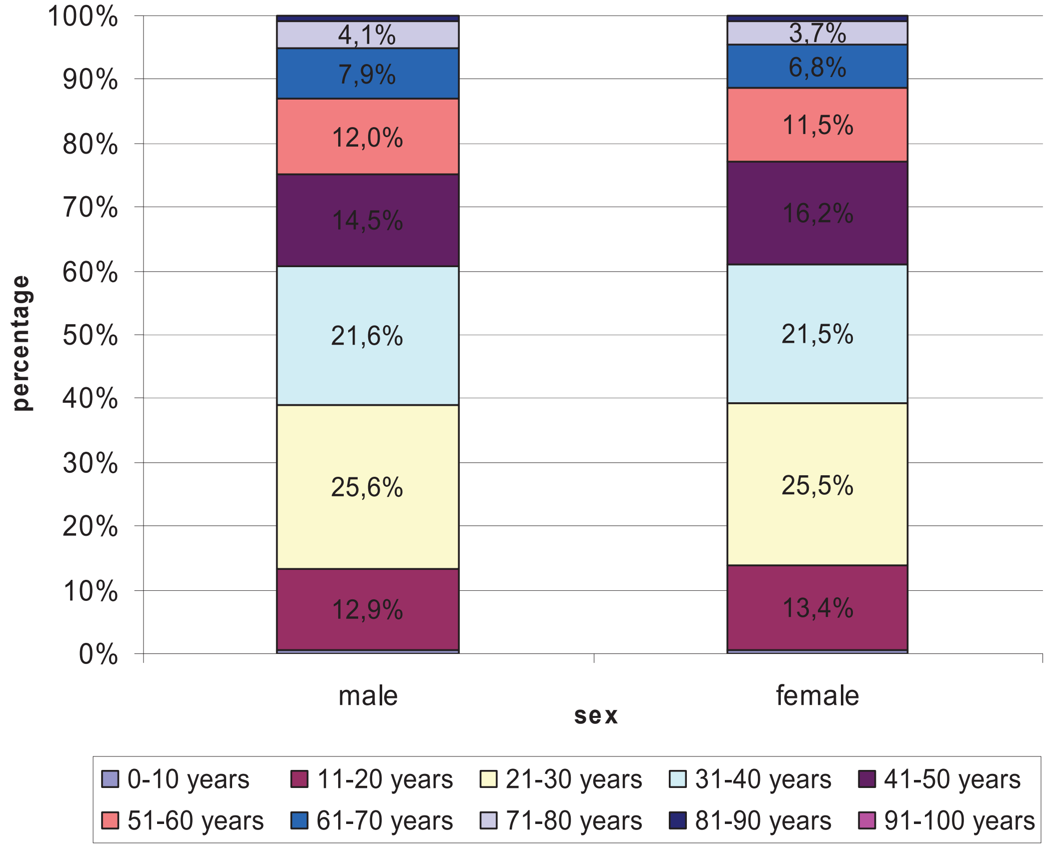
Age and Sex Distribution in the Dataset

The age distribution of the occupants showed that twenty to thirty year old occupants made up the largest group in the dataset [picture 3]. Younger occupants were by far less often involved. This could be due to the age of acquiring a driver's licence and also to the fact that children are often sitting in the rear passenger compartment [21] because of the assumed lower injury risk [4,9,23].

Considering the occupant sex distribution it can be shown that male occupants are overrepresented (59.9%) while no difference in the age distribution appeared here [picture 4].



