Impact of the New Diagnostic Dictionary (AIS 2015) for Traffic Accident Research

Thomas Unger, Henrik Liers, Roxana Schuster, PD Dr. Christian Kleber

Abstract With the publication of the AIS revision of 2015 by the Association for the Advancement of Automotive Medicine a classification of injury severity is available that reflects the current status in the care of road accident victims and their probability of survival. The aim of this study is to forecast the number of injured road users of MAIS 2+ and MAIS 3+ in Germany. In addition, the influence of the use of several AIS revisions on injury severity distributions is shown. The work bases on data from the German In-Depth Accident Study.

The results reveal a decreased severity of individual injuries in specific body regions. On the other hand, some individual injuries were shifted to higher AIS values in the 2015 AIS code revision. The proportion of MAIS 3+ injured persons in the German study increased by 4%. For cyclists, the increase is even at 6%.

The findings of this study are very important, as many safety systems, regulations, and consumer assessments focus on such groups, especially on MAIS 3+. The application of the AIS Revision 2015 will lead to a better understanding of the severity of road accidents and poses a cornerstone for the comparability of different AIS codes.

Keywords: Accident, AIS,GIDAS, injuries, road safety.

I. INTRODUCTION

With the publication of the Abbreviate Injury Scale (AIS) revision of 2015 by the Association for the Advancement of Automotive Medicine (AAAM), an injury severity classification exists that reflects the current medical status in the treatment of road accident victims and their probability of survival. It is therefore desirable that the current AIS revision is also applied in ongoing accident research initiatives, traffic accident registries, and biomechanical studies. Nevertheless, it is necessary to retain previous revisions, e.g. AIS1990 Revision 1998 and AIS2005 Update 2008, to enable comparative evaluations and time series analyses. Upward and downward compatibility between different AIS revisions in accident databases is therefore essential and fundamental for scientific comparison of collectives based on different versions of the AIS code.

The aim of the presented work is to predict the number of the Most Abbreviated Injury Scale MAIS 2+ and MAIS 3+ injured road users in Germany on the basis of the German In-Depth Accident Study (GIDAS). Recent consensus is that MAIS 2+ and 3+ involves severe injury levels and therefore pose protection goals for innovations of care safety. Furthermore, the influence of the use of different AIS revisions on the distribution of individual and total injury severities should be illustrated.

II. METHODS

The work is mainly based on GIDAS data. GIDAS is a collaborative project of the Federal Highway Research Institute (BASt) of Germany and the Research Association of Automotive Technology (FAT e.V.). It started in 1999 and includes accident data from two investigation areas (in/around Dresden/Saxony and Hanover/Lower Saxony). In these areas about 2,000 accidents with personal damage are investigated per year, reconstructed and recorded in the GIDAS database with approximately 3,500 single information per case. To accomplish a comprehensive review of each recorded traffic accident, sensible and thorough coding of suffered injuries is indispensable. This is done on the basis of medical protocols, CT, MRT and X-ray images and medical discharge reports. GIDAS data is considered to be representative for the German accident scenario with personal damage after applying weighting procedures to the data.

T. Unger is Head of the department Data Analysis and Simulation at the Verkehrsunfallforschung an der TU Dresden GmbH (VUFO) (Tel. +49 351 43898935, thomas.unger@vufo.de). H. Liers is CEO and Data Analyst at VUFO. R. Schuster is a medical PhD student at TU Dresden. PD Dr. C. Kleber is Senior Consultant at the UniversityCenter for Orthopedics and Trauma Surgery at the University Hospital Carl Gustav Carus in Dresden.

The Abbreviated Injury Scale (AIS) by AAAM offers a valuable solution to achieve this goal. This study analyses the changes between several AIS revisions and computes the corresponding impact on overall injury severities, allocation to different collectives (MAIS 2+ / MAIS 3+) of road traffic casualties.

The Abbreviated Injury Scale

The first publication of the Abbreviated Injury Scale (AIS) was in 1969 and since then the system has undergone continuous development in the form of revisions. The nine available revisions of the AIS are 1969, 1976, 1980, 1985, 1990, 1998, 2005, 2008 and 2015. The respective revisions take into account the ongoing development in the treatment of traumatic injuries, probability of survival, morbidity and outcome.

The most recent AIS revisions, *AIS 1990 Revisions 1998* (hereinafter referred to as *AIS 1998*) and *AIS 2005 Update 2008* (hereinafter referred to as *AIS 2008*) are frequently used in the context of road and vehicle safety. The AIS code is part of the international Injury Severity Score to classify multiple trauma patients and adjust the trauma burden on each patient. The recently published *AIS Revision 2015* is not yet very often used in publications and papers.

