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ORIGINAL SCIENTIFIC REPORT

Injury Pattern and Injury Severity of In-Hospital Deceased Road Traffic Accident Victims in The Netherlands: Dutch Road Traffic Accidents Fatalities

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Abstract

Background Further reduction in road traffic accident (RTA) fatalities is a key priority in the European Union. Since data on injury patterns related to mortality in RTAs are scarce, the aim of this study was to analyze injury patterns and injury severity of in-hospital RTA fatalities in the Netherlands.

Methods All in-hospital deceased RTA victims in the Netherlands during the period 2015–2016 were analyzed. Data were obtained from the National Trauma Registry. Injury patterns, injury severity, accident and patient characteristics of road user groups were compared.

Results A total of 497 deceased RTA victims were analyzed, of which most were bicyclists. All analyzed motorcyclists had an ISS $\geq$ 16. Head trauma was most frequent in pedestrians (73.7%) and bicyclists (71.3%). Thorax trauma was most frequent in motorcyclists and motorists (60.9% and 65.8%, respectively). RTA victims younger than 25 years were more severely injured (median ISS 38, interquartile range [IQR] 29–46) compared to RTA victims aged over 75 years (median ISS 25, IQR 13–30). More than 10% of the severely injured (ISS $\geq$ 16) RTA victims was not transported to a level I trauma center. The majority of this group was older than 75 years.

Conclusions Further prevention of head trauma is needed to reduce RTA fatalities, especially in bicyclists. Also, undertriage of severe trauma in elderly RTA victims is obvious and should be addressed in the early phases of trauma care, especially during prehospital triage and initial care at admission.

Introduction

Road traffic accidents (RTA) contribute significantly to mortality in both developing and developed countries around the world. RTAs are the main causes of death among the young population (aged 15–29 years). The World Health Organization indicates that the number of RTA fatalities continues to climb, reaching a high of 1.35 million worldwide in 2016 [1]. Despite traffic safety laws and extensive preventive governmental programs, the number of seriously injured RTA victims in the Netherlands has increased by 3% per year since 2006, resulting in 21,300 seriously injured RTA victims in 2015 [2].

The number of RTA fatalities in the Netherlands has declined since the 1990's partly due to the introduction of the systematic approach of trauma patients according to the Advanced Trauma Life Support (ATLS®) [2, 3]. However, this number has stabilized at a higher annual average of 620 fatalities in 2015, which was significantly higher than expected based on the trend seen in previous years (2006 till 2014) [2, 4, 5].

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Further decline in RTA fatalities is one of the key priorities of the "Road Safety Program 2011–2020" initiated by the European Commission, that aims to reduce the number of RTA victims in the Netherlands to less than 10.600 seriously injured victims and 500 fatalities by 2020 [6]. Therefore, we analyzed the injury patterns and injury severity for different types of road users involved in fatal RTAs in the Netherlands. These data may contribute to the awareness of specific high-risk road user groups and potentially lethal injuries during the trauma admissions.

Methods

Study design and patients

This study is a retrospective analysis of all adult (≥ 18 years) RTA victims who died in Dutch hospitals within 30 days after acute admission, during the period 2015 and 2016. All data were obtained from the National Trauma Registry, and RTA victims who died at the accident scene or during transport to the hospital could not be included, as they are not registered in the trauma registry. The study was exempted from ethics review board approval, because the study used coded data from the existing National Trauma Registry.

Data and definitions

Patient data comprised age, gender, road user group (motorists, motorcyclists, moped riders (incl. mobility scooters), bicyclists (incl. E-bikes) and pedestrians), trauma mechanism (blunt or penetrating trauma), mode of transportation to hospital (ambulance, helicopter emergency medical service, self-presenting), hospital of admission (level I, level II or level III trauma centers), season (winter: December–February; spring: March–May; summer: June–August; autumn: September–November) and time (morning: 08.00–12.00; afternoon: 12.00–17.00; evening: 17.00–00.00; night: 00.00–8.00).

Using the Abbreviated Injury Scale update 2008 (AIS 2008) [7], injury characteristics with respect to severity distribution were classified for each anatomic region of the body (head, face, neck, thorax, abdomen, spine, upper extremities, lower extremities and external) [7]. An AIS ≥ 3 was deemed severe injury for the respective system. Ultimately, the total trauma burden was quantified using the injury severity score (ISS) [8], and ISS ≥ 16 was classified as severe trauma. Vital parameters on arrival included revised trauma score (RTS) [9] and Glasgow coma scale (GCS) [10]. Outcomes of care included length of hospitalization in days and admission to the intensive care unit (ICU).