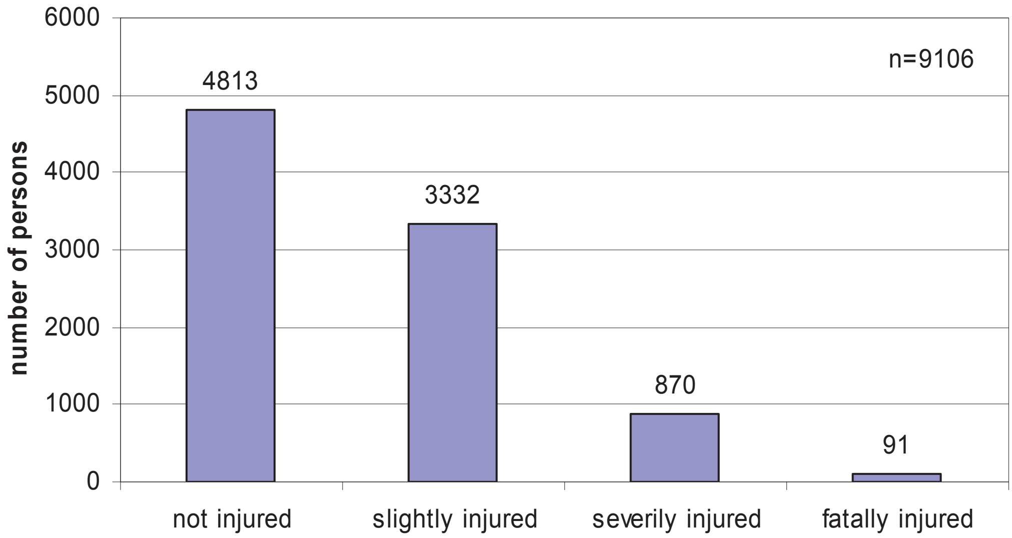
Picture 3 – Occupant Age and Sex Distribution [Source: GIDAS]



Picture 4 – Age and Sex Distribution (normalized) (n=9106) **[Source: GIDAS]**

Injury Severity Distribution in the Dataset

As expected the distribution of the injury severity showed that the greatest part of occupants (89.4%) was not or only slightly injured [picture 5]. It has to be considered though, that this is only representative for accidents where at least one involved person got injured indeed, because of the statistical sample scheme for the GIDAS data collection.



Picture 5 – Injury Severity Distribution [Source: GIDAS]

Overview Most Frequent Single Injuries in the Dataset

In the following table [table 1] all injuries with an AIS severity of three or higher are listed (if they could be found at least four times in the dataset):

injury	AIS value	number in dataset	injury	AIS value	number in dataset
brain injury	3+	132	severe spleen injury	3-5	16
femoral fracture	3	87	lung rupture	3+	11
multiple rib fractures	3-5	81	humeral fracture open/displaced/comminuted	3	10
pulmonary contusion	4	44	intimal injury/rupture thoracic aorta	4+	9
skull base fracture	3	38	contusion/laceration spinal cord	3+	9
hemo- and/or pneumothorax	3-5	34	midfacial fracture Le Fort III	3	8
pelvic fracture	3-5	34	jejunum/ileum rupture	3+	8
cervical spine fracture	3	26	complex fracture calvaria	3+	6
tibial fracture open/displaced/comminuted	3	25	extended contusion/rupture kidney	3-5	5
forearm fracture open/displaced/comminuted	3	22	thoracic spine fracture	3	5
severe liver injury	3+	18	rupture abdominal vessel	3-5	5
severe heart injury	3+	16	ankle joint fracture	3	5

Table 1 - AIS 3+ Injuries in GIDAS

As an examples the following injury will be explained:

Brain Injury

According to the AIS catalogue brain injuries AIS 3+ include the following traumata: all intracranial vessel ruptures, brain stem / cerebellum / cerebrum lesions confirmed by diagnostic imaging, or unconsciousness with neurological involvement or duration of more than one hour. [1]

Methods

Description Energy Equivalent Speed

The energy equivalent speed is a measure of the kinetic energy that was converted into deformation work during the collision of the relevant vehicle [3]. It represents the speed that displays the deformation work for the vehicle in one single value. It equals the speed of the vehicle that would have been necessary to cause the same damage in a collision with a rigid, not deformable barrier. Physical basis of the EES reconstruction are the energy conservation law, the linear momentum conservation law, and the angular momentum conservation law.

For the exact calculation of the EES there are several possible approaches, such as the methods of Cambell and Rau [14]. These do, however, need a lot of mathematical effort and are thus not applicable for a rough EES evaluation at the accident scene. It is hence customary in accident research to estimate the value according to catalogues that show deformations of the same vehicle type. Since this method is also difficult to use at the accident scene, a rough estimation with limited information about type specifications is used.