With the AIS an anatomically-based dictionary for trauma is available where the injury descriptions and severities are standardized. The basic principle of the injury scale is the translation of injuries into codes. Each description is assigned to a unique six digit code consisting of five parts, categorized into body region (1st digit), type of anatomical structure (2nd digit), type of injury (3rd and 4th digit), level (5th and 6th digit) and severity (7th digit; after the dot). In this way, more than 2,000 injuries are stored in a catalogue and assigned to a unique code.

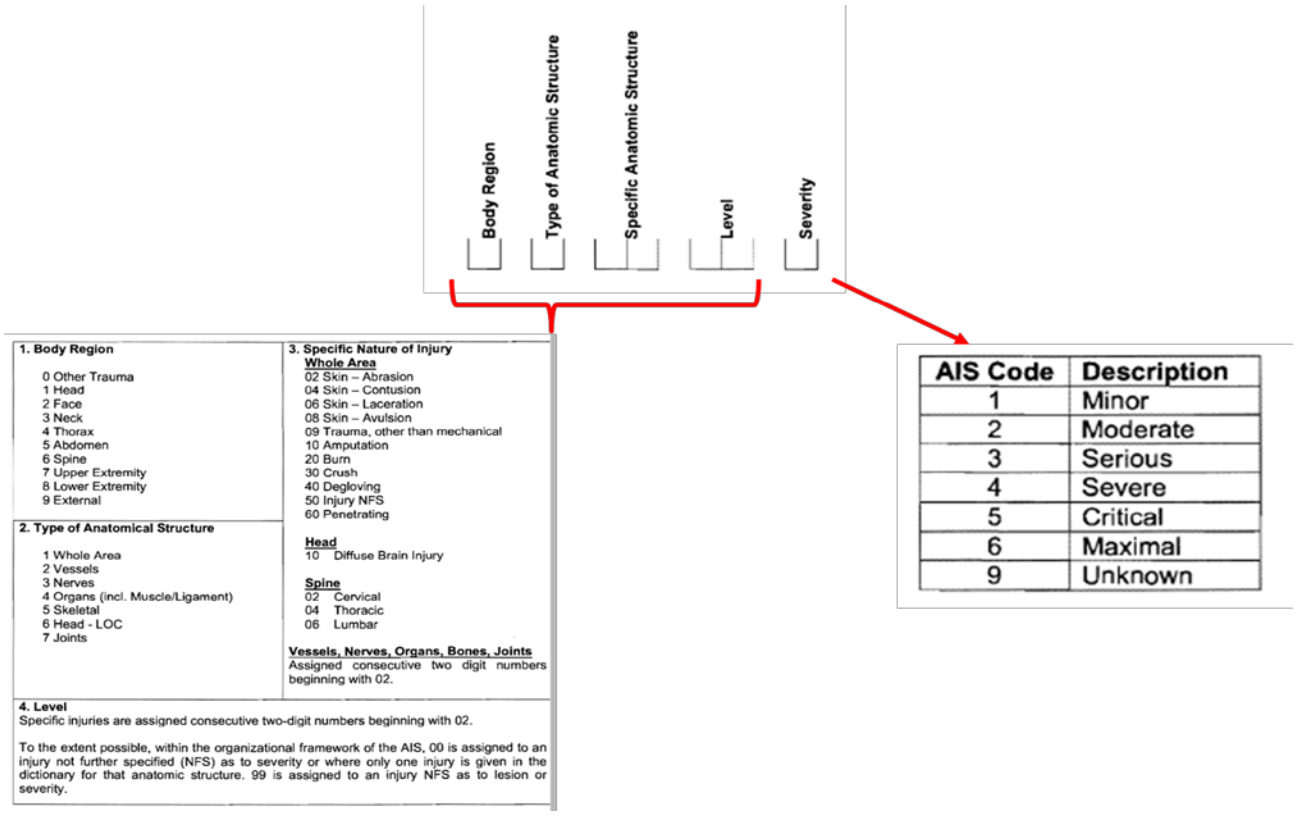

Fig. 1. Structure of the AIS codes [1].

In the in-depth accident investigation project GIDAS, injuries are documented based on the AIS 1998 and AIS 2008. Since the beginning of 2020, each single injury is also coded using the AIS Revision 2015. In a work from 2010, a fundamental relationship between AIS severity and mortality could be shown using GIDAS data [2]. Figure 2 shows one main result of this work. It displays mortality rates (in per mille) of persons who suffered one single injury (AIS) and persons with multiple injuries (MAIS) as well as the available case numbers for the analysis. As an example, the mortality rate of persons with one isolated AIS 3 injury is 17.0 ‰, basing on 242 persons.