The continuous variables were categorized using clinically relevant cutoff points used by the National Trauma Registry for age (18–24, 25–55, 56–75 and > 75 years), GCS (3–8, 9–12, 13–15), respiratory rate (< 10, 10–29, > 29 per minute) and systolic blood pressure (< 75, 75–89, > 89 mmHg).

Analysis

The data was statistically analyzed using IBM SPSS Statistics for Windows, version 23 (IBM Corp., Armonk, N.Y., USA). Patient groups were compared using the chi-squared test for categorical data, the *T* test or ANOVA for normally distributed continuous data and the Mann–Whitney test or Kruskal–Wallis test for skewed continuous data.

Results

A total of 548 RTA victims died in Dutch hospitals between January 1, 2015, and December 31, 2016, of which 51 were excluded from analysis due to age restrictions and/or unknown road user group. The average age of the remaining 497 deceased RTA victims was 63.8 years and 68.6% was male.

Patient and accident characteristics

There were statistically significant differences regarding age and gender between the road user groups (Table 1). Deceased bicyclists (n = 209, 42%) were the largest group and had the highest average age (71.1, standard deviation [SD] 16.3 years), with 45.9% older than 75 years. Deceased motorcyclists were the youngest road user group (mean 42.2 years, SD 13.9) consisting mostly of men (95.7%). A statistically significant difference between road user groups was also found for season, as most fatal accidents with motorcyclists occurred in summer (52.2%), whereas nearly half of the fatal accidents with pedestrians took place in winter (45.6%). No differences between road user groups were found for time of accident and mode of transportation to hospital. All but one of the patients had a blunt trauma mechanism (Table 1).

Clinical characteristics

Injury patterns were strikingly different between the groups of deceased road users (Table 2). Motorcyclists were the most severely injured road user group, and all were diagnosed with severe trauma (ISS ≥ 16), with median ISS 43 (interquartile range [IQR] 34–59). This group had the shortest survival (median hospital stay 2 days, IQR 1–13). Severe head injury occurred in the majority of each group

Table 1 Patient and accident characteristics of 497 in-hospital deceased road traffic accident victims per road user group

Characteristics	Total (n = 497)	Motorists (n = 149)	Motorcyclists (n = 23)	Moped riders (n = 59)	Bicyclists (n = 209)	Pedestrians (n = 57)	p-value
Male, n (%)	341 (68.6)	108 (72.5)	22 (95.7)	47 (79.7)	139 (66.5)	25 (43.9)	<0.0001
Age (years), mean (SD)	63.8 (21.7)	56.2 (25.3)	42.2 (13.9)	63.4 (21.8)	71.1 (16.3)	65.9 (19.0)	<0.0001
By category, n (%)							<0.0001
18–24	42 (8.5)	30 (20.1)	2 (8.7)	4 (6.8)	5 (2.4)	1 (1.8)	
25–55	111 (22.3)	35 (23.5)	16 (69.6)	15 (25.4)	28 (13.4)	17 (29.8)	
56–75	153 (30.8)	32 (21.5)	5 (21.7)	20 (33.9)	80 (38.3)	16 (28.1)	
>75	191 (38.4)	52 (34.9)	0 (0.0)	20 (33.9)	96 (45.9)	23 (40.4)	
Trauma mechanism, n (%)							0.85
Blunt	496 (99.8)	149 (30)	23 (4.6)	59 (11.9)	208 (41.9)	57 (11.5)	
Penetrating	1 (0.2)	0	0	0	1 (100)	0	
Season accident, n%							0.001
Winter	132 (26.6)	45 (30.2)	1 (4.3)	12 (20.3)	48 (23.0)	26 (45.6)	
Spring	116 (23.3)	36 (24.2)	7 (30.4)	18 (30.5)	44 (21.1)	11 (19.3)	
Summer	130 (26.2)	30 (20.1)	12 (52.2)	18 (30.5)	59 (28.2)	11 (19.3)	
Autumn	119 (23.9)	38 (25.5)	3 (13.0)	11 (18.6)	58 (27.8)	9 (15.8)	
Time of arrival in hospital, n (%)							0.07
Morning	67 (13.5)	16 (10.8)	4 (17.4)	7 (12.1)	32 (15.3)	8 (14.0)	
Afternoon	189 (38.2)	49 (33.1)	4 (17.4)	20 (34.5)	93 (44.5)	23 (40.4)	
Evening	187 (37.8)	60 (40.5)	12 (52.2)	22 (37.9)	72 (34.4)	21 (36.8)	
Night	52 (10.5)	23 (15.5)	3 (13.0)	9 (15.5)	12 (5.7)	5 (8.8)	
Mode of transportation to hospital, n (%)							0.63
Ambulance	448 (92.4)	133 (92.4)	19 (82.6)	55 (94.8)	190 (92.7)	51 (92.7)	
HEMS	31 (6.4)	9 (6.3)	4 (17.4)	2 (3.4)	13 (6.3)	3 (5.5)	
Self-presenting	6 (1.2)	2 (1.4)	0	1 (1.7)	2 (1.0)	1 (1.8)	