For an estimation of the EES value the overlapping ratio, the intrusion and the deformation of supporting elements are particularly important. The overlapping ratio characterizes the contact area of the vehicle and the collision opponent or object. This area correlates directly with the intrusion, because the force can affect a larger or a smaller region. Consequently the amount of energy transformed in a small overlapping area (e.g. in a tree or a pole collision) is comparatively high, leading to a deeper intrusion than in a collision with a high overlapping ratio (e.g. in a collision with a wall).

The greatest advantage of the EES for this analysis is the possibility for trained emergency personnel to use it for a rough evaluation of the accident severity right at the accident scene, even though an exact calculation is of course reserved to accident specialists. For this rough evaluation of the accident severity a detailed manual with sketches and photos has been developed to go with the software-tool.

Statistical Analysis

For the evaluation of a covariate regarding a resulting event there are univariate and multivariate methods available. The influencing factors may, however, have different impact in univariat and multivariate analyses. Koch states [12] that this leads to the conclusion, that univariate analyses can be falsified by bias that may be detectable in multivariate models. As this study aimed to calculate the influence of given parameters the analysis was performed with a multivariate model only. This way affected influences and concealed influences in the univariate analysis and correlations between the parameters were considered in the calculations.

As analyses using logistic regression offer the possibility to examine different influencing factors regarding an empirically obtained complementary result, the method is often used for medical questions such as disease risks, survival chances, or injury risk. The logistic regression model can calculate the chance of belonging to a specific group (or category of the dependent variable) depending on one or more independent variables. Since logistic functions are used for the estimation, logistic regression models belong to the non-linear algorithms. This characteristic is necessary because a linear regression model would allow negative values as possible results.

Like all structure checking algorithms the logistic regression analysis requires the user to logically decide about the possible categories of the dependent variable and the influencing factors that define the likeliness [2]. For this study, the considerations about these influencing factors had to mind different criteria. Only variables that are recorded in GIDAS and encoded in the database could be used. Furthermore these parameters had to be obvious and easily acquirable at the accident scene for a fast and functional utilization. The third restriction was the user himself. As especially medical personnel makes up the target group, only parameters that get along with basic technical knowledge instead of engineering know-how could be used. In different studies and works the chosen parameters were proven to be among the most important factors [7,8,13,15,17,19,24] which were hence used for the analysis: a rough EES estimation, the struck vehicle side regarding the main deformation, the seat belt status, and the age and sex of the patient.

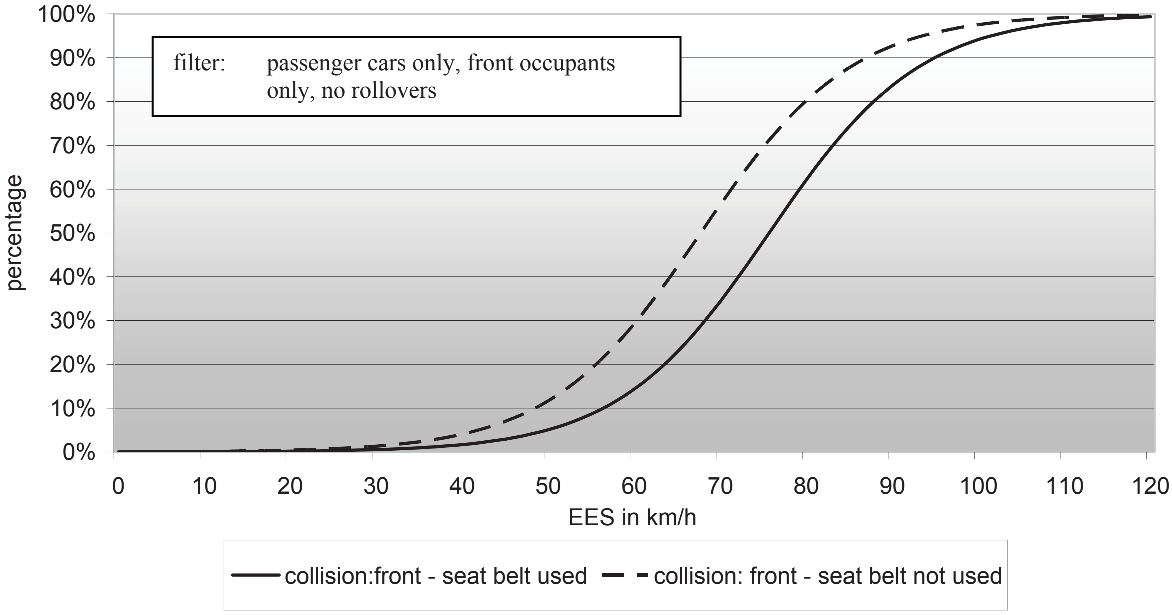
The logistic regression analysis uses the maximum likelihood method to estimate the model parameters. The aspired aim is to maximize the likelihood that the observed results are obtained by optimizing the assumption for the different parameters. In SPSS this maximization of the likelihood function is processed using the Newton-Raphson-Algorithm. This algorithm iteratively changes the estimated parameters until the resulting values of the independent variable maximize the likelihood of one specific event. [2] According to the p-value the single parameters are included or excluded in the analysis. The p-value itself specifies the likelihood that (accepting the null hypothesis) the obtained values or values diverging the null hypothesis are obtained. If this p-value is smaller than the default risk α for a false decline of the true null hypothesis, a statistically significant result is obtained [11]. In this study the default value for α was set to 0.1 (10%) to include as many parameters as possible.

