Original Article

Increased Mortality Among Critically Injured Motorcyclists Over 65 Years of Age

A Retrospective, Multicenter, Cross-Sectional Study Using the TraumaRegister DGU® of the German Trauma Society (DGU)

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Summary

Background: Motorcycle accidents account for a large fraction of the patients with polytrauma treated in German hospitals. Clinical experience indicates that an increasing number of older motorcyclists are having accidents. We studied whether such individuals are subject to higher mortality and longer hospital stays.

Methods: We retrospectively evaluated data from the Traumaregister DGU® (TR-DGU) concerning all patients (n = 13 850) who were registered in the TR-DGU as having sustained trauma in a motorcycle accident from 2002 to 2015 and who had an Injury Severity Score (ISS) greater than 8. The patients were divided into four age groups for further study.

Results: Despite a nearly identical severity of anatomical injury according to the ISS, persons sustaining trauma in motorcycle accidents who were over 65 years of age (n = 892) needed longer and more intensive treatment than their younger counterparts. They were invasively ventilated for a longer time (+ 1.2 days), kept for a longer time on the intensive care unit (+ 1.7 days), and stayed in the hospital three days longer. These older persons injured in motorcycle accidents had a disproportionate mortality in comparison to other polytrauma patients and a significantly elevated mortality in comparison to their younger counterparts—15.8%, compared to 7.2% among patients aged 45 to 64. Older trauma patients are more likely than younger ones to develop lethal complications in the later course of their hospitalization, while younger trauma patients who die generally do so as a direct result of the traumatic injury.

Conclusion: Patients over age 65 who sustain trauma in motorcycle accidents have a higher mortality, a longer duration of ventilation, and longer stays in the intensive care unit and in the hospital overall than their younger counterparts. These patients present a special challenge to the treating medical team.

Cite this as:
Eden L, Kühn A, Gilbert F, Meffert RH, Lefering R: Increased mortality among critically injured motorcyclists over 65 years of age—a retrospective, multicenter, cross-sectional study using the TraumaRegister DGU® of the German Trauma Society (DGU). Dtsch Arztebl Int 2019; 116: 479–85.
DOI: 10.3238/arztebl.2019.0479

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Riding a motorcycle is a popular activity and becoming increasingly so in our society. According to data from the German Federal Motor Transport Authority (*Kraftfahrt-Bundesamt*, KBA), 4.3 million motorcycles were registered with an official license number in Germany in early 2017 (motorcycles, scooters +2.0% compared with 2016), 2 million motorcycles with an insurance indicator number (moped <50 cm^3, etc), and ca 45.8 million motorcars (+1.6% compared with 2016) (1). However, motorcycles are a very high-risk means of transportation.

In 2016, 16 motorcycle users with official license plates and motorcycles with insurance indicator plates were killed in traffic crashes for each 100 000 licensed vehicles, which compares with merely 3 persons in motorcars. For each billion km traveled by a vehicle, motorcyclists had fatal accidents in 10 times as many cases as average motorcar drivers (50 versus 5) (2, 3). On analyzing the age structure of those involved in motorcycle crashes, it transpires that very young as well as older (>65 years of age) people are particularly at risk. More than one third (33.9%, 14 888) of motorcyclists in crashes and more than one fifth (22.7%, 137) of those killed in 2016 were aged 15–24 years. For each 100 000 officially registered motorcycles, 89 fatalities were in this age group. In 2016, this was by some margin the highest number of relevant fatalities in all age groups (3). Only 8.5% of users of small motorcycles (motorcycles with insurance indicator plates) involved in crashes were aged 65 or older, but this was the case for 42.6% of all fatalities, (3). The main cause of human error leading to crashes is inappropriate speed (34%). The effect of alcohol was determined as a factor in merely 1.4% of crashes involving motorcycles with an official registration license.

In Germany, the data of patients injured in accidents have been collected scientifically in the trauma register of the German Society of Trauma Surgery (*TraumaRegister DGU*®/TR-DGU) since 1993 and evaluated in a database. The TR-DGU is considered to be one of the largest registries of trauma patients worldwide (4). Since 2008, participating hospitals have had the option to be certified in a network as a

local, regional, or supraregional trauma center. These regional networks are part of the nationwide project TraumaNetzwerk DGU® (the trauma network of the German Association of Trauma Surgery (*Deutsche Gesellschaft für Unfallchirurgie*, DGU), a project whose aim is to define unified quality standards in the context of optimizing healthcare services for trauma patients (5, 6).