SD standard deviation, *HEMS* helicopter emergency medical service

of deceased road users, but was most prevalent in the bicyclists and pedestrians (71.3% and 73.7%, respectively). Severe thorax trauma was most seen in motorcyclists and motorists (78.3% and 65.8%, respectively), but was also common in moped riders, bicyclists and pedestrians (30–40%). Severe trauma of the lower extremities, abdomen and spine was most often seen in motorcyclists (47.8%, 34.8% and 21.7%). Significant differences between road user groups were found for respiratory rate and systolic blood pressure upon arrival at the emergency department, but no differences were found for GCS, RTS and ICU admission (Table 2).

In all age groups, severe head trauma and severe thorax trauma were most common. A decrease in the presence of severe trauma to the head, face, neck, thorax, abdomen and severe external injuries was seen with increasing age (Table 3). Median ISS also significantly decreased with increasing age. Deceased RTA victims aged 18–24 years were the most severely injured age group with median ISS of 38 (IQR 29–46), had the lowest level of consciousness on hospital admission (GCS 3–8; $p < 0.0001$) and all had RTS < 11 ($p < 0.0001$). Deceased RTA victims aged over 75 years had the lowest median ISS of 25 (IQR 13–30). In this group, 29.8% was not diagnosed with severe trauma and 44.8% had the maximum RTS. RTA victims aged 18–24 years had the shortest survival (median length of hospital stay 2 days; IQR 1–2) (Table 3).

Prehospital triage

In total, 394 of the 497 fatally injured RTA victims (79.3%) were directly transported to a level I trauma center. As expected, patients transported directly to a level I trauma center more often had severe trauma (ISS $\geq$ 16) compared to patients transported to level II and level III trauma centers (91.4% versus 46.1%; $p < 0.0001$; Table 4). Nevertheless, 47 of the 407 (11.5%) of the patients with severe trauma were not transported to a level I

Table 2 Clinical characteristics of in-hospital deceased road traffic accident victims per road user group

