Traffic accident victims and polytrauma patients: injury patterns, outcome and their influencing factors

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INTRODUCTION

1

General introduction, aim and outline of the thesis

Outcome and injury patterns after road traffic accidents

Road traffic accidents (RTA's) contribute significantly to the global burden of trauma. The World Health Organization indicates that approximately 1.3 million people die each year on the world's roads and between 20 and 50 million sustain non-fatal injuries[1].

The introduction of extensive traffic safety laws and extensive preventive governmental programs in The Netherlands resulted in a gradual decrease in road traffic injuries and fatalities in the 1990s and onward[2]. At the same time, the organisation of pre- and in-hospital trauma care changed dramatically. The Advanced Trauma Life Support (ATLS®) program provided a national guideline for the structured and systematic approach to the primary treatment of trauma patients[3]. This was followed in 1997 by the implementation of 11 regional trauma systems by the Dutch government, each of which contains one level I trauma center that provides the highest level of surgical care to trauma patients and is responsible for the trauma network and collaboration in that specific trauma region.

After decades of declining numbers of RTA fatalities, this number has stabilized at an annual average of 620 fatalities in 2015 and since then a slight increase was seen resulting in 661 road traffic-related fatalities in the Netherlands in 2019[4].

Also, despite government measures to improve road safety, the number of serious road traffic injuries has been increasing since 2006. In 2018, an estimated 21,700 people were seriously injured in traffic in the Netherlands, approximately 1,000 more than in 2017[4].

Nowadays, traffic conditions and demographics of road traffic participants are changing continuously. Especially in a densely populated country like the Netherlands, the roads are congesting more and more and motorized two-wheeled vehicles have become an efficient and more important alternative method of transportation. Compared to other motorized road users, such as cars, riders of motorized two-wheeled vehicles are more vulnerable and therefore at greater risk of sustaining severe injuries and death[5-8].

Elderly are over-represented in both RTA fatalities and seriously injured RTA participants. The ageing Dutch population and the increased desire for self-reliance and autonomy of older people will probably strengthen this trend. Although that seems a positive development, it can lead to more safety risks as older people remain more mobile and travel longer distances using more and different methods of transportation such as electric bicycles, mopeds and mobility scooters[9]. Thus, the number of mobility scooters in The Netherlands is expected to grow among this specific part of the population to around

600,000 in 2030[10]. With its low speed, the mobility scooter may seem relatively safe, but especially among older users, safe use of the vehicle can be affected negatively by chronic illnesses, polypharmacy and by changes in physical and cognitive skills[10-13]. Each year, around 1,200 people over 55 (of which more than half are over 75 years of age) visit Emergency Departments (ED) of Dutch hospitals for treatment after an incident with a mobility scooter[10].

Another challenge for road safety programs are traumatic brain injuries (TBI) and unfortunately, the incidence of both non-severe and severe TBIs is rising sharply, mainly as a result of RTA's[14]. The high mortality rates, disability and long-term loss of function as a result of TBI have a significant impact on national health systems[6]. Each year approximately 21,000 RTA victims are admitted to Dutch hospitals with severe injuries and of those 20% sustained TBI. Nevertheless little is known about the epidemiology and risk factors for TBI after RTA's[15].

Effect of alcohol on injury patterns

It is widely recognised that drunk driving is an important risk-increasing factor and contributes to many RTA fatalities. It can be assumed that the real number of alcohol-related road casualties is higher than reported in the official statistics. Previous research found that a weighted average of 21.8% among road deaths worldwide are alcohol-related[16]. In the Netherlands, an estimated 12% to 23% of the RTA fatalities were due to drinking and driving in 2015, which is in line with the worldwide average[17]. A strong correlation exists between alcohol intoxication and the increased risk of sustaining all types of injuries[18,19]. TBI is no exception, with elevated blood alcohol concentrations (BAC) being demonstrated in almost half of the trauma patients diagnosed with TBI in Europe[20]. Nonetheless, the influence of elevated BACs on the outcome of severely injured patients and the corresponding pathophysiological changes remain a controversial issue. Recent literature suggests a neuroprotective effect of alcohol on TBI[21-24], possibly resulting in lower mortality and morbidity rates compared to TBI patients without elevated BAC's [25]. Despite these controversies, only very few studies have addressed the influence of alcohol intoxication in general and specific levels of BACs on TBI pattern and severity.

Influence of severe injuries on quality of life

In the Netherlands, 20% of all trauma patients admitted to hospitals each year since 2014, result from road traffic accidents [26]. It is well known that trauma affects people of all ages, and causes the loss of a considerable number of life years due to premature death and large numbers of years lived with disability[27]. Due to the introduction of an all-inclusive trauma system and centralization of trauma care, more polytrauma patients survive their injuries, often resulting in long-term disabilities and severe deficits in health-related quality of life (HRQoL). Thus, HRQoL has become an important outcome measure of current trauma care. Especially long-term effects on physical and mental health have been extensively reported in literature[28]. However, fatigue and reduced societal participation in polytrauma patients have not been previously reported on and also their association with reduced HRQoL has not been described in the literature.

Aim and outline of this thesis

Polytrauma and especially road traffic accidents often result in and contribute significantly to severe morbidity and mortality. The primary aim of this thesis is to analyse injury patterns, injury severity and mortality for different types of road traffic participants involved in accidents in the Netherlands. Secondly, the association between blood alcohol concentrations, TBI patterns and patient outcome was analysed. Finally, patient and injury characteristics associated with HRQoL, fatigue and societal participation in polytrauma patients were identified.

Chapter 2 gives an overview of injury patterns and injury severity of in-hospital deceased RTA victims in the Netherlands. **Chapter 3** aims to describe the influence of different types of motorized two-wheeled vehicles on the patients' injury severity and mortality upon hospitalization after accidents in the Netherlands. **Chapter 4** provides an analysis of injury patterns, injury severity and mortality among victims of motorized mobility scooter accidents in relation to the trauma mechanism and patient's age. **Chapter 5** analyses the incidence, risk factors, hospital triage and outcome of patients with severe traumatic brain injuries caused by road traffic accidents admitted to hospitals in the Trauma Centre West region. **Chapter 6** discusses the association of different levels of blood alcohol concentration with traumatic brain injury characteristics and outcomes. **Chapter 7** provides the connection between determinants for Health-Related Quality of Life, fatigue and societal participation in polytrauma patients. In **chapter 8** a discussion on the topics described above is presented, together with future perspectives and potential implications of the findings stated in this thesis.

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PART I

INJURY PATTERNS AND OUTCOME

2

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 of road traffic accident (RTA) fatalities is a key priority in the European Union. Since data on injury patterns related to mortality in RTAs is scarce, this study aimed to analyse 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 analysed. 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 analysed, of which most were bicyclists.
All analysed motorcyclists had an ISS≥16. Head trauma was most frequent in pedestrians (73.7%) and bicyclists (71.3%). Thorax trauma was most frequent in motorcyclists and motorists (respectively 60.9% and 65.8%). 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≥16) RTA victims were not transported to a level I trauma centre. 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, under-triage of severe trauma in elderly RTA victims is obvious and should be addressed in the early phases of trauma care, especially during pre-hospital 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 cause 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 to 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].

Further decline in RTA fatalities is one of the key priorities of the "Road Safety Program 2011 – 2020" initiated by the European Commission, which 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 analysed 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 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 was 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 the hospital (ambulance, helicopter emergency medical service, self-presenting), hospital of admission (Level I, level-II or level-III trauma centres), 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 the 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 cut off points used by the National Trauma Registry for age (18-24, 25-55, 56-75 and >75 yrs.), 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 were statistically analysed 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% were male.

Patient and accident characteristics

There were statistically significant differences in 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

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.

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 the 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 the time of the accident and the mode of transportation to the hospital. All but one of the patients had a blunt trauma mechanism (Table 1).

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.

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 a median ISS of 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 of deceased road users but was most prevalent in bicyclists and pedestrians (71.3% and 73.7% respectively). Severe thorax trauma was most seen in motorcyclists and motorists (respectively 78.3% and 65.8%) 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).

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.

In all age groups, severe head trauma and severe thorax trauma were the most common. A decrease in 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 a 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% were 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).

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

Characteristics	Level I Trauma centre (n=394)	Level II or III Trauma centre (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 (%)			<0.0001
ISS <16	34 (8.6)	55 (53.9)	
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.

Pre-hospital triage

In total, 394 of the 497 fatally injured RTA victims (79.3%) were directly transported to a level-I trauma centre. As expected, patients transported directly to a level-I trauma centre more often had severe trauma (ISS≥16) compared to patients transported to level-II and level-III trauma centres (91.4% versus 46.1%; p<0.0001; Table 4). Nevertheless, 47 of the 407 (11.5%) patients with severe trauma were not transported to a level-I trauma centre. These RTA victims, of whom 61.7% were 75 years or older, were significantly older than the 360 RTA victims with severe trauma who were transported to a level-I trauma centre hospital (mean 70.7 versus 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 versus 77.6 years; p=0.30; Table 5). The patients who were directly transported to a level-I trauma centre 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 centre, whereas the other fatally injured road users were distributed more evenly between level-I trauma centre and level-II or level-III trauma centre hospitals (Table 4).

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

Characteristics	ISS< 16			ISS ≥16		
	Level I Trauma centre (n = 34)	Level II or III Trauma centre (n = 55)	p-value	Level I Trauma centre (n = 360)	Level II or III Trauma centre (n = 47)	p-value
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.

DISCUSSION

This nationwide study aimed to analyse injury patterns and – the severity of in-hospital deceased adult road traffic accident (RTA) victims in The Netherlands. Two third 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 centre 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 centre hospital.

The majority of the deceased RTA victims (63.2%) had sustained severe head trauma. This prevalence is almost three times higher than that of all RTA victims in the Netherlands (23.0%) [2]. Thus, it can be assumed that the 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, the 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 of existing governmental protective and preventive measures (traffic education, improved infrastructure design, improved vehicle safety standards and better enforcement of traffic rules) are essential to 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 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 the 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 the 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 centre 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 fewer facilities and less experienced staff. Hence, improving adequate prehospital triage and triage on the admission of all RTA victims is essential.