Since 2002, motorcycle accidents have been collected in the register separately from other traffic crashes. According to the annual report of the TR-DGU, in 2016 almost half (48.2%) of all documented causes of accidents were traffic crashes. Of the patients included, 20.9% were in a car crash in 2016, whereas 12.0% crashed on a motorcycle (7).

In routine clinical practice it has been found that it is mostly "older" patients who are involved in motorcycle crashes (8–11) and thus present their treating doctors with difficulties (8–11). These patients present a therapeutic challenge for treating doctors because their health is often not as good as that of younger patients (12–14). This observation is supported by the two peaks in the age structure of documented causes of crashes in the TR-DGU between 2002 and 2015 (*red line, Figure 1*). For this reason, we undertook an age-related analysis of data from motorcyclists involved in crashes. Our underlying hypothesis was that older patients have a poorer risk profile than younger ones.

Materials and methods

Our study was designed as a retrospective multicenter cross-sectional study. The data were taken from the TR-DGU and analyzed. These data are collected prospectively in four sequential phases:

- Preclinical phase
- Resuscitation area and subsequent surgery phase
- Intensive care unit
- Discharge

The documentation is pseudonymized. The inclusion criterion is inpatient admission via the resuscitation area, with subsequent intensive care monitoring or arrival at the hospital with vital signs and death before admission to intensive care.

Currently, some 35 000 cases from about 700 hospitals are included in the database every year (4, 15).

Those responsible for the TR-DGU assume that since 2014 at the latest, >90% of all trauma patients in Germany are admitted via a participating hospital.

Two thirds of motorcycle crash victims were treated in supraregional trauma centers. For this project, we analyzed all data from patients involved in motorcycle crashes who were included in the TR-DGU with an injury severity score (ISS) above 8 (MAIS 3+) between 1 January 2002 and 31 December 2015. The patients were included via a German hospital, and the course of each crash was documented. Once included in the study, patients were clinically-substantially categorized into four age groups according to the analyzed cohort.

The study analyzed the following variables:

- Preclinical phase: sex, ASA (American Society of Anesthesiologists) classification (ASA ≥ 3 vs ASA < 3), GCS (Glasgow Coma Scale) score (in points), intubation (yes/no); catecholamines required (yes/no), arrival of emergency doctor in minutes, time taken by rescue (minutes between receipt of alert to admission to resuscitation area), means of transport (air rescue helicopter)
- Resuscitation area and surgery phase: ISS (points), type of trauma center (local, regional, supraregional)
- Intensive care ward: duration of ventilation including/excluding deceased patients (in days), length of stay including/excluding deceased patients (in days)
- Discharge: length of entire inpatient stay including/excluding deceased patients (in days), RISC (Revised Injury Severity Classification)-II score (%), mortality (%)
- Other details: Timing of accident (working day/weekend), conditions of light at the time of the crash (daylight/darkness), mortality analysis according to standardized mortality rate.

The RISC score, version II, was developed using data from 30 000 patients in the TR-DGU and validated subsequently. It combines 13 items regarding the patient until shortly after inpatient admission (age, most serious injury according to Abbreviated Injury Scale [AIS]; second most serious injury according to AIS; head trauma; width of pupils and pupillary light reflex; GCS scores, scores of the ASA classification, mechanism of the crash; sex; blood pressure; base excess; INR; Hb readings; resuscitation) and from these it calculates an individual mortality prognosis. For groups of patients, the mean of the RISC-II prognoses is then compared with the actually observed death rate.