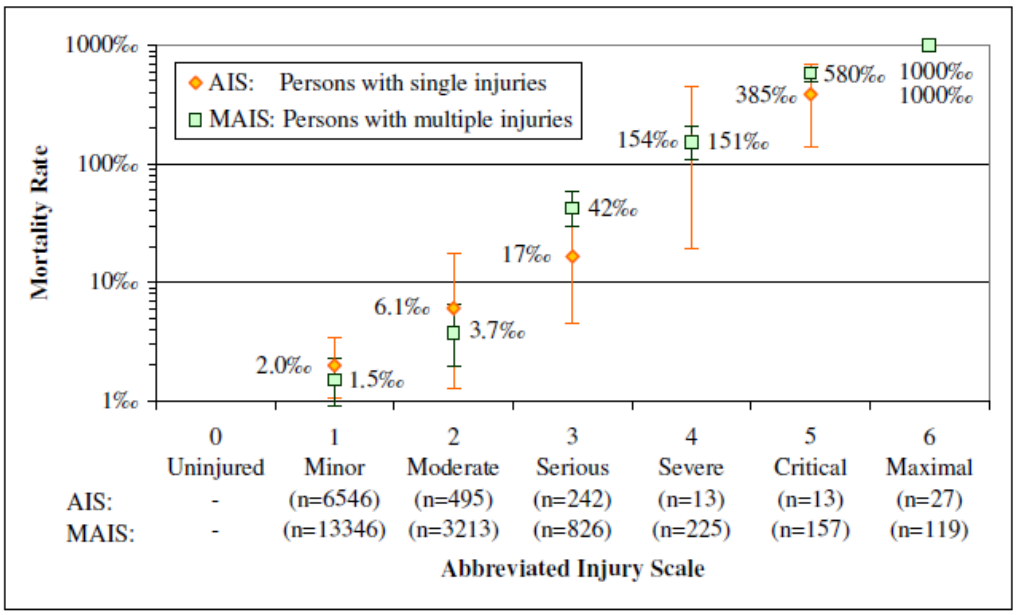

Fig. 2. Mortality rates for each degree of AIS and MAIS injury (AIS 1998), derived from GIDAS data [2].

The injury severity according to the AIS classification is a very common measure in accident research and vehicle safety and is also used as a standard within the GIDAS project. Furthermore, every scientific study on the topic of severe trauma classifies the injury severity using AIS code.

In the first step of this investigation, the structural changes of the AIS Revision 2015 compared to the AIS Revision 2008 have been investigated. In particular, the changes regarding the classification of injury severity are of great importance.

Accident Data Analyses

As of December 2019, the GIDAS database was used for the evaluations within this study. A total of 37,252 traffic accidents with personal injury have been registered. These accidents involve 91,772 persons, of which 48,661 have been injured. More than 134,300 individual injuries were available for the analyses.

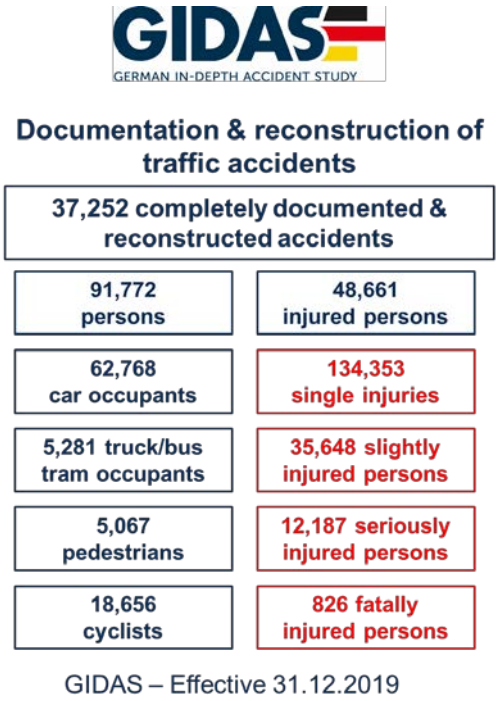

Fig. 3. GIDAS database: Number of cases, persons, injuries (Effective December 2019) [3].

In order to be able to evaluate the data comparably, each injury has been stored in GIDAS with its AIS 1998 and its AIS 2008 coding. To guarantee the evaluability of the GIDAS database also with the current AIS revision, all injuries had to be recoded. Before doing so, each single injury description was analyzed and each change was evaluated. Relevant changes include:

- severity change
- new code / change in the anatomic structure
- new code / change in the type of injury
- recycled code (code existed once, then disappeared and "new" in AIS 2015 again)
- deleted code
- complete new injury

Around 250 codes changed between AIS 2008 and AIS 2015, whilst the other (around 1,750) codes remained identical. It was necessary to examine the injury in each individual case for ca. 100 codes. In the next step, the coding rules and changes have been applied to all 134,353 single injuries coded in GIDAS. The vast majority was recoded automatically. However, a total of 2,070 single injuries were checked and recoded manually by medical experts in the two GIDAS investigation teams. This work was done by case-by-case analyses of each relevant accident dataset on the basis of the available, anonymous medical documentation, e.g. medical protocols, CT-, MRT- and X-ray pictures, medical discharge reports. Finally, different values, e.g. MAIS, ISS, NISS, have been recalculated using the AIS Revision 2015. Subset results of the data analysis are shown in the next few paragraphs.