Characteristics	Total (n = 497)	Motorists (n = 149)	Motorcyclists (n = 23)	Moped riders (n = 59)	Cyclists (n = 209)	Pedestrians (n = 57)	p-value
AIS region (AIS ≥ 3), n (%)							
Head	314 (63.2)	74 (49.7)	14 (60.9)	35 (59.3)	149 (71.3)	42 (73.7)	<0.0001
Face	23 (4.6)	6 (4.0)	1 (4.3)	3 (5.1)	9 (4.3)	4 (7.0)	0.92
Neck	13 (2.6)	4 (2.7)	4 (17.4)	1 (1.7)	2 (2.0)	2 (3.5)	<0.0001
Thorax	224 (45.1)	98 (65.8)	18 (78.3)	23 (39.0)	66 (31.6)	19 (33.3)	<0.0001
Abdomen	37 (7.4)	18 (12.1)	8 (34.8)	2 (3.4)	7 (3.3)	2 (3.5)	<0.0001
Spine	48 (9.7)	23 (15.4)	5 (21.7)	5 (8.5)	12 (5.7)	3 (5.3)	0.006
Upper extremities	4 (0.8)	0 (0.0)	1 (4.3)	0 (0.0)	1 (0.5)	2 (3.5)	0.03
Lower extremities	110 (22.1)	36 (24.2)	11 (47.8)	8 (13.6)	41 (19.6)	14 (24.6)	0.01
External	19 (3.8)	17 (11.4)	0 (0.0)	1 (1.7)	0 (0.0)	1 (1.8)	<0.0001
ISS, median (IQR)	27 (18–38)	34 (22–43)	43 (34–59)	25 (16–33)	26 (16–33)	29 (21–34)	<0.0001
By ISS category, n (%)							0.01
ISS < 16	89 (17.9)	18 (12.1)	0 (0.0)	14 (23.7)	47 (22.5)	10 (17.5)	
ISS ≥ 16	407 (82.1)	131 (87.9)	22 (100.0)	45 (76.3)	162 (77.5)	47 (82.5)	
RTS, n (%)							0.31
12	100 (28.3)	30 (30.0)	2 (14.3)	13 (31.7)	45 (28.8)	10 (23.8)	
11	45 (12.7)	13 (13.0)	0 (0.0)	9 (22.0)	18 (11.5)	5 (11.9)	
< 11	208 (58.9)	57 (57.0)	12 (85.7)	19 (46.3)	93 (59.6)	27 (64.3)	
GCS, n (%)							0.09
13–15	142 (30.7)	42 (30.9)	2 (9.5)	21 (37.5)	63 (32.3)	14 (25.9)	
9–12	38 (8.2)	6 (4.4)	1 (4.8)	7 (12.5)	17 (8.7)	7 (13.0)	
3–8	282 (61.0)	88 (64.7)	18 (85.7)	28 (50.0)	115 (59.0)	33 (61.1)	
Respiratory rate, n (%)							<0.0001
<10	36 (9.4)	21 (18.4)	2 (12.5)	6 (13.6)	5 (3.0)	2 (4.3)	
10–29	327 (85.2)	82 (71.9)	14 (87.5)	35 (79.5)	154 (93.9)	42 (91.3)	
>29	21 (5.5)	11 (9.6)	0 (0.0)	3 (6.8)	5 (3.0)	2 (4.3)	
SBP, n (%)							<0.0001
<75	45 (10.0)	26 (20.2)	3 (15.0)	6 (10.9)	10 (5.2)	0 (0.0)	
75–89	34 (7.6)	10 (7.8)	4 (20.0)	2 (3.6)	15 (7.7)	3 (6.0)	
>89	369 (82.4)	93 (72.1)	13 (65.0)	47 (85.5)	169 (87.1)	47 (94.0)	
LOHS (days), median (IQR)	3 (2–8)	2 (1–8)	2 (1–3)	4 (2–10)	3 (2–9)	4 (2–12)	0.01
ICU admittance, n (%)	344 (70.3)	98 (66.2)	17 (73.9)	39 (67.2)	148 (72.9)	42 (73.7)	0.63

AIS abbreviated injury score, *ISS* injury severity score, *IQR* interquartile range, *RTS* revised trauma score, *GCS* Glasgow coma scale, *ICU* intensive care unit, *SBP* systolic blood pressure, *LOHS* length of hospital stay

trauma center. These RTA victims, of whom 61.7% was 75 years or older, were significantly older than the 360 RTA victims with severe trauma who were transported to a level I trauma center hospital (mean 70.7 vs. 59.9 years; $p = 0.001$). In contrast, no age difference was found between the RTA victims without severe trauma who were transported to a level I and those transported to a level II or level III hospital (mean 74.0 vs. 77.6 years; $p = 0.30$; Table 5). The patients who were directly transported to a level I trauma center had more often severe trauma to the head, thorax and spine ($p < 0.001$; Table 4). Fatally injured motorcyclists were mainly transported to a level I center, whereas the other fatally injured road users were distributed more evenly between level I trauma center and level II or level III trauma center hospitals (Table 4).

Table 3 Clinical characteristics of 497 in-hospital deceased road traffic accident victims per age category