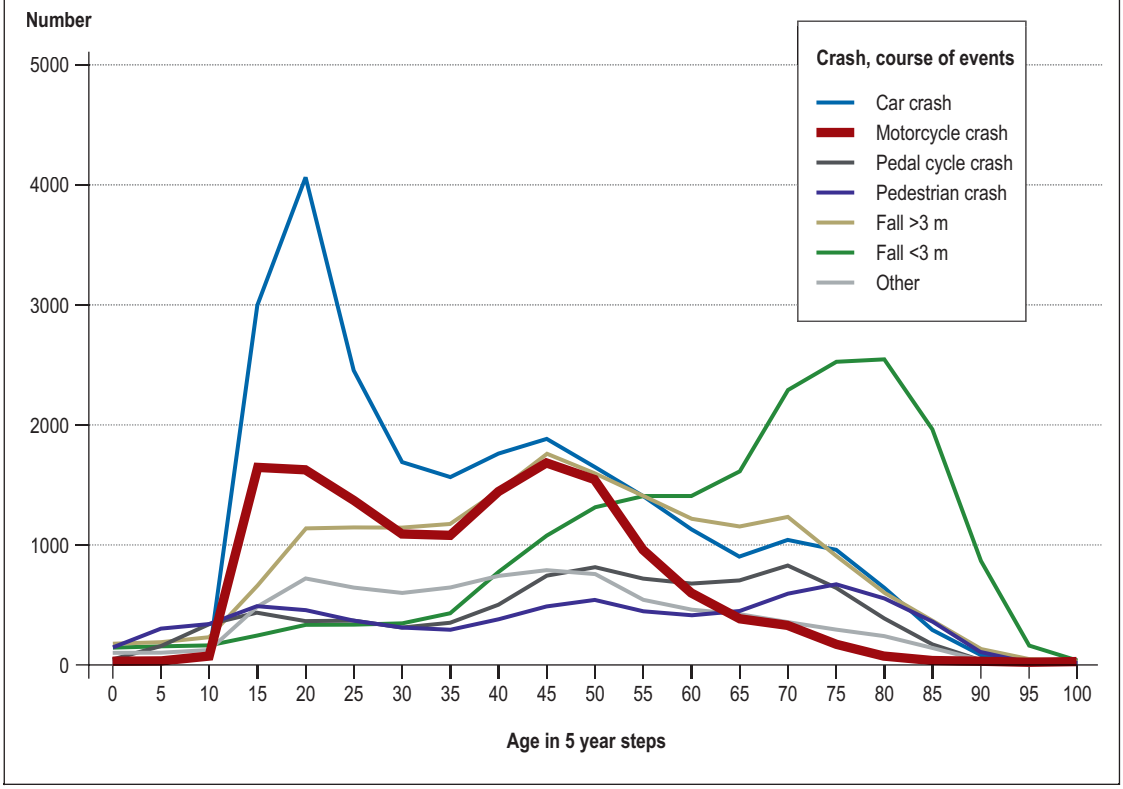
This study was undertaken in accordance with the publication guideline of the TR-DGU and is registered under the TR-DGU project ID 2015–053. In order to assess the effect of the crash mechanism (motorcycle, among others) on survival in the entire population, we conducted a logistic regression analysis while taking into account RISC-II scores, the target hospital, the year of the crash, and the cause of the crash. Furthermore, a possible age effect in motorcyclists that exceeds the general age effect (as categorized by using RISC-II) was investigated, and we undertook a further multivariate analysis (logistic regression).

To this end, we regarded in addition to the RISC-II score four age groups, day/night/means of transport, time lapse between crash and inpatient admission, and the type of trauma center as independent predictors.

Results

We divided the results of the TR-DGU into four age groups, as shown in *Table 1*. In all age groups in our patient population, the crashed motorcyclists were primarily male. The average age at the time of the crash

FIGURE 1



Graphic representation of the number of traffic crashes, documented in TraumaRegister DGU®, age-dependent in 5 year steps after course of crash events

was 38.7 years (median 42.0 years, standard deviation 17.3 years; 10–84 years); 10.3 years below the average age (49 years) of all patients included in the TR-DGU from 2007 to 2016 (7). We analyzed the health status of the crash victims pre-trauma in the TR-DGU by dividing the ASA classification into ASA <3 vs ASA ≥ 3. The group of patients older than 65 is particularly conspicuous in this context (74%/26%).

The oldest patient population (>64 years, n=892) was invasively ventilated for a notably longer period (+1.2 days). Similar proportionalities were observed regarding the length of the entire inpatient stay (+1.8 days) and the intensive care unit (+1.7 days). Older patients spent a median 3 days longer in hospital, although the severity of their anatomical injury was similar or slightly lower according to the ISS (*Table 1*). Mortality in the oldest group was more than double that in the next group down (65–84 years: 15.8% of patients died, 45–64: 7.2% of patients died). The calculated predicted mortality (RISC-II) is also higher than in the rest of the patients in the study, but it is proportionally lower than the real mortality (*Figures 2*, *3*). Comparing the youngest and oldest groups shows a significant difference (P<0.05) that even exceeds the age effect considered in the RISC-II score *(Table 2)*. For the age group older than 64, annual excess mortality is 7.