Our analysis shows that the overall injury severity in fatally injured RTA victims is inversely related to age and that younger RTA victims had a 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 younger deceased trauma patients. This underlines that the elderly are more vulnerable road users, mostly due to pre-existing 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 the head and thorax, that do not seem life-threatening at the 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 centre, 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 centre, 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 under-triage [21,22]. Including age, alongside prehospital RTS, in the pre-hospital triage of RTA victims may improve the clinical outcome of this specific group of trauma patients. To prevent under-triage in the elderly Calland et al. suggested treating all elderly trauma patients (>65 years) with at least one AIS>3 injury in a Level-I Trauma centre [23]. As RTA victims aged over 75 years in this study were the largest group, with the lowest mean ISS and the most favourable 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 regarding injury pattern and severity is 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 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 pre-existent 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 the 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 under-triage of injury severity in the elderly is obvious and should be addressed in the early phases of trauma care, especially during pre-hospital triage and the initial care at the admission of elderly RTA victims.

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Injury pattern, injury severity, and mortality in 33,495 hospital-admitted victims of motorized two-wheeled vehicle crashes in The Netherlands.

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ABSTRACT

Background

Road traffic accidents involving motorized two-wheeled vehicle (MTV) riders often result in severe morbidity and mortality. This nationwide study aims to describe the influence of the type of motorized two-wheeled vehicle on the patient injury severity and mortality upon hospitalization, after MTV accidents in the Netherlands.

Methods

Data from the Institute for Road Safety Research and the Hospital Trauma Databases were analysed. All MTV crash victims admitted to Dutch hospitals from 1993 to 2008 were included. Logistic regression analysis was performed on sex, age, type of MTV, Injury Severity Score and Abbreviated Injury Scale to calculate the relative risks of severe trauma and mortality for motor and light-moped riders according to the Mantel and Haenszel procedure (RRmh).

Results

Among 33,495 MTV crash victims, 10,607 were motorcyclists, 19,708 moped riders and 3,180 light-moped riders. In the light-moped rider group head injury, especially severe head injury was most common in light-moped riders and the prevalence of severe trauma (17.1%) and mortality (4.2%) were highest, compared to motorcyclists and moped riders. In elderly crash victims (> 55 years) the risk to sustain severe trauma was almost twofold higher in light-moped riders compared to moped riders (RRmh 1.79). Young motorcyclists (< 25 years) had the highest chances of dying (RRmh 1.64).

Conclusions

Hospitalized light-moped riders show more severe head injuries, severe trauma, and higher mortality than moped riders and motorcyclists. Young motorcyclists and elderly light-moped riders are most vulnerable, with the highest chances of severe trauma and mortality. Continuing improvement of MTV safety is urgent.

INTRODUCTION

Road traffic accidents involving motorized two-wheeled vehicle (MTV) riders often result in severe morbidity and mortality. Nevertheless, due to increasing congestion on Dutch roads, the MTV is becoming an efficient and increasingly important method of transportation. Compared to other motorized road users (such as cars and trucks), MTV riders are at greater risk of sustaining severe multiple injuries and death after road traffic accidents, because of their vulnerability and relative high driving speed.[1-4] In the ’70s of the previous century helmet laws for motorcyclists and moped riders were introduced in the Netherlands. Since then, virtually 100% of motorcyclists use motorcycle helmets. The percentage of moped riders not wearing a helmet at all, or not wearing it correctly has been increasing over the past 10 years.[5] Light-moped riders are not obliged to wear a helmet, which makes this vehicle especially popular amongst young people and the elderly in the Netherlands. In 1993 295,000 persons owned at least one motorcycle and 461,000 persons at least one moped or light-moped. The number of motorcycle owners increased to 431,000 in 2008, and the number of mopeds and light-moped owners increased to 482,000. Light-mopeds and mopeds have an engine cylinder capacity of 50cc and a permitted maximum speed of respectively 25 km/h and 45 km/h. Motorcycles have an engine capacity exceeding 50cc and a permitted maximum speed of 120 km/h. Between 1993 and 2008 a total of 37,779 motorcycle-, 115,054 moped-, and 20,429 light-moped accidents were registered in the Netherland.[6] These numbers concern both hospitalized and none hospitalized crash victims.

The three categories of MTVs in the Netherlands offer the possibility to compare the effects of different types of MTV and their specific driver groups, on injury severity and mortality in hospital-admitted MTV crash victims. Although previous studies described injury severity and mortality related to moped and motorcycle accidents only, none described this relationship in three different types of MTV. [7-10]

This nationwide study aims to analyse injury patterns, -severity and mortality in hospital-admitted MTV crash victims, per MTV group. Additionally, the association between severe trauma, mortality and MTV rider group will be determined according to ascending age categories.

METHODS

Study design

The nationwide Hospital In-patient Registration (LMR) and the Database Registered Crashes in the Netherlands (BRON) were combined and matched by the SWOV Institute For Road Safety Research to create a nationwide traffic accident database containing specific medical data. The SWOV is an independent institute that aims to improve road safety by using knowledge from scientific research. The linked databases, encompassing the most complete and largest collection of traffic accidents assembled in the Netherlands, enabled an analysis of all MTV crash victims, admitted to hospitals from 1993 to 2008. Victims who only visited the emergency department without being admitted, as well as victims who deceased at the scene of the accident or on arrival at the hospital, were not included. No detailed data on helmet use were available.

Definitions & Methods

MTV groups were defined as light-mopeds, mopeds and motorcycles (permitted maximum speeds of respectively 25 km/h, 45 km/h and 120 km/h). MTV accidents were identified using the International Statistical Classification of Diseases and Related Health Problems (ICD-9 Classification). The analysed data included age, sex, type of MTV, Abbreviated Injury Scale update 1998 (AIS)[11], Injury Severity Score (ISS)[12], severe trauma (ISS ≥16), injury severity distribution (AIS > 2 i.e. severe injury) injury pattern description according to AIS anatomical region (Head, Face, Neck, Thorax, Abdomen, Spine, Upper extremities, Lower Extremities, External), and mortality.

Overall changes in severe trauma over time and numbers of hospital admittances during the analysed period were described per MTV group. The anatomic distribution of injury and severe injury (AIS>2) was analysed using the injury description according to AIS per MTV group.

A subgroup analysis was performed on patients with severe head injury (AIS Head > 2) to quantify the expected mortality due to severe head injury. Continuous variables were dichotomized using clinically relevant cut-off points: age (<25yrs, 25-55yrs, >55yrs) and ISS (<16 vs. ≥16). Relative Risks (RR) and corresponding 95% confidence intervals (95% CI) were calculated for severe trauma (ISS ≥16) and mortality per MTV group with moped riders used as the reference category. All risk ratios are adjusted for sex and age category according to the Mantel Haenszel procedure (RRmh).[13]

RESULTS

A total of 33,495 MTV crash victims were admitted to the hospital between January 1st, 1993, and December 31st, 2008. Table 1 shows the demographics of the crash victims. There were 10,607 motorcyclists, 19,708 moped riders and 3,180 light-moped riders. The median age was 24 years (IQR = 21) and 6,516 (19.5%) victims were female. The median age per MTV group was respectively 33 years (IQR =21), 18 (IQR=13) and 30 years (IQR=40). In total, 4,253 (12.7%) crash victims had severe trauma (ISS ≥16), and 816 (2.4%) victims died in the hospital after being admitted.

Table 1. Comparisons of demographics by three groups of motorized two-wheeled vehicle crash victims.

	Total Patients	Motorcyclists	Moped Riders	Light-Moped Riders
	N=33,495 (%)	N=10,607 (%)	N=19,708 (%)	N=3,180 (%)
Sex				
Female	6,516 (19.5)	1,071 (10.1)	4,232 (21.5)	1,213 (38.1)
Age				
Median	24 (IQR [A] = 21)	33 (IQR = 17)	18 (IQR = 13)	30 (IQR = 40)
<25 yrs	17,318 (51.7)	1,926 (18.2)	13,936 (70.7)	1,456 (45.8)
25-55 yrs	13,661 (40.8)	8,188 (77.2)	4,579 (23.2)	894 (28.1)
>55 yrs	2,516 (7.5)	493 (4.6)	1,193 (6.1)	830 (26.1)
Injury Severity				
ISS [B] ≥16	4,253 (12.7)	1,385 (13.1)	2,325 (11.8)	543 (17.1)
Mortality				
Deceased	816 (2.4)	260 (2.5)	423 (2.1)	133 (4.2)

[A] Interquartile range
[B] Injury Severity Score

Injury severity

Severe trauma was diagnosed in 13.1% of the motorcyclists, 11.8% of the moped riders and 17.1% of the light-moped riders (Table 2). Overall, severe trauma was most prevalent in the light-moped rider group (adjusted RR 1.46). In all age categories severe trauma was most prevalent in the light-moped rider group: especially in light-moped riders older than 55 years (RR 1.79) (Table 3).

Despite the increasing number of motorcycle owners during our study period, the annual number of hospital admissions after motorcycle crashes decreased. The percentage of severe trauma remained approximately equal over the years. The situation for the moped riders was similar. After a decrease in admissions of light-moped riders, the number of admissions remained stable during the onward studied years. Even a slight increase was seen at the end of our study period (Figure 1).

Table 2. Mantel Haenszel risk ratios of severe trauma (ISS ≥ 16) and mortality for three groups of hospital admitted MTV crash victims.

			MH risk ratio°		MH risk ratio *	
		N	RR#	95% CI ‘	RR	95% CI
ISS ≥ 16	Motorcycle	1385	1.11	1.04 - 1.18	1.14	1.06 - 1.23
	Moped	2325	1	Ref	1	Ref
	Light-moped	543	1.45	1.33 - 1.58	1.46	1.33 - 1.60
Mortality	Motorcycle	260	1.14	0.98 - 1.33	1.12	0.94 - 1.33
	Moped	423	1	Ref	1	Ref
	Light-moped	133	1.95	1.61 - 2.36	1.49	1.21 - 1.83

Moped riders were used as reference group
° Crude MH risk ratios per type of motorized two-wheeled vehicle.
* MH risk ratios adjusted for age and sex per type of motorized two-wheeled vehicle
# Risk Ratio
‘ Confidence Interval

Table 3. Mantel Haenszel risk ratios of severe trauma (ISS ≥16) and mortality per age category adjusted for sex divided in three groups of hospital admitted MTV crash victims.