Characteristics	Total (n = 497)	18–24 yrs. (n = 42)	25–55 yrs. (n = 111)	56–75 yrs. (n = 153)	>75 yrs. (n = 191)	p-value
AIS region (AIS ≥ 3), n (%)						
Head	314 (63.2)	31 (73.8)	83 (74.8)	99 (64.7)	101 (52.9)	0.001
Face	23 (4.6)	6 (14.3)	5 (4.5)	3 (2.0)	9 (4.7)	0.01
Neck	13 (2.6)	2 (4.8)	7 (6.3)	3 (2.0)	1 (0.5)	0.02
Thorax	224 (45.1)	26 (61.9)	58 (52.3)	62 (40.5)	78 (40.8)	0.02
Abdomen	37 (7.4)	8 (19.0)	12 (10.8)	8 (5.2)	9 (4.7)	0.004
Spine	48 (9.7)	4 (9.5)	18 (16.2)	14 (9.2)	12 (6.3)	0.05
Upper extremities	4 (0.8)	1 (2.4)	1 (0.9)	1 (0.7)	1 (0.5)	0.67
Lower extremities	110 (22.1)	11 (26.2)	17 (15.3)	34 (22.2)	48 (25.1)	0.22
External	19 (3.8)	7 (16.7)	6 (5.4)	3 (2.0)	3 (1.6)	<0.0001
ISS, median (IQR)	2718–38)	38 (29–46)	33 (25–43)	26 (17–36)	25 (13–30)	<0.0001
By ISS category, n (%)						<0.0001
ISS < 16	89 (17.9)	1 (2.4)	7 (6.4)	24 (15.7)	57 (29.8)	
ISS ≥ 16	407 (82.1)	41 (97.6)	103 (93.6)	129 (84.3)	134 (70.2)	
GCS, n (%)						<0.0001
13–15	142 (30.7)	2 (5.4)	8 (7.6)	37 (26.4)	95 (52.8)	
9–12	38 (8.2)	0 (0.0)	3 (2.9)	17 (12.1)	18 (10.0)	
3–8	282 (61.0)	35 (94.6)	94 (89.5)	86 (61.4)	67 (37.2)	
RTS, n (%)						<0.0001
12	100 (28.3)	0 (0.0)	10 (12.8)	25 (23.1)	65 (44.8)	
11	45 (12.7)	0 (0.0)	1 (1.3)	17 (15.7)	27 (18.6)	
<11	208 (58.9)	22 (100.0)	67 (85.9)	66 (61.1)	53 (36.6)	
ICU admission, n (%)	344 (70.3)	28 (66.7)	84 (76.4)	123 (80.9)	109 (58.9)	<0.0001
LOHS in days, median (IQR)	3 (2–8)	2 (1–2)	2 (1–5)	4 (2–10)	4 (2–10)	<0.0001

AIS abbreviated injury score, *ISS* injury severity score, *IQR* interquartile range, *RTS* revised trauma score, *GCS* Glasgow coma scale, *ICU* intensive care unit, *LOHS* length of hospital stay

Discussion

This nationwide study aimed to analyze injury patterns and severity of in-hospital deceased adult road traffic accident (RTA) victims in the Netherlands. Two-thirds of the patients over 56 years and all motorcyclists suffered severe trauma (ISS ≥ 16). Also, of all deceased RTA victims, the severely injured and young patients were mainly transported to a level I trauma center hospital, whereas the older severely injured patients and less severely injured patients of all ages were often transported to a level II or level III trauma center hospital.

The majority of the deceased RTA victims (63.2%) had sustained severe head trauma. This prevalence is almost three times higher than that in all RTA victims in the Netherlands (23.0%) [2]. Thus, it can be assumed that prevention of head trauma may substantially reduce the number of RTA fatalities. In the Netherlands, helmet use is mandatory for motorcyclists and some types of moped vehicles, but not for bicyclists even though bicycling is the most common form of transportation [11]. The highest percentage of fatal RTA accidents in this study involved bicyclists in whom head injuries were the most prevalent type of severe injury (AIS > 3). In a previous Dutch study, similar results were found as severe traumatic brain injuries were mostly diagnosed in bicyclists, pedestrians and moped riders [12]. Yilmaz et al. found that severe head injuries were more prevalent in bicycle-related trauma admissions in the Netherlands, compared to Australia where helmet use is required by law [13]. Therefore, implementation of strict nationwide guidelines on helmet use in bicyclists and all moped riders can be considered to help reduce the number of head trauma-related RTA fatalities in the Netherlands. Also, the introduction of new and the improvement in existing governmental protective and preventive measures (traffic education, improved infrastructure design, improved vehicle safety standards and better enforcement of traffic rules) are essential to

Table 4 Characteristics of in-hospital deceased road traffic accident victims, by hospital level of trauma care