Our analysis of the differences in length of inpatient stay and ventilation of crash fatalities in the TR-DGU shows that younger patients (4.5 days) die much earlier from the effects of their traumatic injuries than older ones (13.3 days).

We found that younger motorcyclists (35.6%) crash notably more often in darkness than older ones (11.5%).

Logistic regression analysis regarding the crash mechanism did not show any significant difference for survival after a motorcycle crash compared with a car crash (odds ratio 0.93; 95% confidence interval 0.84 to 1.04). Regarding darkness, means of transport, time elapsed between the crash and inpatient admission, and type of trauma center, no significant correlation with mortality was found.

Discussion

Few clinical studies about motorcyclists have been published. The existing studies often relate to questions that are location specific and were mostly conducted in non-European countries. No data have been published on the TR-DGU.

This study yields some new insights relating to motorcycle crashes. In contrast to the available scientific data, in this study the severity of the traumatic injury according to the ISS when comparing age groups

TABLE 1

List of the collected der parameters (total and classified into four age groups)

Variable	Total	10–24 years	25–44 years	45–64 years	65–84 years	Key
n	**13 850**	**3298**	**4924**	**4736**	**892**	
Sex	90.4% ♂. 9.6% ♀	90.5% ♂. 9.5% ♀	90.4% ♂. 9.6% ♀	89.4% ♂. 10.6% ♀	96.2% ♂. 3.8% ♀	Male/female
ISS (points)	23.3/20 (14–29)	23.6/20 (14–29)	23.9/20 (14–29)	22.6/20 (14–29)	23.2/20 (14–29)	Mean/median (IQR)
ASA classification	95.5%/4.5%	100%/0%	98.8%/1.2%	93.6%/6.4%	74%/26%	ASA < 3/ASA ≥ 3
Catecholamines required	23.5%	23%	25.1%	21.1%	27.3%	
GCS pre-hospital (% <8)	18.9%	23.7%	20.4%	14.9%	14.4%	
Pre-hospital intubation	39.8%	45.5%	44.4%	33.1%	28.8%	
Time of crash	61%/39%	63.9%/36.1%	57%/43%	60.7%/39.3%	74.6%/25.4%	Weekday/weekend
Light conditions at time of crash	74.4%/25.6%	64.4%/35.6%	73.3%/26.7%	79.6%/20.4%	88.5%/11.5%	Light/dark
Time to arrival of emergency doctor (mins)	17.9/15 (10–21)	17.9/15 (10–20)	17.9/15 (10–21)	18.0/15 (10–21)	18.3/15 (10–20)	Mean/median (IQR)
Rescue time (mins)	62.2 / 60 (46–75)	63.3/60 (48–79)	63.2 / 60 (47–79)	60.9/58 (45–75)	59.0 / 55 (43–72)	Mean/median (IQR)
Mortality	8.5% [8; 9]	9.2% [8.2; 10.3]	8.1% [7.3; 8.9]	7.2% [6.4; 8.0]	15.8% [13.2; 18.4]	"Observed mortality" [95% confidence interval]
RISC-II score	9.0%	9.9%	9.0%	7.5%	13.9%	"Expected mortality"
Mortality analysis according to SMR	0.95 [0.894; 1.005]	0.93 [0.823; 1.038]*	0.9 [0.813; 0.994]	0.96 [0.853; 1.061])	1.14 [0; 952; 1;32]*	> 1 higher than average mortality [95% CI]
Length of intubation (days), survivors	4.5/1 (0–4)	3.8/1 (0–4)	4.8/1 (0–5)	4.6/0 (0–4)	5/0 (0–5)	Mean/median (IQR)
Length of intubation (days), deceased patients	5/1 (0–5)	3.2/1 (0–3)	3.9/1 (0–4)	5.8/1 (0–6)	9.9/2 (0.5–12)	Mean/median (IQR)
Length of stay in intensive care (days), survivors	8.9/4 (2–12)	8/4 (2–10)	9.11/4 (2–13)	9.1/4 (2–12)	9.7/4 (2–14)	Mean/median (IQR)
Length of stay in intensive care (days), deceased patients	5.5/1 (0–5)	3.4/1 (0–3)	4.2/1 (0–5)	6.4/1 (0–8)	11.4/4 (1–14)	Mean/median (IQR)
Total inpatient stay (days), survivors	26.2/20 (12–32)	23.1/18 (11–28)	27.9/21 (12–34)	26.9/20 (12–33)	24.9/21 (12–31)	Mean/median (IQR)
Total inpatient stay (days), deceased patients	7.4/2 (1–7)	4.5/1 (1–4)	6.1/1 (1–5)	9/2 (1–9)	13.3/5.5 (1–17)	Mean/median (IQR)