			< 25 yrs		25 - 55 yrs		> 55 yrs	
		N	RRmh#	95% CI ‘	RRmh	95% CI	RRmh	95% CI
ISS ≥ 16	Motorcycle	1385	1.19	1.06 - 1.34	1.13	1.02 - 1.25	1.05	0.80 - 1.38
	Moped	2325	1	Ref	1	Ref	1	Ref
	Light-moped	543	1.34	1.17 - 1.52	1.44	1.20 - 1.71	1.79	1.47 - 2.18
Mortality	Motorcycle	260	1.64	1.24 - 2.16	1.13	0.88 - 1.45	0.36	0.19 - 0.65
	Moped	423	1	Ref	1	Ref	1	Ref
	Light-moped	133	1.31	0.91 - 1.87	1.86	1.24 - 2.80	1.45	1.06 - 1.99

Moped riders were used as reference group
Mantel-Haenszel Risk Ratio
‘ Confidence Interval

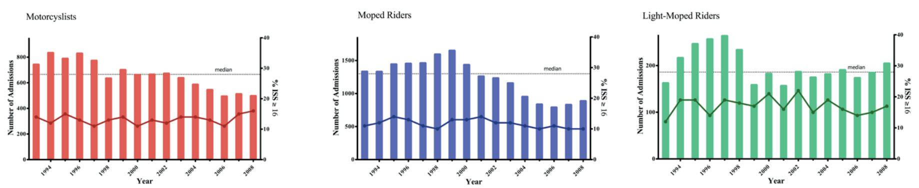

Fig 1. Number of crash victims admitted to hospitals across the Netherlands (coloured bars) per MTV group and the percentages of severe trauma (ISS ≥ 16) (coloured lines) per year during the period 1993-2008.

Injury pattern

As shown in figure 2, in the light-moped rider group head and face/neck injuries were the most common injuries sustained, respectively 32.2% and 11.3%. The most common injuries in the motorcyclist group were upper-extremity and spine injuries (25.7% and 5.9%). Moped riders were mostly diagnosed with a lower-extremity injury (37.5%, see Figure 2).

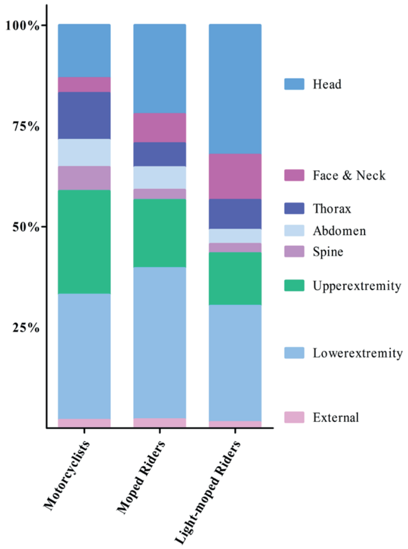

Fig. 2. Distribution of injuries per anatomical region (according to the AIS classification) in fatally and non-fatally injured motorized two-wheeled vehicle riders per MTV group. The External category comprises of burns.

In figure 3A only the most severe injuries were considered (AIS>2). In the light-moped rider group, nearly half of all severe injuries concerned head injury (49.3%). In the motorcyclist group, severe thorax injury and severe lower-extremity injury were most common (respectively 24.3% and 39,1%). In admitted moped riders severe lower extremity injury was most common (48.5%), followed by severe head injury (29.6%).

Mortality

Death after admission to the hospital was most prevalent in the light-moped group (4.2%). The relative risks of death upon hospital admission are displayed in table 2. Relative risks stratified per age category are displayed in table 3. Compared to the occurrence of severe trauma, a similar pattern was visible for mortality: when compared to moped riders, the risk of death was highest in light-moped riders (RR 1.49, 95%CI 1.21 – 1.83). When stratified for age, the risk of death following a motorcycle accident after admission to a hospital was highest in the youngest age category (RR 1.64, 95% CI 1.24 – 2.16). In advancing age categories, the risk of death was highest in light-moped riders.

The distribution of severe injuries among fatally injured riders per MTV group is displayed in figure 3B. Severe head injury was most frequently diagnosed in all three groups of MTV riders: 47% in motorcyclists, 64% in moped riders and 73% in light-moped riders who deceased. The second most common severe injury was thoracic injury: respectively 20%, 14% and 13%.

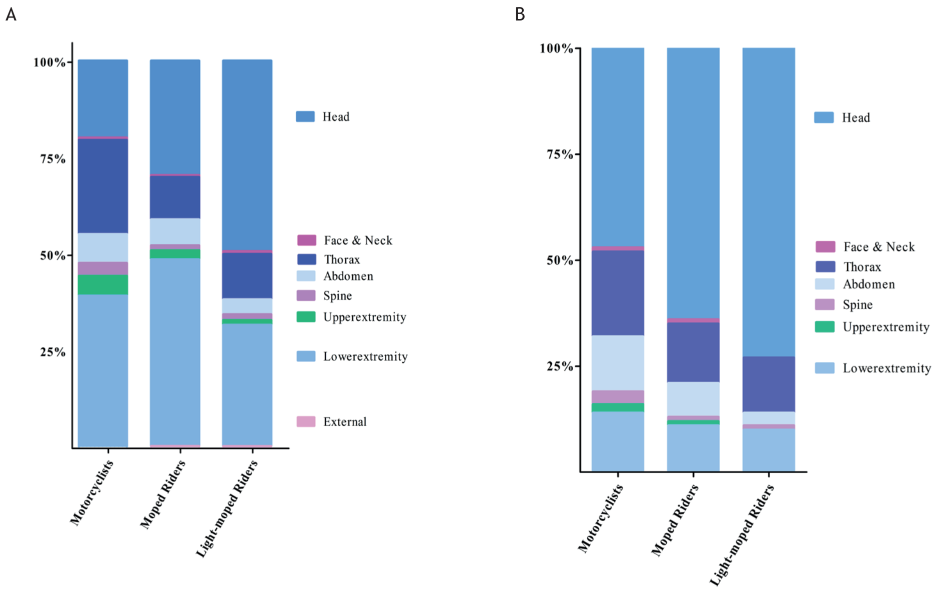

Fig. 3. Distribution of severe injuries per anatomical region (according to the AIS classification: AIS > 2) in non-fatally and fatally injured (A) and in fatally injured (B) motorized two-wheeled vehicle riders per MTV group.

DISCUSSION

This nationwide study aimed to describe the influence of the type of MTV on patient injury pattern, severity and mortality upon hospitalization after MTV accidents.

Important to note is that MTV groups were used as a proxy for several differences between these types of MTV: helmet use is not mandatory for light-moped drivers and the permitted maximum speed is of course different for each group of MTV (Light-mopeds 25 km/h, mopeds 45 km/h and motorcycles 120 km/h). In addition, the rider characteristics for the three classes differ in age and sex. Although we control for these two differences, all our results should be interpreted with the notion that MTV class is used as a proxy for these measures and therefore no definite conclusions can be drawn regarding one single property.

MTV crashes are associated with injuries in multiple anatomic regions and often result in instant death. This is largely due to their great vulnerability in daily traffic. In the Dutch situation, the light-moped can be seen as the most vulnerable MTV because helmet use is not mandatory by law. Our findings showed that driving a light-moped is associated with a high risk to sustain severe trauma and dying when admitted to a hospital after a crash compared to the better-protected motorcyclist and moped rider.

Interestingly, the present study shows a significantly higher risk of mortality after being involved in a traffic accident for motorcyclists younger than 25 years old, compared to moped and light-moped riders in the same age group. In contrast to the higher risk in the younger group of motorcyclists, advancing age in the light-moped group was associated with worse outcomes. Especially light-moped riders aged 55 years and older were significantly more likely to suffer severe injury and death compared to hospital-admitted moped riders and motorcyclists. Younger riders may have less experience in riding a motorized vehicle, more easily overestimate their riding skills and are more prone to accept excessive risks. Another influence might be the phenomenon of illegally upgraded engines in mopeds and light-mopeds, especially by younger riders. In 2007, 22% of the moped and light-moped riders halted by Police forces on Dutch roads were driving illegally upgraded mopeds and light-mopeds. This percentage was the same as in 2006, but lower than in 2005 (28%) and 2004 (31%). [14] Although a decrease was seen in the number of illegal modifications of mopeds and light-mopeds, these modifications still might increase the risk of crashes because of higher driving speeds.

Older riders are, in general, more careful on the road, but they are physically more vulnerable. Several governmental reports and scientific studies also suggested that advancing age might be associated with higher risks of suffering severe extensive injury and mortality.[4, 8, 15-17]

Our findings concerning injury pattern and injury severity may hold important implications for the treatment of MTV crash victims and the prevention of severe injury and mortality after crashes. The results of this study showed that motorized two-wheeled accidents are often associated with injuries in multiple anatomic areas. Besides head injuries, many injuries to the trunk, abdomen and extremities were registered. Therefore, the MTV crash victim can be seen as a complex trauma patient who needs an adequate poly-trauma evaluation and management by specialised healthcare personnel, both pre-hospital and hospital personnel. Moreover, the seemingly simple and low-energy light-moped crashes result in substantial injury or death relatively more frequent than in other MTV crashes. Therefore, especially for these light-moped crash victims, extra care should be taken on beforehand, so as not to underestimate their potential injuries and their sequels. Even though, their primary presentation may not be as impressive as that of a motorcycle crash victim. Bearing this in mind, low threshold admittance to a trauma centre facility may be advisable.