Characteristics	Level I trauma center (n = 394)	Level II or III trauma center (n = 103)	p-value
Road user group, n (%)			0.23
Motorists	124 (31.5)	25 (24.4)	
Motorcyclists	21 (5.3)	2 (1.9)	
Moped riders	44 (11.2)	15 (14.6)	
Bicyclists	159 (40.4)	50 (48.5)	
Pedestrians	46 (11.7)	11 (10.7)	
ISS, median (IQR)	30 (25–38)	13 (9–25)	<0.0001
By category, n (%)			
ISS < 16	34 (8.6)	55 (53.9)	<0.0001
ISS ≥ 16	360 (91.4)	47 (46.1)	
AIS region (AIS ≥ 3), n (%)			
Head	278 (70.6)	36 (35.0)	<0.0001
Face	20 (5.1)	3 (2.9)	0.35
Neck	13 (3.3)	0 (0.0)	0.06
Thorax	194 (49.2)	30 (29.1)	<0.0001
Abdomen	33 (8.4)	4 (3.9)	0.12
Spine	47 (11.9)	1 (1.0)	0.001
Upper extremities	4 (1.0)	0 (0.0)	0.31
Lower extremities	83 (21.1)	27 (26.5)	0.26
External	16 (4.1)	3 (2.9)	0.59
Age (years), mean (SD)	61.1 (22.2)	74.0 (16.2)	<0.0001
By category, n (%)			
18–24	39 (9.9)	3 (2.9)	<0.0001
25–55	103 (26.1)	8 (7.8)	
56–75	127 (32.2)	26 (25.2)	
> 75	125 (31.7)	66 (64.1)	

ISS injury severity score, *IQR* interquartile range, *AIS* abbreviated injury score, *AIS ≥ 3* severe injury

promote traffic safety in the Netherlands so that the number of RTA fatalities in all road user groups can be decreased.

The second most diagnosed injury in our study was severe thorax trauma, which was found in almost half of all deceased RTA victims. This type of severe injury was most often diagnosed in young victims and in motorists and motorcyclists. Our current findings are in line with recent German studies that were retrospectively conducted with autopsy data from deceased RTA victims [14, 15]. Both studies found that the majority of RTA victims died from severe head and thorax trauma.

In our study, motorcyclists were the youngest group of RTA victims that died in hospital and all were admitted with severe trauma (ISS ≥ 16). In total, 92 motorcyclists died during the study period in the Netherlands [16], so 69 of them died on scene. Compared to other vulnerable RTA victims such as pedestrians and bicyclists (of whom, respectively, 108 and 374 victims died during the studied period), it can be deducted that motorcyclists are the most vulnerable road users as most of them died on scene. This conclusion is supported by an earlier Dutch study, which pointed out that young motorcyclists are more vulnerable than other two-wheeled road users [17]. The fact that all but two severely injured motorcyclists were presented in a level I trauma center shows that during prehospital triage motorcyclists are recognized as potentially complex patients with severe injuries in multiple anatomic regions. Unfortunately, this is not always the case for other types of road users with life-threatening injuries since many of those were presented in level II or level III hospitals with less facilities and less experienced staff. Hence, improving adequate prehospital triage and triage on admission of all RTA victims is essential.

Our analysis shows that the overall injury severity in fatally injured RTA victims is inversely related with age and that younger RTA victims had an higher prevalence of severe (AIS ≥ 3) head and thorax injuries. Similar findings were reported by Heinrich et al. and by Osler et al. [15, 18]. Both studies found that in-hospital deceased elderly trauma patients showed lower overall injury severity compared to

Table 5 Characteristics of in-hospital deceased road traffic accident victims by severity of trauma and hospital level of trauma care