* Difference reaches significance (p = 0.046) regarding in-hospital mortality despite adjustment for age

ASA, American Society of Anesthesiologists; GCS, Glasgow Coma Scale; ISS, Injury Severity Score; RISC, Revised Injury Severity Classification; SMR, standardized mortality rate

pretty much remains the same with increasing age, or even falls slightly. Several authors have described that older victims of motorcycle crashes typically present with more severe injuries than their younger counterparts (13, 14, 16). This is explained largely by reduced physical resilience as a result of physiological aging processes, accompanied by a larger number of relevant comorbidities (10–12).

The data showed that younger motorcyclists crash notably more often during the hours of darkness. Other authors described a similar phenomenon (17). In a study by Stephens et al., older crash victims wore appropriate protective clothing in more cases than their younger counterparts (18). Older motorcyclists also seem to be more experienced, take fewer unnecessary risks, and do not tend to overestimate their driving skills vis-à-vis the actual conditions (19–21). If crashes occurred, however, the oldest patient population (65–84 years) in the TR-DGU had the highest in-hospital mortality ("observed mortality," 15,8%) (10–12, 14, 16). The calculated predicted mortality ("expected mortality"), the RISC-II score, was also highest in the oldest patient population (13.9%) (22) (*Figure 2*). The standardized mortality ratio (SMR), in which observed mortality is divided by expected mortality (23), is 1.14 in the oldest patient population (65–84 years); it is therefore the only group with a value >1 in which observed mortality is higher than expected mortality. The population comprising the oldest victims of motorcycle crashes therefore has a higher mortality risk than "average" polytrauma patients *(Figure 3)* and a significantly

higher risk of dying than young motorcyclists. This means that motorcycle crashes as the cause of accidents in this age group per se represent an unfavorable factor for survival.

This is entirely consistent with the existing scientific data, but as far as we know it has not been worked out in this form to date.

What is of note is the large difference in the length of in-hospital stays in the deceased patients. The younger patients mainly died early on (median 1 day), whereas older patients died after an average of 13.3 days. The median is 5.5 days, which implies that most patients died around the 5th or 6th day, but this still represents a big contrast to the median in younger patients (median 1 day), of whom most died on the first day. Dischinger et al. showed that younger patients died significantly more often at the site of the crash. They associated this with a higher incidence of severe mediastinal injuries (cardiac, vascular, and pulmonary injuries), which result in massive hemorrhagic complications or acute pump failure at the crash site (14). The early death of the young patients in hospital is presumably still a consequence of the primary trauma. Older crash victims with increasing age are at risk of dying during the following inpatient stay. This can be explained with the already reported higher incidence of pre-traumatic comorbidities and the increased risk for secondary events (for example, pulmonary embolism, pneumonia (11, 16, 24–27).

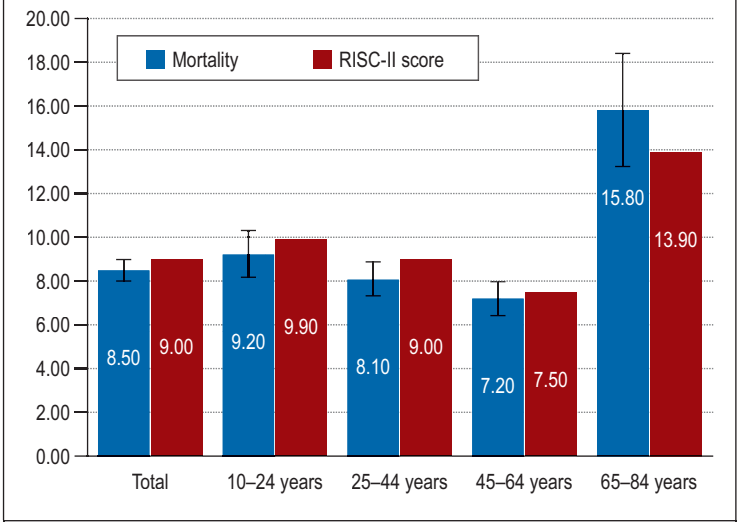
Analyzing the sex distribution confirmed what many other studies and sources have already shown: most of the motorcycle crash victims were male (3, 8–10, 13, 28).