The likelihood for the appropriate event can finally be calculated using the regression coefficients and the logistic function. Therefore the regression coefficients of the specific parameters and the constant $ß_0$ are included in one equation to calculate the combined influence z to estimate the likelihood of a specific injury depending on the chosen parameters. To verify the models the ROC-curve, the AUC-value and the Hosmer-Lemeshow-Test were used.

Analysis

Example: Brain Injuries

There were 132 brain injuries available for the analysis. After excluding all unknown injuries 9100 cases were included in the analysis. In the iterative regression analysis the EES, the struck vehicle side and the seat belt status were included according to their p-value. The different likelihoods for a brain injury AIS 3+ suffered by a specified patient were calculated. An example for frontal collision is given in picture 6.



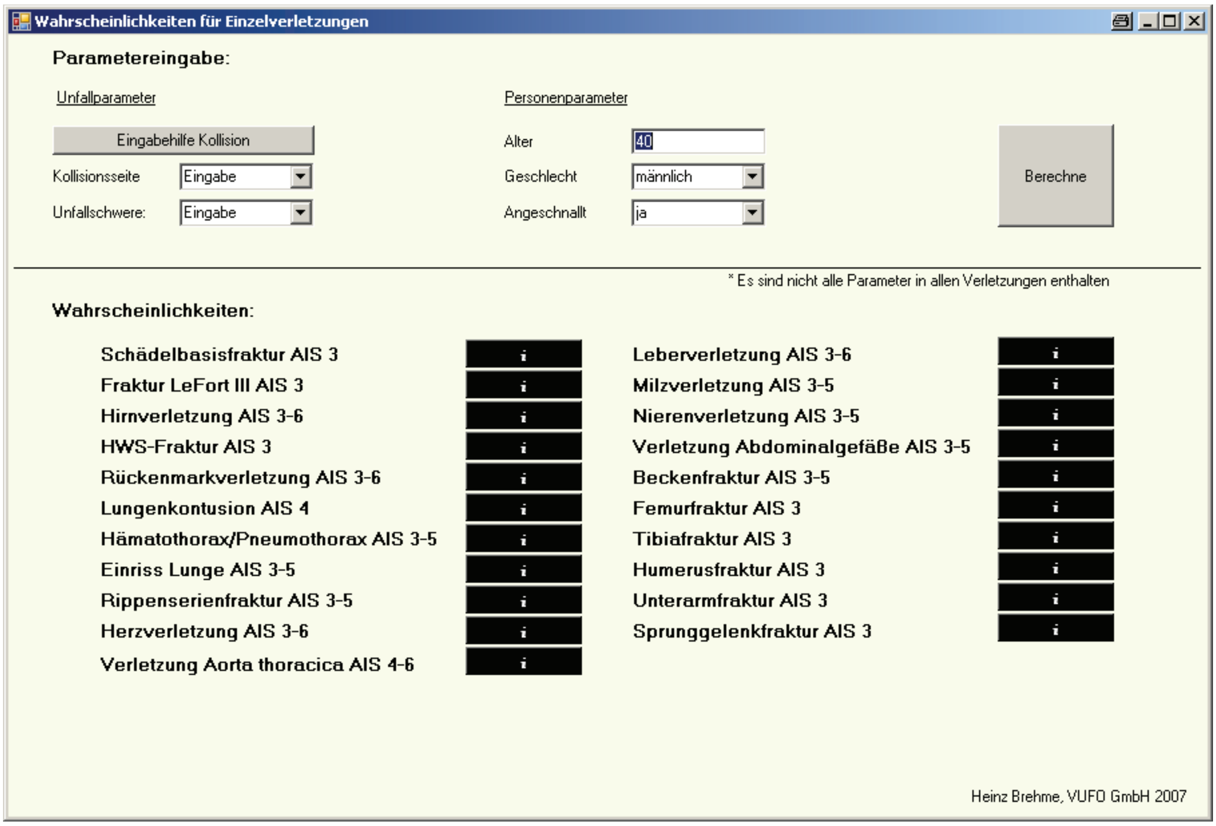
Picture 6 – Brain Injury – Collision: Front