Characteristics	ISS < 16		*p*-value	ISS ≥ 16		*p*-value
	Level I trauma center (*n* = 34)	Level II or III trauma center (*n* = 55)		Level I trauma center (*n* = 360)	Level II or III trauma center (*n* = 47)	
Road user group, *n* (%)			0.24			0.58
Motorists	10 (29.4)	8 (14.5)		114 (31.7)	17 (36.2)	
Motorcyclists	0	0		21 (5.8)	1 (2.1)	
Moped riders	4 (11.8)	10 (18.2)		40 (11.1)	5 (10.6)	
Bicyclists	18 (52.9)	29 (52.7)		141 (39.2)	21 (44.7)	
Pedestrians	2 (5.9)	8 (14.5)		44 (12.2)	3 (6.4)	
AIS region (AIS ≥ 3), *n* (%)						
Head	9 (26.5)	4 (7.3)	0.03	269 (74.7)	32 (68.1)	0.33
Face	0	0	–	20 (5.6)	3 (6.4)	0.74
Neck	0	0	–	13 (3.6)	0	0.38
Thorax	8 (23.5)	9 (16.4)	0.40	186 (51.7)	21 (44.7)	0.37
Abdomen	1 (2.9)	1 (1.8)	1.00	32 (8.9)	3 (6.4)	0.78
Spine	0	0	–	47 (13.1)	1 (2.1)	0.03
Upper extremities	0	0	–	4 (1.1)	0	1.00
Lower extremities	6 (17.6)	18 (32.7)	0.12	77 (21.4)	9 (19.1)	0.72
External	1 (2.9)	0	0.38	15 (4.2)	3 (6.4)	0.45
Age (years), mean (SD)	74.0 (17.8)	77.6 (11.0)	0.30	59.9 (22.2)	70.7 (19.5)	0.001
By category, *n* (%)						
18–24	1 (2.9)	0	0.40	38 (10.6)	3 (6.4)	<0.0001
25–55	4 (11.8)	3 (5.5)		99 (27.5)	4 (8.5)	
56–75	9 (26.5)	15 (27.3)		118 (32.8)	11 (23.4)	
>75	20 (58.8)	37 (67.3)		105 (29.2)	29 (61.7)	

ISS injury severity score, *SD* standard deviation, *AIS* abbreviated injury score, AIS ≥ 3 severe injury

younger deceased trauma patients. This underlines that elderly are more vulnerable road users, mostly due to preexisting comorbidities and functional decline in daily life [19, 20]. Our study showed that the RTA victims aged over 75 years had better vital signs at initial presentation than RTA victims aged 18–24 years. This may bias the clinicians' interpretation of injury severity during admission and its impact on the chance of survival. Clinicians should be suspicious of (combinations of) potentially lethal injuries to head and thorax that do not seem life-threatening at time of admission.

According to national guidelines set up by the Dutch Trauma Association, trauma patients with an ISS ≥ 16 (severe trauma) should directly be transported to a level I trauma center, but in the prehospital phase injury severity often is difficult to determine. Although 88% of all deceased RTA victims with severe trauma in this study were transported to a level I trauma center, this percentage decreased with advancing age from 93% in the youngest age group (18–24 years) to 78% in the elderly (75 years and older). This finding is in line with other studies that have shown that old age is a risk factor for undertriage [21, 22]. Including age, alongside prehospital RTS, in the prehospital triage of RTA victims may improve the clinical outcome of this specific group of trauma patients. To prevent undertriage in elderly, Calland et al. suggested to treat all elderly trauma patients (> 65 years) with at least one AIS > 3 injury in a level I trauma center [23]. As RTA victims aged over 75 years in this study were the largest group, with the lowest mean ISS and the most favorable clinical parameters, more awareness of the vulnerability of elderly RTA victims in prehospital triage is needed. This is even more important as the proportion of elderly RTA victims in both the Netherlands and in the Europe Union has risen during the past decade and will probably continue to rise in the future [2, 24].

Limitations

Results were based on retrospective data from the National Trauma Registry, which did not include the 702 on-scene deceased RTA victims. These victims represent a group that was probably more severely injured than the in-hospital deceased victims. However, no factual data of the on-scene deceased group about injury pattern and severity are available. A second limitation is that the trauma registry includes only a limited and pre-determined set of parameters. In the registry, road users are not classified in detail, so that bicycles and e-bikes are combined in one group and mopeds also include different types of vehicles. This lack of detailed specification may have blurred the results in these more heterogeneous road user groups. Also, it was impossible to study the effects of preexistent vulnerability, speed, helmet use and other forms of protection as these data are not available.

Conclusion

Further prevention of head trauma is needed to reduce the lethality of RTA victims, especially bicyclists, who are the largest group of deceased RTA victims with head trauma as predominant injury pattern. Elderly form a large part of the deceased RTA victims in the Netherlands, despite the fact that they have the lowest mean ISS and the best clinical parameters on admission. Thus, the risk of undertriage of injury severity in elderly is obvious and should be addressed in the early phases of trauma care, especially during prehospital triage and the initial care at admission of elderly RTA victims.

Compliance with ethical standards

Conflict of interest All the authors declare that they have no conflict of interest.

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