III. RESULTS

Changes between the different AIS Revisions

All analyses in this chapter are only valid for the injury codes and descriptions in the AIS revisions. They are not linked to the actual occurrence (frequency) of injuries in road traffic accidents.

The AIS Revision 2015 contains 2,006 different injuries. Table I shows the number of injuries and their severity for AIS 2008 and AIS 2015. A total of 81% of injuries have a severity of AIS 3 or less. Major changes are found in the AIS level 3 (increase by 30 injuries) and AIS 5 (decrease by 28 injuries). At first glance, the AIS 2015 seems to contain less severe injuries than the AIS 2008 version. This is subject to the next analyses.

Table I. Number of injuries and their severities (AIS 2008 and AIS 2015)

Number of injuries and their severities			
	AIS 2008 (n=1.999)	**AIS 2015 (n=2.006)**	**Difference (AIS 2008 → AIS 2015)**
AIS 1	447	455	**+8**
AIS 2	729	722	**-7**
AIS 3	419	449	**+30**
AIS 4	172	176	**+4**
AIS 5	155	127	**-28**
AIS 6	33	35	**+2**
AIS 9	44	43	**-1**

One part of this study involved the analysis of the single severity changes for individual codes. Due to combinations in the translation between AIS 2015 and AIS 2008, the total number of changes is higher than the number of injury codes. Such combinations occur when two, three or more injury codes in AIS 2008 are summarised to one code in AIS 2015 or one code in AIS 2008 is split into several codes in AIS 2015. Finally, 2,181 different combinations were available and for each combination, the injury severity in AIS 2008 has been compared to the injury severity of the same injury in AIS 2015.

Figure 5 shows the direction and magnitude of changes in AIS levels. In 1,931 cases (88.5% of all combinations), the injury severity remained constant. The severity of 72 injuries was reduced (3.3%). In contrast, 48 injury codes (2.2%) were shifted upwards to a higher injury severity level. For 130 injuries (6.0%) a calculation was not possible as the injury was first introduced in AIS 2015 or at least one AIS level was 9.

Changes in the injury severity - absolute figures	
Severity change AIS 2008 → AIS 2015	**Number of changes (n= 2,181)**
Severity change -4	3
Severity change -3	9
Severity change -2	16
Severity change -1	45
No severity change	1,930
Severity change + 1	46
Severity change + 2	1
Severity change + 3	1
Severity change + 4	0
New injury/not computable	130

[n – number of possible injury combinations (not number of different injuries)]

Fig. 5. Changes of the injury severities (overview).

Changes in injury severities – direct comparison	
AIS 2008 → AIS 2015	**number**
change: AIS 5 → AIS 1 (-4)	3
change: AIS 5 → AIS 2 (-3)	9
change: AIS 5 → AIS 3 (-2)	12
change: AIS 3 → AIS 1 (-2)	4
change: AIS 5 → AIS 4 (-1)	19
change: AIS 3 → AIS 2 (-1)	16
change: AIS 2 → AIS 1 (-1)	9
change: AIS 4 → AIS 5 (+1)	2
change: AIS 3 → AIS 4 (+1)	2
change: AIS 2 → AIS 3 (+1)	36
change: AIS 1 → AIS 2 (+1)	6
change: AIS 1 → AIS 3 (+2)	1
change: AIS 1 → AIS 4 (+3)	1

Fig. 6. Changes in injury severities (details).

Figure 6 shows the details of the severity changes and cause of absolute increase in AIS 3 injuries (see Figure 4). Sixteen codes were downgraded from AIS 3 to AIS 2, 36 AIS codes were upgraded from AIS 2 to AIS 3. This resulted in the remarkable increase in the number of AIS 3 injuries in the AIS revision 2015 compared to AIS 2008.

As already mentioned the severity changes in the injury definitions do not necessarily have an impact on accident databases. A substantial decrease or increase in injury severity of a certain injury may be of no consequence if a particular injury does not occur in road traffic accidents. Contrary to that, changes in few injury descriptions may have a remarkable impact when they occur very frequently in real accidents. Therefore, the next step of the study is the application of the AIS revision 2015 to the GIDAS database, including the recode of all single injuries and the analysis of the effects on injury severity distributions.