The analysis showed that the highest risk to suffer a brain injury AIS 3+ exists for accidents with an underride collision, followed by collisions to the side of the vehicle. The differences between left and right are only marginal. In frontal and rear end collisions there is the lowest risk. Additionally all collision sides show that the injury risk is notably higher if the patient did not use a seatbelt. For the other parameters (age, sex) statistically significant differences to these values could not be shown.
To verify the quality of the model the ROC-curve and the AUC-value were calculated. With an area under the curve of 0.936 the model adjustment lies far above the null hypothesis of 0.5. The Hosmer-Lemeshow test showed a p-value of 0.310 and verified the good model fit as well.

Utilization of the Results in the Software-tool

To make the results available at the accident scene a software-tool was developed that calculates the likelihood for a specific injury in three gradations according to the input of the necessary parameters.

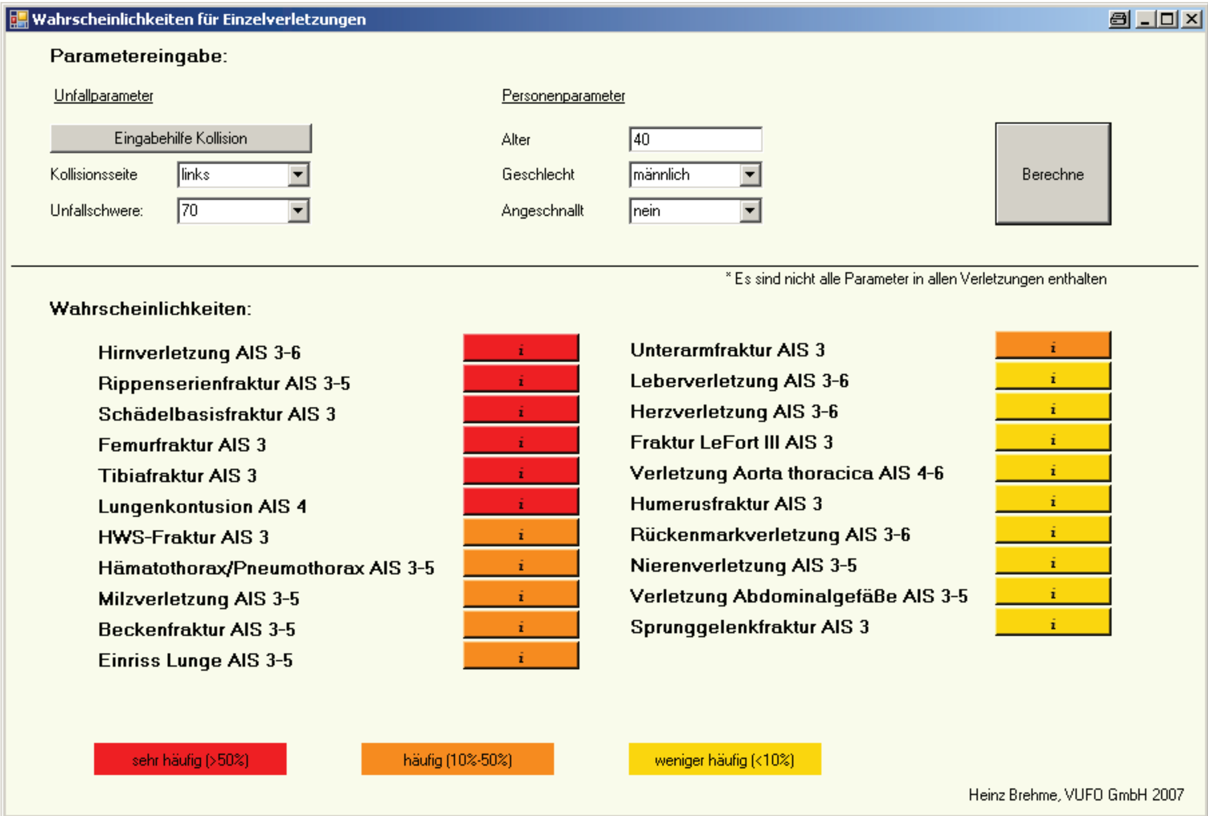
In the upper part of the initial screen [picture 7] the parameters collision side, accident severity, age, sex and seat belt status can be entered. For the collision parameters “collision side” and “accident severity” there is an additional help menu given. The collision parameters are mandatory while there are default values pre-set for the person parameters.