During our study period, a total of 1,342 motorcycle, 973 moped and 323 light-moped-related deaths were registered in the Netherlands.[5, 6, 14, 18] On average, 31% of these deaths occurred after hospitalization (motorcyclists 19%, moped riders 43%, light-moped riders 42%), and the other 69% of the deceased MTV crash victims died before they arrived at the hospital. Since medical staff in emergency rooms, operating theatres and intensive care units, will treat patients who only survive the initial crash, we designed this study to describe the injury pattern and severity amongst MTV crash victims after hospitalization. Therefore, the risks and injury patterns described here are large underestimations of the absolute mortality risks associated with MTV crashes, especially for motorcyclists (81% of the deceased motorcyclists died before arrival at the hospital). The percentage of victims who died before hospitalization (57% of the deceased) is equal for moped and light-moped riders, which reduces the bias in these calculations. Nonetheless, the current results should be interpreted with this selection in mind and cannot be used to draw conclusions on the absolute risks of motorised two-wheeled vehicle use.

The percentage of severe head injury upon hospitalization was most frequent in both non-fatally and fatally injured light-moped crash victims and lowest in motorcycle crash victims. Assuming that motorcyclists with severe head injury are more prone to die at the scene of the accident because of the high-energy trauma mechanism, the protective effect of helmets on head injury can probably account for the relatively low amount of severe head injury in hospitalized motorcyclists. When the initial severe head trauma was survived, motorcyclists probably died because of other severe trauma after hospitalization. This could implicate that a large proportion of severe head injuries in light-moped riders could have been prevented with the usage of protective helmets.

The protective effect of helmets has been confirmed in many studies regarding helmet use on MTV's.[1-4, 9, 15, 19-21] Furthermore, the trend of prevention of head injury is already accepted in sports in which the athlete is at a higher risk of sustaining a head injury, such as skiing[22, 23] and cycling[24]. But our data point out that apart from head injury, thoracic injury, abdominal injury and extremity injury also represent a high percentage of sustained injury and severe injury in the non-fatally and fatally injured MTV rider.

The present study, therefore, indicates that it is important to not only strive for strict helmet usage to prevent brain damage for all types of motorized two-wheelers but that the protection of other vital organs in the chest and abdomen is just as important. Continued improvement of existing MTV rider safety measurements and risk perception is of major importance. Mandatory protective and striking clothing, educational improvement and improvement of road conditions are additional measures that could improve MTV rider safety.

As a result of the increased numbers of MTV owners and to improve traffic safety in the Netherlands, several governmental protective and preventive measures were introduced during the study period. In 1998 the Ministry of Health, Welfare and Sport designated 11 hospitals across the country as Level 1 trauma centres. Their goal was to regionalize and deliver the full spectrum of healthcare to an injured patient. This strategy of regionalized expert trauma care has shown to be both efficient and cost-effective.[25] Since 1998 a growing number of MTV crash victims were transported directly to Level 1 trauma centres in the Netherlands. Through the implementation of more efficient prehospital triage systems and improved prehospital care, regionalized trauma care may have attributed to the initial decline in hospital admissions, although the percentage of severe trauma remained at a stable level (figure 1).

A limitation of this study is the absence of complete and reliable data on helmet use. It is assumed that 100% of motorcyclists use motorcycle helmets and less than 10% of light-moped riders. The true impact of helmet use cannot, therefore, be interpreted in this study. Liu et al estimated that motorcycle helmets reduce the risk of head injury by 69% and death by 42%. Another limitation is the absence of information on whether the crash victims were the driver or the passenger. Also, the number of safety features present on the different vehicles which were involved in the MTV crashes was not available.

Although every effort was made to code injuries accurately, a possible bias might have been introduced concerning the interpretation of injury pattern, injury outcome and accident demographics; therefore, influencing the AIS and ISS coding. Also, cases in which the local authorities registered a hospital visit and this was not registered by the hospital, and vice versa, were not included in the database.

This study presents an analysis of the current situation in The Netherlands concerning injury pattern, injury severity and mortality among hospitalized motorized two-wheeled vehicle crash victims. Overall, the hospital admitted light-moped riders show more severe head injuries and higher mortality than moped riders and motorcyclists. The young motorcycle rider and elderly light-moped rider are two very vulnerable groups in daily MTV traffic, with the highest chances of severe injury and mortality, upon hospitalization. The differences in age and also the use of different types of motorized two-wheeled vehicles are of significant importance, both medically and socially. This study points out that despite previous protective measurements continuing improvement of the safety of all MTVs is urgent.

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4

Accidents involving a motorized mobility scooter: a growing problem.

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ABSTRACT

Background

The aim of the study was to analyse injury patterns, injury severity and mortality among victims of motorized mobility scooter (MMS) crashes in relation to trauma mechanisms and patient's age.

Methods

Data obtained from the trauma registry of the Trauma Centre West (TCW) was analysed. All MMS crash victims aged 18 years and older, admitted to hospitals in the trauma centre region during the period 2003-2013, were included.

Results

A total of 242 MMS crash victims were analysed, of whom 51% were aged 75 years and older. Severe trauma (Injury Severity Score ≥ 16) was diagnosed in 15% of all cases and was more common in victims who sustained a high-energy accident ($p < 0.001$) and patients 75 years and older ($p = 0.04$). Severe injuries after low-energy accidents mostly affected the extremities and particularly the legs in elderly patients. Severe injuries after high-energy accidents mostly involved the chest and head, especially in patients younger than 75 years. A total of 10 patients (4%) died during their hospital admission. Of those 5 patients were over 75 years old and sustained a low-energy accident.

Conclusions

Low-energy, as well as high-energy accidents involving the MMS, may result in serious injuries and sometimes death. Awareness by multidisciplinary treatment teams may help to avoid the underestimation of injury severity. MMS drivers need to improve their driving skills in order to reduce the number of MMS crashes.

INTRODUCTION

Halfway through 2006, there were an estimated 150,000 motorized mobility scooters (MMS) in the Netherlands. The Netherlands Social Support Act (WMO) dictates that municipalities loan mobility scooters to persons with limited physical capabilities who still want to remain mobile. As a result of this desire for mobility, the number of mobility scooters is expected to grow among this specific group of persons to around 600,000 in 2030.[1] With its low speed, the mobility scooter may seem a relatively safe mode of transport, but especially among older users, safe usage of the vehicle can be affected negatively by chronic illnesses and polypharmacy and by changes in physical and cognitive skills.[1 - 4] Annually around 1,200 people over 55 (of which more than half are over 75 years of age) visit Emergency Departments (ED) of Dutch hospitals for treatment after an incident with a mobility scooter.[1] Of these patients, around 380 (33%) are hospitalised. This is a high rate of hospitalisation, especially when it is considered that these accidents often are a low-energy impact and no other road users are involved[5]. In comparison, of all road traffic victims treated in EDs approximately 23% are hospitalised.[6] As a result of co-morbidity – which is often quite extensive – and reduced physical reserves, it is considered that elderly trauma victims respond differently to trauma and a hospitalisation indication may arise more easily. The chance of complicated hospitalisation is also higher among the elderly, which harms the quality of life and the chance of survival.[7] In addition, higher age is associated with an increased risk of (severe) injury after traffic accidents.[8 - 10] The goal of this study is to describe the injury pattern, injury severity and chance of survival of hospitalised victims of mobility scooter incidents compared to incident type and age.

METHODS

All adult victims of MMS accidents who were hospitalised between 2003 and 2013 in one of the 11 hospitals in the Trauma Centre West (TCW) region were analysed. The data was obtained from the trauma registry of the TCW. The trauma registry prospectively gathers data concerning, among other things, injury (severity) and cause of injury of the hospitalised crash victims. [11]

The injury diagnosis and severity are coded in the trauma register according to the Abbreviated Injury Scale (AIS) of 1998[12] and the Injury Severity Score (ISS).[13] This study defines severe injury as an AIS score >2, rated per anatomical region (head, face, throat/neck, thorax, abdomen, back, upper and lower extremities and external). Injury severity may vary from slightly injured (AIS 1) to (almost) fatally injured (AIS

6). Polytrauma was defined as ISS ≥16 and mortality as death during hospitalisation. The type of accident was determined by two authors independently from each other, using the description of the accident mechanism, in which the estimated amount of energy transferred to the patient during the accident serves as a basis for establishing a categorisation of low-energy trauma (LET) and high-energy trauma (HET). For example, falling from a stationary or slowly moving (<10 km/hour) mobility scooter was regarded as a LET, while a collision or falling from a fast-moving (>10 km/hour) mobility scooter was a HET. Differences in patient characteristics between groups were analysed using the Fisher's exact test.

RESULTS

Between January 1, 2003, and December 31, 2013, 242 adult victims of MMS accidents were hospitalised in hospitals in the TCW region. The number of hospitalisations rose during this period from 3 in 2003 to 64 in 2013. Half of the victims were over 75 years of age, and in 151 (62%) of the cases the accident was the result of a LET. There was no relationship between age group and type of accident (p=0.60). There were almost equal numbers of male and female victims (126 and 116, respectively).

Injury severity

Severe injuries (AIS score >2) were found in almost half of all hospitalised victims. This percentage did not differ between age groups and between HET and LET (table 1). Polytrauma (ISS ≥16) was found in 35 victims (15%) and was more common among victims of a HET (p<0.0001) and among patients under 75 years of age (p=0.04).

Table 1. Injury demographics of hospitalised motorized mobility scooter accident victims.

Injury severity	Patients n (%) (n = 242)	Accident mechanism n (%)			Age n (%)		
		LET (n = 151)	HET (n = 91)	p	< 75 yrs (n = 119)	≥ 75 yrs (n = 123)	p
Severe injury *	121 (50)	76 (50)	45 (50)	1,0	60 (50)	61 (50)	1,0
Polytrauma†	35 (15)	12 (8)	23 (25)	< 0,001	23 (19)	12 (10)	0,04
In-hospital mortality	10 (4)	5 (3)	5 (6)	0,51	3 (3)	7 (6)	0,33

HET = high-energy trauma; LET = low-energy trauma.
* AIS > 2.
† ISS ≥ 16.