Accident Data Analyses with GIDAS

First, the complete GIDAS dataset was weighted towards the German road traffic accident statistics of 2018 [5]. This was essential to ensure representative results as in-depth accident database are usually slightly biased. After the application of the weighting process the derived conclusions can be used for statements that can be considered as representative for a German accident scenario. For this study all accidents in GIDAS were weighted towards all accidents in Germany that happened in 2018. The weighting uses three criteria:

- accident category (accident with slightly / seriously / fatally injured persons)
- type of accident (seven different categories)
- accident location (urban / rural / motorway)

As the GIDAS database consists of data from 20 years, the weighting process may disguise shifts within the accident scenario that happened during this time. However, accident location and accident category are rather stable within the considered period, and the shifts in the accident types (e.g. continuous reduction of loss of control accidents) have no substantial influence on the AIS distribution.

Then, the AIS revision 2015 was applied to all single injuries in GIDAS and the MAIS (according to AIS revision 2015, named *MAIS 15*) of all 48,672 injured persons in GIDAS (accident years 1999 – 2019). For these persons, the MAIS 15 was compared to the MAIS according to the AIS 2008 (named *MAIS 08*). Figure 7 shows both MAIS distributions. Some remarkable shifts in the MAIS distributions can be obtained from the figure.

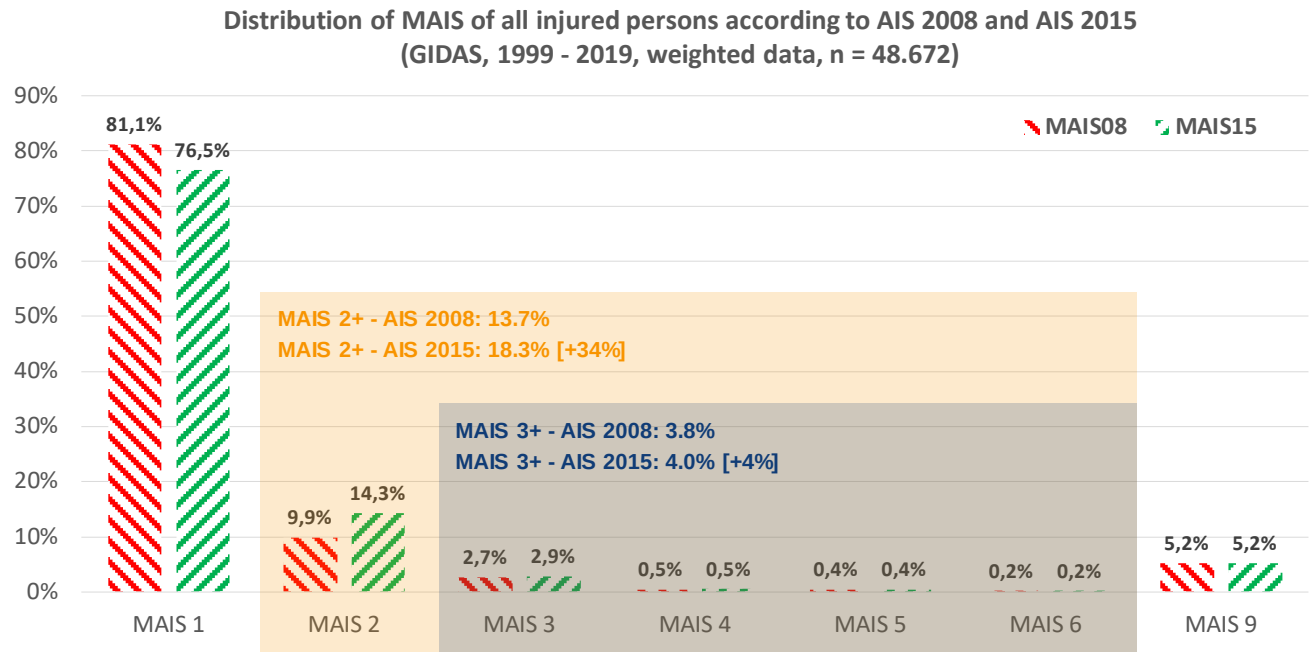

Fig. 7. Distribution of MAIS of all injured persons in GIDAS (AIS 2008 vs. AIS 2015).

The most important findings from this figure are:

- There is an increase of both the share of MAIS 2+ and MAIS 3+ injured persons when using the AIS 2015.
- The proportion of MAIS 2+ injured persons strongly increased by 33.9% (13.66% → 18.29%).
- The proportion of MAIS 3+ injured persons moderately increased by 4.2% (3.80% → 4.96%).
- There are less MAIS 1 injured persons, which are usually referred to as *slightly injured*.
- The shares of MAIS 4, MAIS 5, and MAIS 6 (and MAIS 9) remain rather constant.

The observed changes are very important as many stakeholders, i.e., legislators, manufacturers and suppliers, authorities, consumer protection organisations, etc., in the field of road safety focus on MAIS 2+ and/or MAIS 3+ injured persons as protective goals for road safety innovations. On the European level, for example, the classification into *seriously injured road casualties* should be done with the criteria *MAIS 3+ injured* [4]. As this information is not investigated by the German police and thus, not available in the official road accident statistics of Germany, the information is gained by extrapolation of GIDAS data and thus, will be directly affected by the used AIS revision.