Picture 7 – Initial Screen Software-tool

Using the help button for the collision parameters the menu for the collision side is started where a choice of the side leads to another help menu for the accident severity estimation. Here the accident severity is explained with different short texts and sketches. When the particular picture is selected the values are automatically transferred to the initial screen.

As soon as the “start-button” is selected the likelihood for each injury is calculated and the injuries are given in the correct order. Values below 10% are given in yellow, values between 10% and 50% are depicted in orange and very likely injuries with values above 50% are shown in red [picture 8].



Picture 8 – Output Screen Software-tool

Behind the injuries there are info-buttons. After a short click the exact definition of the injury is given and the parameters that were included in the calculation are listed.

If the parameters are changed, the tool can be restarted and the new likelihoods for the injuries will be calculated.

Conclusions

In Germany averagely two million traffic accidents happen each year and emergency medical services are called to more than 400 000 patients [20]. Even though this number is decreasing continuously (due to improvements in the fields of vehicle safety, road construction, and accident prevention) every case is yet a challenge for the rescuers and requires improvements in emergency medicine as well. Especially during diagnostics right at the accident scene there are only limited instruments available to gain the necessary knowledge of the injuries suffered, to come to essential decisions about treatment or transport. To provide an additional diagnostic aid by scouting and estimating the situation, a software-tool calculating the likeliness of the most frequent severe injuries (AIS 3-6) of front occupants in passenger cars has been developed to deliver this necessary information about particular accident scenarios.

In a multivariate regression analysis using the parameters EES, collision side, age and sex of the patient and the seat belt status, logistic risk functions have been calculated for all AIS 3+ injuries that happened more than three times in the GIDAS data of the years 1999-2006. That way statistical models were developed for twenty different injuries that provide information about the likelihood of these traumata for a front occupant of a passenger car involved in a traffic accident. With the development of a comprehensive instruction for the estimation of the accident severity that has been verified in another study, the calculated models were utilized in a software-tool. Having knowledge about the likelihood of the severe injuries given in a comprehensible chart, a faster start of diagnostics of not easily accessible patients can be achieved and the attention of the rescue staff can be drawn to less obvious injuries or injuries that are concealed by impressive superficial traumata, immediately.

Finally the given software-tool shall by no means replace or hold up any part of a physical examination but rather extend and expedite the restricted diagnostic possibilities at the scene of an accident to ease necessary decisions about emergency treatment, calling additional rescue forces, transport and appropriate hospitals.

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