Injury pattern

More than 25% of all registered injuries were severe injuries (AIS score >2). The injury pattern differed between the patient groups (figure 1). Among patients hospitalised after a HET, more severe head injuries were found than among patients hospitalised after a LET. Among the elderly (> 75 years) hospitalised after a LET, mainly severe injuries were found to the lower extremities. Among younger patients (< 75 years) hospitalised after a HET, severe head and thorax injuries were more common.

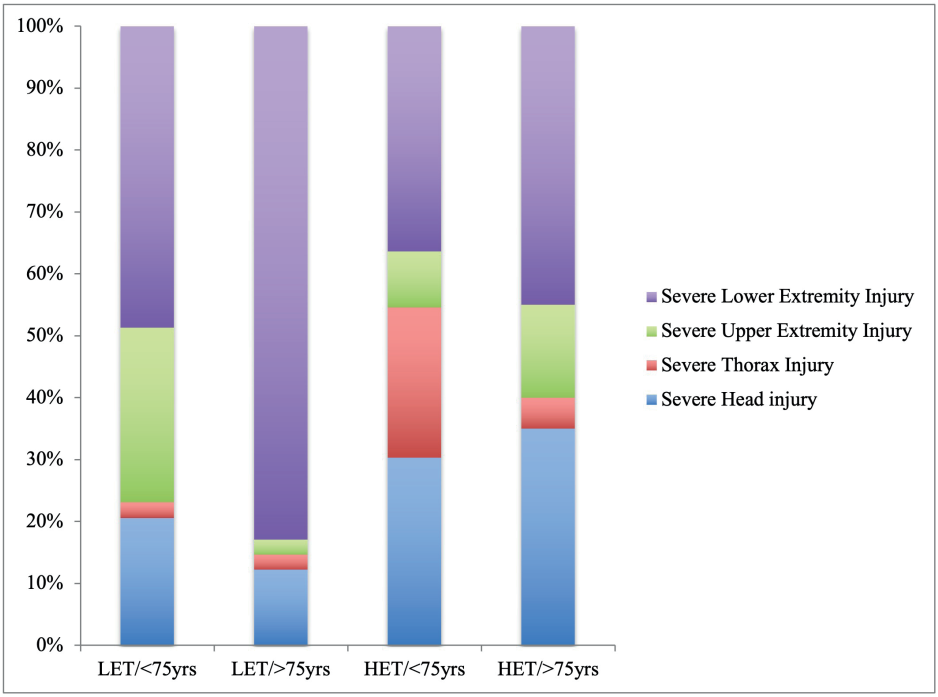

Figure 1. Distribution of severe injuries (AIS>2) per anatomical region (according to the AIS classification) of hospitalised motorized mobility scooter accident victims, by type of accident mechanism and age group.

Hospitalisation and mortality

The median hospitalisation for all MMS accident victims in both age groups and after both a HET and a LET was 6 days (range 1-65). Considerably more patients were admitted to the ICU after a HET than after a LET (21% resp. 5%, p<0.0001). Ten patients (4%) died during hospitalisation (table 1). The five patients who died after a LET were all older than 75 years. All patients who died had one or more severe injuries. In older patients mortality was the result of isolated lower extremity injuries, injuries to the spine or isolated head injuries. In the case of younger patients (< 75 years) mortality was the result of combined head and lower extremity injuries, isolated lower extremity injuries and after thorax injuries.

DISCUSSION

Motorized mobility scooter (MMS) drivers form a vulnerable group of road users, for whom accidents often result in unpredictable injury patterns and sometimes death. It can be difficult for both ambulance and hospital staff to adequately assess the severity of injuries after an accident.[14 - 16] The circumstances of the accident play an important role in this. Injuries among drivers of an MMS after a low-energy accident can therefore easily be underestimated. This is reflected in our results: almost 10% of the patients hospitalised after a LET had multiple serious injuries and 3% of them died during hospitalisation. This mortality rate is therefore higher than for admitted victims of motor bike and moped accidents.[17]

The injury pattern among deceased MMS accident victims varied: half of the deceased patients had only extremity injuries and no thorax or head injuries. Unlike pointed out in studies involving cyclists and motorised two-wheelers, the results of our study do not allow us to conclude that helmet use by MMS drivers will lead to a relevant reduction in the number of fatalities.[18]

Studies concerning road traffic accidents have shown that high-energy accidents are associated with more severe injuries and higher mortality than low-energy accidents.[4, 19] We did not find this difference in mortality between HET and LET in our study, possibly partly because of the low power of the study. It was striking that the five patients who died after a LET were all older than 75 years and that four of the five had not sustained multiple severe injuries. This emphasises that age and factors possibly related to victims of mobility scooter accidents such as chronic illnesses and polypharmacy, influence the risk of death road traffic users.[2 - 4] Upon hospitalisation of this vulnerable group of patients, it is important to involve other specialists (such as the trauma surgeon, neurologist and geriatric specialist) at an early stage in the care and treatment to prevent underestimation of the sustained injuries.

In three-quarters of the MMS accidents, no other road users were involved, and it is the driver himself who loses control, falls, falls over or causes a collision.[5] This is reflected in our results. Thus, it can be concluded that many MMS users are apparently insufficiently skilled at driving the vehicle. So, it can be advised that novice drivers of an MMS should follow a training programme to improve their driving skills.

CONCLUSION

Motorized mobility scooter (MMS) drivers are a vulnerable group of road users. Accidents with the apparently safe MMS are associated with unpredictable injury patterns and may lead to unexpected severe injury. Multidisciplinary treatment teams need to be aware of this in order to limit any negative consequences. In addition, preventive measures aimed at the driving skills of MMS drivers are necessary to reduce the number of MMS accidents.

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Injury pattern, hospital triage, and mortality of 1250 patients with severe traumatic brain injury caused by road traffic accidents.

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ABSTRACT

Background

This epidemiological study analysed the incidence, risk factors, hospital triage and outcome of patients with severe traumatic brain injuries (sTBI) caused by road traffic accidents (RTA) admitted to hospitals in the Trauma Center West-Netherlands (TCWN) region.

Methods

Trauma registry data were used to identify TBI in all RTA victims admitted to hospitals in the mid-West region of the Netherlands from 2003 to 2011. Type of head injury and severity were classified using the Abbreviated Injury Scale (AIS). Head injuries with AIS severity scores ≥ 3 were considered sTBI.

Results

Ten percent of all 12,503 hospital admitted RTA victims sustained sTBI, ranging from 5.4% in motorcyclists, 7.4% in motorists, 9.6% in cyclists and 12.7% in moped riders to 15.1% in pedestrians ($p<0.0001$). Amongst RTA victims admitted to hospital, sTBI was most prevalent in pedestrians (OR 2.25; 95% CI 1.78-2.86) and moped riders (OR 1.86; 95% CI 1.51-2.30). Injury patterns differed between road user groups. The incidence of contusion ranged from 46.6% in cyclists to 74.2% in motorcyclists, whereas basilar and open skull fractures were least common in motorcyclists (22.6%) and most common in moped riders (51.5%). Haemorrhage incidence ranged from 44.9% (motorists) to 63.6% (pedestrians). Subdural and subarachnoid bleedings were most frequent. Age, Glasgow Coma Scale, and type of haemorrhage were independent prognostic factors for in-hospital mortality after sTBI. In-hospital mortality ranged from 4.2% in moped riders to 14.1% in motorists.

Pedestrians have the highest risk to sustain sTBI and more specifically intracranial haemorrhage. Haemorrhage and contusion both occur in over 50% of the patients with sTBI.

Conclusions

Specific brain injury patterns can be distinguished for specific road user groups and independent prognostic risk factors for sTBI were identified. This knowledge may be used to improve the vigilance for particular injuries in specific patient groups and stimulate development of focussed diagnostic strategies.

INTRODUCTION

Road traffic accidents (RTA) contribute to morbidity and mortality in developing and industrialized countries around the world.[1] The World Health Organization estimated that each year more than 1.2 million people die and another 50 million people are injured as a result of RTAs worldwide.[2] Traumatic brain injury (TBI) due to RTAs is a global public health problem, and the incidence of both TBI and severe TBI (sTBI) is rising sharply, mainly due to RTAs.[3] The high mortality rates, disability and long-term loss of function pose a great burden on national health systems[1] and present a challenge for road safety programs. During the period 2003 – 2007, approximately 290,000 RTA victims in the Netherlands needed medical attention each year, of whom 21,000 were admitted to hospitals across the country. Although 20% of the admitted RTA victims sustained TBI, little is known about the epidemiology and risk factors for TBI after RTAs.[4]

In the Netherlands, traffic safety laws and extensive preventive governmental programs have gradually resulted in a decrease in RTA fatalities.[5] Simultaneously with these extensive governmental safety programs, the pre-hospital and in-hospital care for trauma patients changed dramatically during the 1990s. The Advanced Trauma Life Support (ATLS®) program provided a national guideline for the structured and systematic approach to the primary treatment of trauma.[6] This was followed in 1997 by the implementation of 11 regional trauma systems in the Netherlands, each of which contains a level I trauma center that provides the highest level of surgical care to trauma patients. Level II trauma hospitals work in collaboration with a level I trauma center to provide 24/7 comprehensive trauma care supplementing the clinical expertise of a Level I institution. Level III trauma hospitals do not have the full availability of specialists, but they have resources for emergency resuscitation, surgery, and intensive care for most trauma patients. Pre-hospital patient triage is performed by emergency services based on the injury type and severity and the subsequent required level of trauma care. Because sTBI patients mostly need advanced neurologic care, adequate pre-hospital triage is of major importance for TBI patients.

The purpose of this region-wide study is to analyze the incidence, risk factors, hospital triage and outcome of patients with severe traumatic brain injuries (sTBI) for different types of road users.