For a better understanding of the consequences of the AIS 2015, the results of some analyses are provided here to get better insights into the MAIS shifts caused by the AIS2015 codebook for different types of road users. Figure 8 shows that the impact of the use of the AIS 2015 depends on the type of injured road user. The diagram shows that (injured) car occupants are less often MAIS 2+ injured than bicyclists and pedestrians. However, there is a strong increase in the portion of MAIS 2+ injured persons in each group. The proportion of MAIS 2+ injured car occupants (ECE classes M1 and N1) increases by 52% (from 9.1% to 13.8%). For bicyclists and pedestrians the increase is 30% and 27% respectively, which results in tremendous changes in reference to *seriously injured persons*. This is a strong indication that there are some single injuries that occur very often and that were shifted to higher AIS levels (namely, from AIS 1 to AIS 2) in the AIS revision 2015.

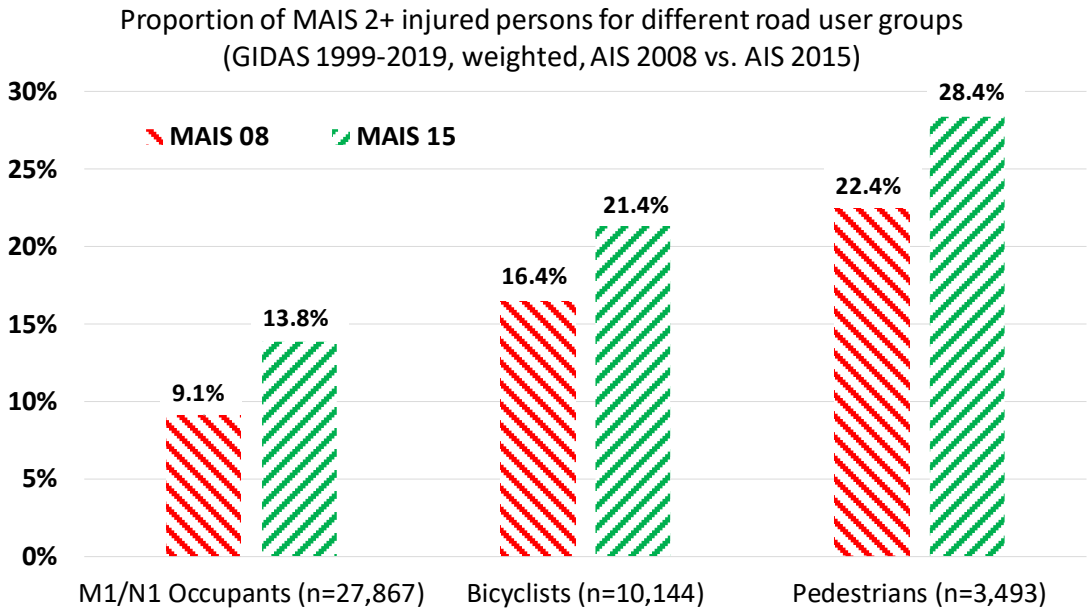

Fig. 8. Proportion of MAIS 2+ injured road users for AIS 2008 and AIS 2015 (GIDAS 1999-2019, weighted data).

The analysis for MAIS 3+ injured casualties (Figure 9) shows that there are only slight changes between MAIS 08 and MAIS 15. The proportion of MAIS 3+ injured persons slightly increases in all road user groups. For bicyclists, the (relative) increase is the highest with 6%, followed by M1/N1 passengers (+ 4%) and pedestrians (+ 3%).