What is also known is that old age is accompanied by more chronic comorbidities and therefore restricted health even pre-trauma (29, 30). In this study we selected an ASA score of 3, since earlier studies showed that a pre-traumatic ASA score of 3–4 is associated with more than double the mortality risk compared with a healthy person without relevant comorbidities (ASA 1) (31). It was shown that this affects the length of the treatment (inpatient stay) and posttraumatic morbidity and mortality (11, 22, 32, 33). What is of note in this study is in particular the patient population older than 65 years, which had an ASA score ≥ 3 in many more cases than the comparison groups. The fact that the mortality rate is double in this group what it is in other groups is consistent with this finding (65–84 years: 15.8%, 45–64 years: 7.2%, 25–44 years: 8.1%, 10–24 years: 9.2%).

Aufmkolk et al. found that the pre-existing chronic comorbidities in older crash victims mostly have a cardiac and cardiopulmonary pathogenesis (25). This may explain why older age is associated with a notably higher need for catecholamines in order to stabilize a patient's cardiorespiratory circulation sufficiently. This is also the case for the initial rescue phases (pre-hospital, resuscitation area, and first surgical phase), as well as for the length of the stay in the intensive care setting. Several authors have described as the cause the poorer posttraumatic compensatory mechanisms in older crash victims (11, 25–27). This could also provide a possible explanation for the prolonged intubation phases and inpatient stays in the older patient population (>65 years).

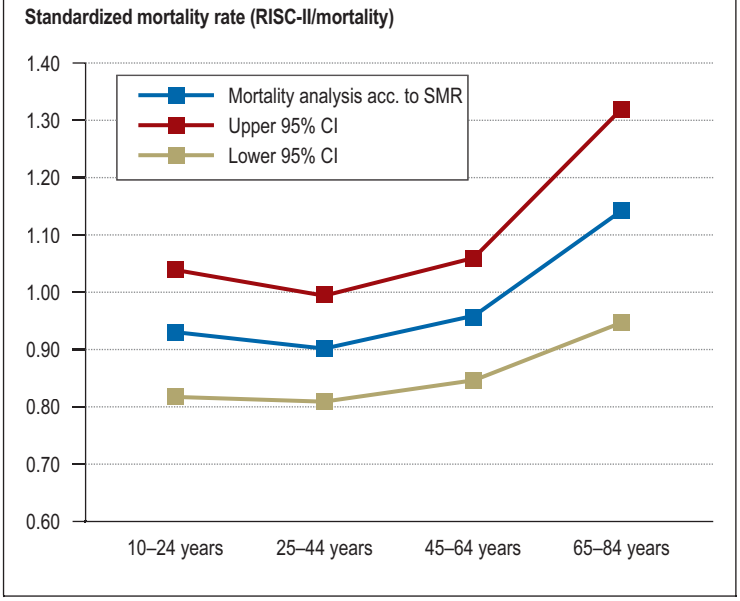
Alcohol undoubtedly plays a large part in the genesis of road traffic crashes. In the TR-DGU, alcohol

FIGURE 2



Graphic representation of mortality rate and calculated mortality prognosis on the basis of RISC (Revised Injury Severity Classification)-II scores (total and classified by age groups)

FIGURE 3



Graphic representation of the SMR with 95% confidence intervals [95% CI] classified by age groups
RISC, Revised Injury Severity Classification; SMR, standardized mortality rate

TABLE 2

Results of the logistic regression analysis with "in-hospital mortality" as dependent variable (n = 9869)

Predictor	Coefficient	SE	Significance	Odds ratio (OR)	[95% CI] for OR
RISC-II score*	−1.007	0.028	<0.001	0.363	[0.346; 0.386]
Transport to hospital by air rescue helicopter (reference: ground-based transport)	−0.18	0.12	0.15	0.84	[0.66; 1.06]
Darkness (reference: daylight hours)	−0.12	0.13	0.33	0.88	[0.69; 1.13]
Pre-hospital phase (in minutes)	−0.002	0.002	0.39	0.998	[0.993; 1.003]
Service level 2, RTC Service level 3, LTC (reference: service level 1, STC)	0.14 0.22	0.13 0.29	0.28 0.46	1.15 1.24	[0.89; 1.45] [0.70; 2.20
Motorcyclist, age 25–44 Motorcyclist, age 45–64 **Motorcyclist, age 65–84** (reference: motorcyclist, age 10–24)	−0.01 0.08 **0.37**	0.14 0.15 **0.19**	0.93 0.59 **0.046**	0.99 1.08 **1.45**	[0.75; 1.31] [0.81; 1.44] **[1.01; 2.08]**
Constant	0.07	0.21	0.74	1.07	