MATERIALS AND METHODS

Study Design

The regional Trauma Center West-Netherlands (TCWN) is one of the 11 Dutch trauma centers and includes three level I trauma center hospital locations and 9 level II and III trauma hospital locations in the Mid-Western part of the Netherlands. The TCWN region covers an urban area with approximately 2.5 million inhabitants. All trauma patients presenting to the Emergency Departments of the TCWN hospitals are assessed and treated according to ATLS® principles. [6]

Data for this retrospective study were obtained from the TCWN trauma registry. An analysis of all RTA victims admitted to the TCWN hospitals from 1-1-2003 to 1-1-2011 was performed. Patients who were deceased upon arrival to the Emergency Department were included in the registry, whereas patients who were deceased at the scene of the accident and patients who were not admitted to the hospital were not included in the registry. Patients without data on the means of transport were excluded from the analysis. The use of the anonymous data in the regional trauma registry is exempt from ethics review board approval.

Data and definitions

The trauma registry dataset includes the Major Trauma Outcome Study (MTOS)[7] variables completed with pre-hospital data to create the MTOS+ dataset. The TCWN audits the dataset to monitor the data validity so the registry measures up to the international standards of Good Clinical Data Management Practice.

The analyzed data included age, sex, type of road user, inter-hospital transfers, discharge data, injury data coded according to the Abbreviated Injury Scale (AIS) update 1998[8], injury severity coded according to the Injury Severity Score (ISS)[9], Glasgow Coma Score (GCS)[10], and mortality. The AIS codes consist of 7 numbers; the first 6 numbers specify the type of injury, whereas the last number of the AIS code represents the severity of the injury. TBI was defined as all AIS codes for intracranial injury and skeletal injury of the cranium, and sTBI included all of these injuries with AIS severity code ≥ 3. For the analyses, the continuous variables were categorized using clinically relevant cut-off points for age (<25 years, 25-55 years and >55 years), GCS (GCS <8 and GCS 8-12 vs. GCS>12) and ISS (<16 vs. ≥ 16). The ISS is an anatomical scoring system that provides an overall score for patients with multiple injuries. Severe trauma was defined as ISS ≥16. Severe trauma was calculated using AIS scores ≥ 3 in one or more body systems (including intracranial injury and skeletal injury of the cranium). If a single injury is assigned AIS score of 6 (fatal injury), the ISS score is automatically assigned to 75.

Five road user groups were defined: motorists (cars and trucks with permitted maximum speed of respectively 130 km/h and 80 km/h), motorcyclists (permitted maximum speed 130 km/h), moped riders (permitted maximum speed 45 km/h), cyclists and pedestrians. Data on helmet use and driving speed were not available. Because the use of helmets by motorcyclists is obligatory by law, it was estimated that virtually 100% in this group were wearing a helmet while driving the vehicle.[11] The moped group defined in the registry consists of both moped and light-moped riders. Helmet use is mandatory for moped riders but not for light-moped riders. The proportion of light-moped users in this group is estimated to be 14% based on previous results.[12] The helmet use in the entire moped group is estimated to be approximately 85%. In the Netherlands, cyclists are not obligated to wear helmets. Helmet use in this group is currently still very rare. We did not differentiate between drivers and passengers for all vehicles, nor did we classify the accidents by the level of energy of the impact.

Statistical analysis

The risk of sTBI was assessed for the specific road user groups after correction for age and sex in a multivariate logistic regression analysis. Road user groups with sTBI were compared with respect to demographic and clinical characteristics using the Chi-square test for categorical data and one-way ANOVA for continuous data. Within the group with sTBI, the anatomical locations and types of the injuries were analyzed per road user group, using the injury description according to the AIS. The outcome after sTBI (length of hospital stay and in-hospital mortality) was compared between road user groups using Kruskal-Wallis and Chi-square tests. The predictive value for in-hospital mortality of road user group and clinically relevant characteristics (age, ISS, GCS and type of hemorrhage) was univariately assessed using the Chi-square test and multivariately assessed with logistic regression analysis. The level of the primary referral hospital per RTA victim over time was described.

Data analysis was performed with SPSS version 20.0. P-values <0.05 were considered statistically significant.

RESULTS

Risk of sTBI

A total of 13,427 road traffic accident (RTA) victims admitted to hospitals in the region of the TCWN between 2003 and 2011 were selected from the trauma registry. 924 were excluded from the analysis mainly because type of road user was not specified or because they had been incorrectly coded as RTA victim. The remaining group of 12,503 patients included 1,020 pedestrians, 6,701 cyclists, 2,106 moped riders, 571 motorcyclists and 2,015 motorists. Of these, 1,250 patients were admitted to hospitals with sTBI, the majority being cyclists (51.2%). The incidence of sTBI was highest in the oldest age group (>55 years; p=0.02, Table 1) and was similar for men and women (p=0.20). Amongst all hospital admitted RTA victims in the region of the TCWN, sTBI was most prevalent in pedestrians and moped riders. These findings were confirmed in the multivariate analysis (Table 1).

Characteristics of sTBI patients by road user group

Table 2 presents demographic and clinical characteristics of the hospitalized RTA victims with sTBI by road user group. Patients with sTBI were predominantly male (61.2%), especially in the motorcyclist group (93.5%). The mean age of the studied population with sTBI was 45.2 years (SD 23.2). The age distribution differed between road user groups with sTBI. Pedestrians and cyclists had the highest ages. The percentage of young patients (aged <25 yrs) with sTBI was highest in moped riders; the majority of hospitalized motorcyclists and motorists were between 25-55 years. The overall percentage of young patients (<25 yrs) with sTBI in the total group of hospitalized RTA victims declined over the years from 36.2% to 28.7%, and the percentage of elderly RTA victims (>55 yrs) with sTBI increased from 30.9% to 37.6% during the study period.

The majority of the sTBI patients (58.8%) were severe trauma patients (ISS ≥16). Data on Glasgow Coma Scale (GCS) scores were not available in 23.8% of all patients with sTBI (Table 1). A total of 14.3% had a GCS<8 in the Emergency Department, most frequently in motorists and pedestrians.

Table 1. Patient characteristics and their predictive value for severe traumatic brain injury (AIS ≥ 3) in 12,503 hospitalized victims of road traffic accidents.

	sTBI (N=1,250)	No sTBI (N=11,253)	Risk of sTBI	
	N (%)	N (%)	Crude OR (95% CI)*	Adjusted OR (95% CI)*
Age				
<25 yrs	341 (9.0)	3464 (91.0)	1	1
25-55 yrs	423 (10.0)	3804 (90.0)	1.13 (0.97-1.31)	1.26 (1.08-1.47)
>55 yrs	486 (10.9)	3985 (89.1)	1.24 (1.07-1.43)	1.32 (1.14-1.54)
Sex				
Female	488 (9.6)	4604 (90.4)	1	1
Male	762 (10.3)	6649 (89.7)	1.08 (0.96-1.22)	1.11 (0.98-1.26)
Road user group				
Motorists	156 (7.4)	1949 (92.6)	1	1
Motorcyclist	31 (5.4)	540 (94.6)	0.72 (0.48-1.07)	0.68 (0.46-1.02)
Moped riders	268 (12.7)	1838 (87.3)	1.82 (1.48-2.24)	1.86 (1.51-2.30)
Cyclists	641 (9.6)	6060 (90.4)	1.32 (1.10-1.59)	1.31 (1.09-1.57)
Pedestrians	154 (15.1)	866 (84.9)	2.22 (1.75-2.82)	2.25 (1.78-2.86)

* Odds ratio with corresponding 95% confidence interval

Table 2. Demographic and clinical characteristics of 1,250 hospitalized road traffic accident victims with severe TBI per road user group.

	Total	Pedestrians	Cyclists	Moped Riders	Motorcyclists	Motorists
	N=1250	**N=154**	**N=641**	**N=268**	**N=31**	**N=156**
Sex, n (%)						
Male	776 (61.2)	86 (55.8)	348 (54.3)	191 (71.3)	29 (93.5)	108 (69.2)
Age,						
Mean (SD)	45.2 (23.2)	47.8 (27.2)	49.7 (23.5)	38.0 (19.7)	37.5 (15.6)	38.2 (19.3)
By category, n (%)						
<25 yrs	341 (27.3)	45 (29.2)	139 (21.7)	104 (38.8)	5 (16.1)	48 (30.8)
25-55 yrs	423 (33.8)	41 (26.6)	185 (28.9)	93 (34.7)	23 (74.2)	81 (51.9)
>55 yrs	486 (38.9)	68 (44.2)	317 (49.5)	71 (26.5)	3 (9.7)	27 (17.3)
Injury Severity Score						
Mean (SD)	18.3 (9.2)	21.0 (10.6)	16.7 (7.5)	18.3 (8.6)	23.0 (11.5)	21.4 (12.6)
By category, n (%)						
Missing	4 (0.3)	0 (0)	2 (0.3)	1 (0.4)	0 (0)	1 (0,6)
ISS <16	511 (40.9)	47 (30.5)	285 (44.5)	109 (40.7)	11 (35.5)	59 (37.8)
ISS ≥16	735 (58.8)	107 (69.5)	354 (55.2)	158 (59.0)	20 (64.5)	96 (61.5)
Neurological Scale, n (%)						
Missing	297 (23.8)	33 (21.4)	162 (25.3)	67 (25.0)	7 (22.6)	28 (17.9)
GCS <8	179 (14.3)	32 (20.8)	64 (10.0)	34 (12.7)	5 (16.1)	44 (28.2)
GCS 8-12	145 (11.6)	26 (16.9)	77 (12.0)	30 (11.2)	4 (12.9)	8 (5.1)
GCS >12	629 (50.3)	63 (40.9)	338 (52.7)	137 (51.1)	15 (48.4)	76 (48.7)
Length of Hospitalization In days, Median (range)						
	5 (0-102)	9 (0-83)	4 (0-102)	4 (0-96)	6 (0-61)	5 (0-93)
In-hospital Mortality						
N (%)	101 (8.1)	20 (13.1)	46 (7.2)	11 (4.2)	2 (6.5)	22 (14.1)

Location and type of sTBI

The types of sTBI and their anatomical locations are presented in Table 3. Most patients with sTBI sustained injuries of the cerebrum (86.2%), with up to 100% in motorcyclists. Injuries of the brainstem or cerebellum were uncommon. Most patients suffered from combined injuries, and the injury pattern differed between road user groups. Motorcyclists had the highest incidence of contusions, whereas skull fractures were least common in motorcyclists and motorists. Skull fractures were diagnosed in 43.8% of all admitted sTBI crash victims and were most frequently diagnosed in moped riders. Respectively, 25.0% and 23.9% of the sTBI patients sustained a skull base or skull vault fracture (Table 3).