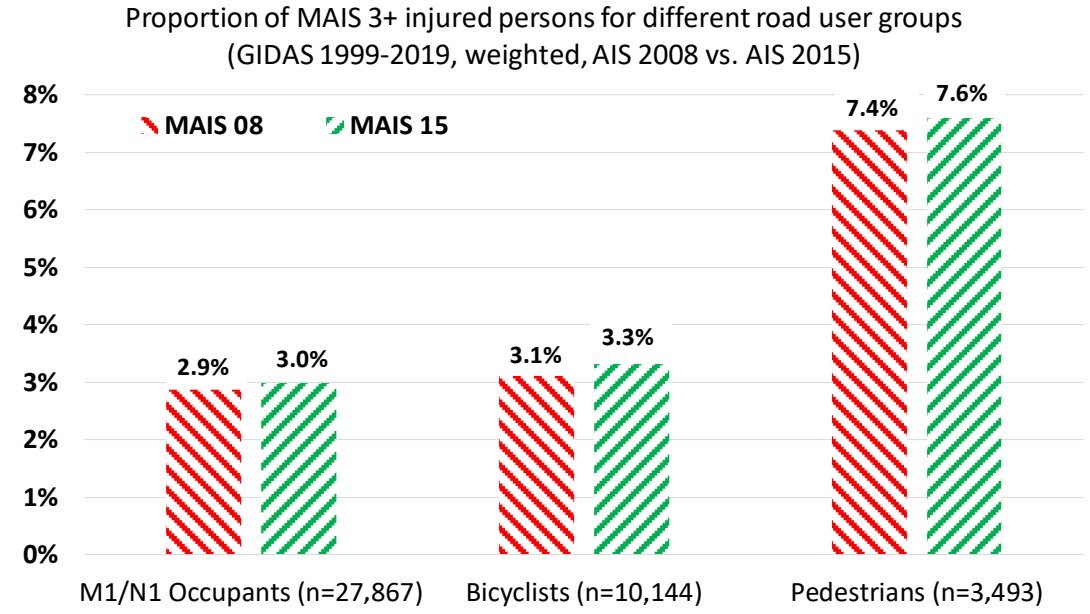

Fig. 9. Proportion of MAIS 3+ injured road users for AIS 2008 and AIS 2015 (GIDAS 1999-2019, weighted data).

In the next step, the focus was on affected body regions. Therefore, the example of severely injured (MAIS 3+) cyclists was used to illustrate potential changes more in detail. Figures 10 and 11 provide the number of MAIS 3+ injured bicyclists, their total number of injuries and the number of AIS3+ injuries. The following conclusions can be derived from the figure:

- The number of MAIS 3+ injured bicyclists increased by 6.0% from 318 (AIS 2008) to 337 (AIS 2015).
- A substantial increase in AIS3+ injuries were observed in the body region *upper extremities* when applying the AIS revision 2015.
- The frequency of AIS 3+ injured body regions seemed to decrease slightly in the majority of body regions, which is mainly a consequence of more MAIS 3+ injured bicyclists. However, the absolute number of AIS3+ injuries was not changing in the most body regions.

MAIS 3+ injured bicyclists (n = 318)			
AIS 2008			
AIS body region	Number: region injured (n_{Inj})	Number: region AIS3+ injured (n_{AIS3+})	Ratio (n_{Inj}/n_{AIS3+})
Head	201	142	71%
Face	119	14	12%
Neck	11	3	27%
Thorax	123	90	73%
Abdomen	38	13	34%
Spine	61	21	34%
Upper extr.	173	6	3%
Lower extr.	195	104	53%
External/other	7	0	0%

Fig. 10. Injured body regions of MAIS 3+ bicyclists according to AIS 2008.

MAIS 3+ injured bicyclists (n = 337)			
AIS 2015			
Body Region	Number: region injured (n_{Inj})	Number: region AIS3+ injured (n_{AIS3+})	Ratio (n_{Inj}/n_{AIS3+})
Head	204	141	69%
Face	1227	14	12%
Neck	11	3	26%
Thorax	125	89	71%
Abdomen	39	13	32%
Spine	61	21	34%
Upper extr.	190	27	14%
Lower extr.	202	103	51%
External/other	8	0	0%

Fig. 11. Injured body regions of MAIS 3+ bicyclists according to AIS 2015.

The reason for this substantial change in the proportion of AIS3+ injuries on the upper extremities was the severity change of around 15 injuries in the AIS revision 2015 (from AIS2 to AIS 3), most of them open radius, ulna, or humerus fractures. As these injuries occur quite often to MAIS3+ injured bicyclists, the ratio changes strongly.

It can be clearly seen that single injuries may have a remarkable effect on the overall injury severity and even influence the MAIS distributions in larger datasets. Therefore, the last analysis in this paper deals with the substantial changes between MAIS 1 (*slightly injured*) and MAIS 2+ (*seriously injured*) persons (see Figure 7) for different road user groups.

The goal was to identify the relevant single injuries that led to the significant increase in the share of MAIS 2+ injured persons for car occupants (+52%), bicyclists (+ 30%) and pedestrians (+ 27%). Therefore, the most frequent injuries for each road user group were extracted from the database and severity changes were identified. Then, the relevance of these injuries for the overall injury severity was analysed. The results are the following:

Passenger car occupants

Relevant injuries include:

- 161001.2 (mild concussion, no loss of consciousness), 2.2% of all injuries
- 161000.2 (cerebral concussion NFS); 0.8% of all injuries

Although the frequencies of these two injuries were not extremely high, the relevance of these injuries in terms of MAIS is high. Out of all 28,285 injured car occupants in GIDAS, 1,761 (6.2%) suffered one of these injuries. The important fact is that for 1,371 persons (4.8% of all injured car occupants) the concussion was the only AIS2 injury, defining the person as MAIS 2 injured.