For categorical variables the effects shown as the odds ratio relates to the named reference group;
for constant variables the odds ratio describes the effect for an increase by one unit.
* In the RISC II, 13 different prognostic factors of the severely injured patient are combined in a point score, which for prognostic purposes can be converted into a probability value by using the logistic function. A high RISC-II score is associated with a greater probability of survival.
LTC, local trauma centers; RISC, Revised Injury Severity Classification; RTC, regional trauma centers;
SE, standard error; STC, supraregional trauma centers; 95% CI, 95% confidence interval.

levels have been documented only since 2017. More detailed analyses are currently being undertaken. However, in motorcyclists the effects seems to be relatively small, according to data from the Federal Statistical Office (3). In 43 943 crashes, a cause was found for 28 657 of them (65.2%). Of these 28 657, 410 (2.15%) were caused by alcohol.

Methodological strengths and limitations of the study

Our study is a multicenter retrospective cross sectional study of prospectively collected data that were entered consecutively. The data collection by the TR-DGU provides an excellent option for exposing the reality of seriously injured road crash victims and for quickly gaining information on different crash entities and patient populations, making these objectively comparable. Large case numbers enable generalizable conclusions that constitute a valuable basis for scientific health services research (15). Since 2014 at the latest, 90% of seriously injured crash patients have been admitted via a certified hospital and all hospitals are obliged to enter those patients into the register, this we can assume that this analysis is representative for Germany, even though the scientific proof is currently lacking.

However, obviously only those data can be evaluated that have been documented in the TR-DGU. In order to even better reconstruct the crash mechanism (for example, wearing a helmet, speed at the time of the crash) and the precise treatment course of individual patients, single center analyses are required, or an even more comprehensive data collection by means of the TraumaRegister DGU®.

In our multivariate model (*Table 2*) we intentionally omitted analyzing individual predictors in favor of the RISC-II, for reasons of simplicity—The RISC-II combines 13 known and validated prognostic factors and thus has a high degree of collinearity with the mortality rate.

According to the German Federal Statistical Office, the population will continue to get older in the future. In 2060, the median age is predicted to be older than 50 (2013: 45 years) (34). In a scenario of increasing life expectancy, combined with an active lifestyle and increasing mobility of older people, a rising number of seriously injured crash victims in these age groups is to be expected. But it is especially the age group of motorcyclists older than 65 years which presents extreme challenges for doctors and requires particular attention during diagnostic evaluation and therapy.

Conflict of interest statement
Prof Lefering's institute receives funding from an ongoing service contract with AUC GmbH, the owner of the TR-DGU. This includes statistical consultations relating to scientific evaluations.

The remaining authors declare that no conflict of interests exists.

Manuscript received on 4 December 2018, revised version accepted on 15 May 2019.

Translated from the original German by Birte Twisselmann, PhD.

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Key messages

- According to the TraumaRegister DGU®, numbers of motorcyclists involved in traffic crashes show two distinct peaks: in the 15-20 year age group and in the 45050 year age group.
- A motorcycle crash per se does not represent a poorer prognosis for survival, but the subgroup of those older than 65 years has a notably higher case fatality rate than one might expect on the basis of the RISC-II score as the reference tool.
- Younger motorcyclists mostly die at the site of the crash and in their first days after hospital admission.
- Older motorcyclists mostly die only during the course of their inpatient stay.
- Older patients spend longer in intensive care, are ventilated for longer, and spend more days in hospital.

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Cite this as
Eden L, Kühn A, Gilbert F, Meffert RH, Lefering R: Increased mortality among critically injured motorcyclists over 65 years of age—a retrospective, multicenter, cross-sectional study using the TraumaRegister DGU® of the German Trauma Society (DGU). Dtsch Arztebl Int 2019; 116: 479–85. DOI: 10.3238/arztebl.2019.0479