Table 3. Anatomical location and type of severe traumatic brain injury (AIS ≥ 3) in 1,250 hospital admitted RTA victims per road user group. Results are presented as numbers (%) of patients with that specific injury. Patients may have multiple TBI locations or types.

	Total N = 1,250	Pedestrians N = 154	Cyclists N = 641	Moped riders N = 266	Motorcyclists N = 31	Motorists N = 156
Brainstem	15 (1.2)	2 (1.3)	6 (0.9)	3 (1.1)	0	4 (2.6)
Cerebellum	88 (7.0)	14 (9.1)	56 (8.7)	9 (3.4)	1 (3.2)	8 (5.1)
Cerebrum	1077 (86.2)	137 (89.0)	540 (84.2)	227 (84.7)	31 (100)	142 (91.0)
- Contusion	648 (51.8)	86 (55.8)	299 (46.6)	151 (56.3)	23 (74.2)	89 (57.1)
- Hemorrhage	684 (54.7)	98 (63.6)	362 (56.5)	138 (51.5)	16 (51.6)	70 (44.9)
Skull fracture	547 (43.8)	71 (46.1)	285 (44.5)	138 (51.5)	7 (22.6)	46 (29.5)
- Skull base fracture	312 (25.0)	43 (27.9)	153 (23.9)	91 (34.0)	3 (9.7)	22 (14.1)
- Skull vault fracture	299 (23.9)	35 (22.7)	163 (25.4)	69 (25.7)	5 (16.1)	27 (17.3)

Hemorrhage, especially subdural and subarachnoid bleedings, was the most common head injury in sTBI patients. It was diagnosed in more than 50% of all RTA victims with sTBI, ranging from 44.9% in motorists to 63.6% in pedestrians. Motorcyclists had the highest incidence of subarachnoid hemorrhage and the lowest incidence of subdural bleeding compared to the other road user groups (Figure 1).

Outcome after sTBI

The median hospitalization duration of the sTBI patients was 5 days (range 0-102 days; Table 2). Pedestrians were hospitalized longest (median 9 days). Of the 1,250 admitted sTBI patients, 101 (8.1%) died during their stay in the hospital. In-hospital mortality was highest in the motorists (14.1%) and pedestrians (13.1%) (Table 2). In the univariate analysis, GCS<12, ISS≥16, subdural, subarachnoid and intra-cerebral hemorrhage were also associated with increased in-hospital mortality (Table 4). In the multivariate analysis, age, GCS and ISS were independent prognostic factors for in-hospital mortality in RTA victims with sTBI (Table 4). The strongest predictor of in-hospital mortality was the GCS; patients with sTBI with a GCS<8 were the most at risk to die in the hospital

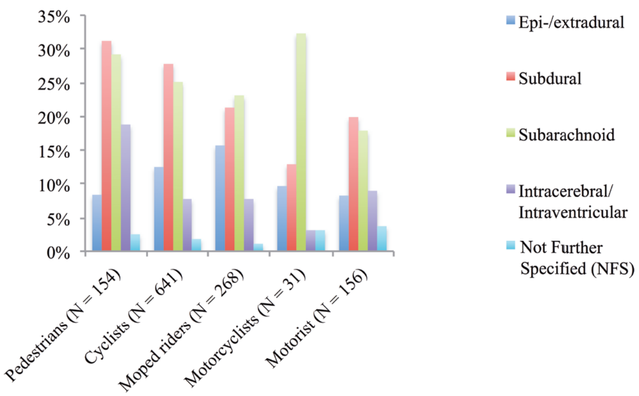

Figure 1. Distribution of haemorrhage type in road traffic accident victims with severe traumatic brain injury, according to the AIS classification per road user group.

Table 4. Clinical characteristics and their predictive value for in-hospital mortality in 1,147 victims of road traffic accidents with severe traumatic brain injury.*

	Deceased (N=101)	Survived (N=1,146)	Risk of in-hospital mortality	
	N (%)	N (%)	Crude OR (95% CI)**	Adjusted OR (95% CI)**
Age, n (%)				
<25 year	23 (6.8)	317 (93.2)	1	1
25-55 year	29 (6.9)	393 (93.1)	1.02 (0.58-1.79)	0.89 (0.47-1.70)
>55 year	49 (10.1)	436 (89.9)	1.55 (0.93-2.60)	1.91 (1.01-3.59)
ISS, n (%)				
<16	3 (0.6)	506 (99.4)	1	1
≥16	98 (13.4)	636 (86.6)	25.99 (8.19-82.47)	12.58 (3.71-42.67)
GCS, n (%)				
>12	10 (1.6)	617 (98.4)	1	1
8-12	12 (8.3)	133 (91.7)	5.57 (2.36-13.15)	3.89 (1.61-9.40)
<8	56 (31.1)	123 (68.7)	28.09 (13.95-56.58)	19.24 (9.11-40.62)
Unknown	23 (7.8)	273 (92.2)	5.20 (2.44-11.07)	4.46 (2.05-9.68)
Hemorrhage, n (%)				
No hemorrhage	17 (3.0)	547 (97.0)	1	1
Epi- or extradural	3 (3.3)	89 (96.7)	1.09 (0.31-3.78)	0.47 (0.13-1.78)
Subdural, -arachnoidal, or intracerebral	79 (13.8)	494 (86.2)	5.15 (3.01-8.81)	1.60 (0.85-3.01)
Not further specified type	2 (11.1)	16 (88.9)	4.02 (0.86-18.90)	1.81 (0.34-9.61)
Road user group, n (%)				
Motorists	22 (14.1)	134 (85.9)	1	1
Motorcyclists	2 (6.5)	29 (93.5)	0.42 (0.09-1.89)	0.59 (0.12-3.00)
Moped riders	11 (4.1)	256 (95.9)	0.26 (0.12-0.56)	0.30 (0.13-0.71)
Cyclists	46 (7.2)	594 (92.8)	0.47 (0.27-0.81)	0.61 (0.31-1.18)
Pedestrians	20 (13.1)	133 (86.9)	0.92 (0.48-1.76)	0.76 (0.35-1.65)

* Data on in-hospital mortality was missing for 3 patients with sTBI.
** odds ratio with corresponding 95% confidence interval

(OR 19.24, 95% CI 9.11-40.62). ISS ≥16 also proved to be a strong predictor for mortality after hospitalization (OR 12.58, 95% CI 3.71-42.67) (Table 4). After correction for the clinically relevant factors, there was no statistically significant difference in mortality between the road user groups ($p=0.08$).

Hospital triage

A total of 77% of RTA victims with sTBI were admitted in a level I trauma care hospital. This percentage was fairly stable over time (Figure 2). The percentage of sTBI patients admitted to a level II trauma hospital almost doubled from 11.7% in 2003 to 21.3% in 2011, whereas the percentage of sTBI patients who were admitted to a level III trauma hospital decreased from 9.7% to 5.7%.

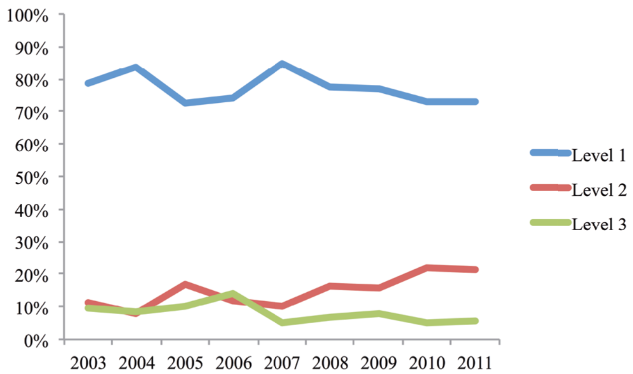

Figure 2. Distribution of admissions to level I, II or III trauma centres of road traffic accident victims with severe traumatic brain injury in the TCWN region during the study period.

DISCUSSION

This region-wide study aimed to determine the incidence, risk factors, hospital triage and outcome of severe traumatic brain injuries (sTBI) for different types of road users involved in RTAs. The study included 12,503 RTA victims who were admitted to hospitals in the regional trauma network of TCWN during a 9-year period (2003–2011).

Incidence and injury distribution.

In the study group, 10% of all RTA victims sustained sTBI, which is comparable with data from a Finnish study.[13] A comparison of our study with other international literature is difficult because of the absence of a clear clinical description of (severe) TBI. Differences in the definitions of TBI may result in divergent estimates of (severe) TBI incidence. The most widely used classification for scoring the severity of TBI is the GCS, but others used the AIS or ICD-9 (International Classification Disease – Ninth Edition) to classify TBI.[14-19]

Most hospital admitted RTA victims were cyclists. This is not surprising because 84% of Dutch citizens own a bicycle, and cycling is a very common mode of transportation in the Netherlands.[20] The WHO and a recent European Union summary of the most recent injury statistics classified cyclists as a vulnerable group of road users, along with pedestrians and motorcyclists(2). Due to their high risk of head injury, helmet laws for cyclists have been introduced in many countries. The preventive effect is still a topic of debate.[21,22] In the Netherlands, no obligatory helmet law for cyclists exists, and wearing a helmet when riding a bicycle is still very rare.[23] Our current findings may be helpful to set policy concerning the legislation of helmet usage in cyclists.

The majority of the sTBI patients were trauma patients with an ISS of 16 or higher. The explanation for this finding is two-fold. On the one hand, sTBI is often caused by high-energy trauma, which is likely to result simultaneously in severe traumatic brain injury and injury to other anatomical regions. The other explanation concerns the documentation and AIS classification. Within the current AIS coding manual, most cranial hemorrhages score a 4 in severity, which means that if cranial hemorrhage is the only diagnosis, the patient automatically has an ISS of 16 and is considered a severe trauma patient. An updated AIS scoring version will correct for this phenomenon in the future.