Bicyclists

Relevant injuries include:

- 161001.2 (mild concussion, no loss of consciousness), 1.8% of all injuries
- 161000.2 (cerebral concussion NFS); 0.5% of all injuries

Out of all 10,316 injured bicyclists in GIDAS, 716 (6.9%) suffered one of these two injuries. Again, for the majority of them (520 persons; 5.0% of all injured bicyclists) the concussion was the only AIS2 injury, resulting in the MAIS 2 according to the AIS 2015.

Pedestrians

Relevant injuries include:

- 161001.2 (mild concussion, no loss of consciousness), 2.3% of all injuries
- 161000.2 (cerebral concussion NFS); 0.7% of all injuries

Out of all 3,522 injured pedestrians, 322 (9.1%) suffered one of these two injuries. Two-hundred and thirteen (6.1% of all injured pedestrians) suffered a concussion as the only AIS2 injury, resulting in an MAIS 2 according to the AIS 2015.

The comparison of the numbers in Figure 8 describing shares of people only suffering a concussion as the most severe injury shows that the increase in the MAIS 2+ numbers solely based on these two injury codes. As they are very prominent in accidents, they completely influence the distribution of overall injury severity.

IV. DISCUSSION

This paper deals with the implementation of the recently published AIS revision 2015 in an accident database (GIDAS) and the resulting effects. Although the GIDAS database also provides AIS 1998 codes, only the AIS revisions 2008 and 2015 are compared in this paper. The revisions of the Abbreviated Injury Scale represent the current status in emergency medicine, trauma surgery, and polytrauma management. For accident research and road safety initiatives, it is necessary to incorporate these developments into accident databases. The changes of the AIS 2015 coding range from re-grouping, severity changes, splitting or aggregating injuries to new codes.

The main goal of this work was to analyze the influence of these changes in terms of injury severity and to assess the resulting outcome of casualties involved in accidents. Therefore, GIDAS data was used as this dataset contains information about single injuries and provides AIS codes.

Basically, a remarkable number of injury codes were reduced in terms of injury severity. However, the analysis of documented traffic accidents in GIDAS shows that the proportion of moderately injured (MAIS 2+) and severely injured (MAIS 3+) persons in traffic accidents increases when applying the new AIS 2015 to the GIDAS data. For example, the proportion of MAIS 2+ injured persons increased substantially for several types of road users. There was also an increase in the portion of MAIS 3+ injured persons whilst the magnitude is not that high as for MAIS 2+ injured casualties.

Further analyses showed that particular body regions are especially affected by the changes between AIS 2008 and AIS 2015. This, for example, includes the region *upper extremities* where the frequency of AIS 3+ injuries increased substantially (for bicyclists) as the severity of open radius, ulna, and humerus fractures was changed from AIS 2 to AIS 3.

The most important changes with a remarkable impact on accident databases are found in the body region *head*. Here, the severity of two single injuries (concussion injuries) has been changed from AIS 1 to AIS2. As between 6% (car occupants) and 9% (pedestrians) of all injured road users suffer these injuries, the effect on the overall injury severity (expressed by the MAIS) is tremendous.

The results of the paper demonstrate the importance of introducing and using appropriate injury scales and evaluation of codebook changes. For a focused and goal-oriented development of measures and systems for traffic and vehicle safety, current medical developments must also be taken into account. Otherwise, wrong priorities may be set.

Finally, the used dataset and applied weighting methods have some limitations. The complete GIDAS dataset was used for the study, containing accidents from 1999 to 2019. The data was then weighted towards the German road traffic accident statistics of the year 2018 to remove biases in the data that are typical for in-depth databases. The weighting of 20 accident years to one year in the national statistics may mask some effects and/or recent developments. However, annual weighting for each year is not appropriate because of the “small” number of cases per year (around 2,000) and the large number of weighting categories (63). In order to solve this problem, a limitation to a certain period of time (e.g. last decade) could be useful as far as the number of cases is still sufficient to achieve robust and/or statistically significant results.

V. CONCLUSIONS

For the evaluation, development, prioritization, and legislation of future safety measures, it is essential to also assess accident consequences according to the current state of medical care and rescue medicine. The application of the AIS Revision 2015 will lead to a better understanding of the severity of traffic accidents. The changes will lead to shifts in the ratio of minor, moderate and severe injuries.

The shifts show that the proportion of serious (AIS 3+) injuries will increase with the application of the AIS Revision 2015. Depending on the type of road user, this increase varies. The application of the scale means that safety developments can be better focused and prioritised in line with the occurrence of severe accidents and current medical knowledge. With the help of the presented findings, even more targeted safety measures can be derived, which can lead to a reduction in the number of MAIS 3+ injured casualties.

VI. ACKNOWLEDGEMENT

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