Injury patterns differed between road user groups. Pedestrians were the most vulnerable road user group in our study. They had the highest risk of sTBI, and skull fractures and intracranial hemorrhages were their most common injuries, which may account for this road user group having the longest hospitalization and the second highest mortality. These findings are in accordance with recent epidemiological studies conducted in several European countries, which demonstrated that pedestrians are vulnerable participants in daily traffic and have the most severe TBI with the worst outcome.[24-27] Both the high incidence of specific types of sTBI and the combination with severe trauma in pedestrians may be due to their unprotected traffic participation and relatively high age. The latter was confirmed in this study by a multivariate analysis. Moped riders sustained skull fractures more often than motorcyclists, whereas the incidences of other sTBI types were almost similar in both groups. The difference in the amount of skull fractures can most likely be ascribed to the protective effect of helmets[1,28-30] because helmet use is not mandatory for light-moped riders in the Netherlands.

Risk factors for in-hospital mortality

The study results indicate that a lower GCS was related to higher risks of in-hospital mortality after sTBI. The GCS is therefore a very relevant parameter that should be documented adequately in all ED admitted trauma patients. In our registry, 25% of GCS scores were missing for hospital admitted RTA victims. For future research and clinical strategy development, accurate documentation of all aspects (e.g., GCS, trauma scoring systems, vital parameters) of TBI by the initial trauma management teams is of major importance, not in the least for the purpose of early recognition of high-risk patients with head injury.

Other strong and independent prognostic factors for in-hospital mortality after sTBI were advancing age and severe trauma (ISS ≥16). No significant differences in the risks for in-hospital mortality between road user groups were found in our study after adjusting for clinical risk factors.

Hospital triage

The study period concerns an era in which centralization of trauma care was initiated and all-inclusive trauma systems in level I trauma centers became a standard of care. As part of this system, regional medical networks agreed on pre-hospital patient distribution to specific hospitals, depending on the level of care required for the patient. Following this principle, all severely injured patients (ISS≥16) should be brought to a center with at least level II facilities, but preferably to level I centers because direct transportation of these patients to a high-care facility reduces mortality and morbidity.[31] The results of our study show that the proposed centralization of trauma care was implemented gradually during the study period. The vast majority of patients with sTBI were transported directly to a level I trauma center, and this percentage remained stable (approximately 75% each year) during the studied period. The number of patients with sTBI presented directly to a level II trauma center almost doubled in the study period, whereas the number of sTBI patients presented to level III centers declined.

Limitations

We based our analyses on the data in the regional trauma registry, which includes data for trauma patients admitted to TCWN hospitals. Data for RTA victims who were deceased at the scene of the accident are absent in the registry. Based on figures on registered RTAs of the Dutch Ministry of Infrastructure and Environment, this concerned about 400 RTA victims in the study period in our region, who were not included in the initial study population of 13,427 hospital admitted RTA victims. Pre-hospital mortality in RTA is therefore estimated to be around 3% and represents about two third of all RTA related mortality. The causes of pre-hospital mortality remain however unknown.

The risks of sTBI and mortality presented in our study should be interpreted with care because they apply to a specific subgroup of RTA victims and do not reflect these risks in the entire population of RTA victims. Because we compared five different groups of road users, it is important to note that the groups differ from one another with respect to vulnerability and speed in daily traffic. It was impossible to control for speed, helmet usage and other protection because of the absence of these characteristics in the registry. Consequently, no conclusions can be drawn regarding the effect of speed and protection on the risks of sTBI and mortality within groups of traffic participants.

CONCLUSION

Severe traumatic brain injury patients represent 10% of all hospital admitted road traffic accident victims. Cyclists, moped riders and pedestrians have a high risk for sustaining sTBI in RTAs. Of all road traffic participants, pedestrians have the highest risk of sustaining sTBI and, more specifically, intracranial hemorrhage, whereas hemorrhage and contusion both occur in over 50% of the patients with sTBI after an RTA.

Awareness of these crash characteristics and risk factors will improve the vigilance for specific types of head injury in road user groups, will stimulate the development of focused diagnostic strategies and will consequently help to achieve better outcomes for the trauma patient with sTBI.

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PART II
INFLUENCING FACTORS

6

Traumatic brain injury and alcohol intoxication: effects on injury patterns and short-term outcome.

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ABSTRACT

Background

A significant number of patients with traumatic brain injuries (TBI) are diagnosed with elevated blood alcohol concentration (BAC). Recent literature suggests a neuroprotective effect of alcohol on TBI, possibly associated with less morbidity and mortality. Our goal is to analyse the association of different levels of BAC with TBI characteristics and outcome.

Methods

Adult patients with moderate to severe TBI (AIS ≥2) and measured BAC admitted to the Trauma Centre West (TCW), during the period 2010 - 2015, were retrospectively analysed. Data included injury severity (AIS), length of hospitalization, admittance to the Intensive Care Unit (ICU) and in-hospital mortality. The association of BAC with ICU admittance and in-hospital mortality was analysed using multivariable logistic regression analysis with correction for potentially confounding variables.

Results

BACs were available in 2,686 patients of whom 42% had high, 26% moderate, 6% low and 26% had normal levels. Patients with high BAC's were predominantly male, were younger, had lower ISS scores, lower AIS-head scores and less concomitant injuries compared to patients in the other BAC subgroups. High BACs were associated with a lower risk for in-hospital mortality (AOR 0.36, 95% CI: 0.14-0.97). Also, patients with moderate and high BACs were less often admitted to the ICU (resp. AOR 0.36, 95% CI:0.25-0.52 and AOR 0.40, 95% CI: 0.29-0.57).

Conclusions

The current study suggests that in patients with moderate to severe TBI, increasing BACs are associated with less severe TBI, less ICU admissions and a higher survival. Further research into the pathophysiological mechanism is necessary to help explain these findings.

INTRODUCTION

Trauma remains the leading cause of severe morbidity and mortality around the world. Especially traumatic brain injuries (TBI) contribute significantly to mortality and morbidity in trauma patients. The multidisciplinary nature of both the acute and long-term treatment of TBI patients is complex and expensive [1,2]. TBI represents a major public health problem; its estimated incidence varies from 91 to 546 per 100,000 people per year in Europe and accounts for one-third of all trauma-related death in the United States [3,4].

A strong correlation exists between alcohol intoxication and the increased risk for sustaining all types of injuries [5,6]. TBI is no exception, with elevated blood alcohol concentrations (BAC) being demonstrated in 24% to 54% of the trauma patients diagnosed with TBI in Europe [4]. However, the influence of elevated BACs on the outcome of severely injured patients and the corresponding pathophysiological changes remain a controversial issue. Recent literature suggests a neuroprotective effect of alcohol on TBI [7-10], possibly resulting in lower mortality and morbidity rates compared to TBI patients without elevated BAC's [11]. Despite this controversial suggestion and the questions that it raises about cause-and-effects, only very few studies have addressed the influence of alcohol intoxication in general and of specific levels of BAC's on TBI pattern and severity.

The aim of this study was to analyse the association between BAC's, TBI pattern and patient outcome.

PATIENTS AND METHODS

Data for this observational retrospective cohort study was obtained from the Dutch Trauma Centre West (DTCW) trauma registry. The DTCW trauma registry is part of the National Trauma Registry (LTR), and it encompasses the information of all trauma patients admitted to three level I trauma centres and nine level II and III trauma hospitals within the mid-Western part of the Netherlands, serving a population of 2.5 million. The DTCW trauma registry consists of Major Trauma Outcome Study (MTOS) [12] variables and pre-hospital data gathered from patients' records by trained registrars. Trauma patients who only visited the emergency department without being admitted, as well as patients who deceased at the scene of the accident are not included in the registry. Also, in our study patients who were transferred to hospitals not belonging to the DTCW region after initial presentation, were excluded from the analysis. The study was exempted from ethics review board approval because the study made use of existing data sources and the patients had made no objection to use their coded data for scientific research.

An analysis of all adult (≥18 years) trauma patients who were admitted to one of the three regional level I trauma centres from January 1, 2010, to January 1, 2015, with moderate to severe TBI and measured BAC upon admission was performed. The analysed data included age, gender, mechanism of injury and moderate to severe TBI (AIS ≥2) coded according to the Abbreviated Injury Scale 2005 update 2008 [13], injury severity coded according to the Injury Severity Score (ISS) [14], Glasgow Coma Scale (GCS) [15] on admittance, the Revised Trauma Score (RTS) [16], and vital signs on admittance (including systolic blood pressure, heart rate, respiratory rate).

BACs in blood samples obtained in the ED on admission were gathered from patients' laboratory records. These patients were then categorized in four groups: normal (<0.1 g/L), low (0.1-1.0 g/L), moderate (1.0-2.3 g/L) and high (≥2.3 g/L).

The study outcomes were type and severity of TBI, length of hospitalization, admittance to and length of stay in the Intensive Care Unit (ICU) and in-hospital mortality.

Statistical analysis

Group comparisons for continuous variables were performed using ANOVA for normally distributed data and using the Kruskal-Wallis test for skewed data. For comparing categorical variables, the Chi-square test was used. The association of BAC with ICU admittance and in-hospital mortality was analysed using multivariable logistic regression analysis with correction for potentially confounding factors as categorical variables (age group, gender, head-AIS, associated severe injuries according to AIS anatomical regions (AIS≥3)). GCS was not included in the multivariable analyses, because this parameter was missing in 20.9% of cases. All statistical analyses were repeated after exclusion of the patients with isolated brain concussions (AIS = 2), i.e., without other traumatic brain injuries. Data-analysis was performed using IBM SPSS Statistics for Windows, version 23 (Armonk, NY: IBM Corp.). P values < 0.05 were considered statistically significant.

RESULTS

Demographic and clinical characteristics

During the studied period 6,061 patients with TBI were admitted to the level-1 trauma centres in the DTCW region. Of those, 216 were excluded because they were transferred between hospitals after their initial presentation and 51 were excluded due to missing or inconsistent data. BACs were reported in 2,686 of the remaining 5,794 patients (44.3%).

Of these 2,686 patients, 1,120 (42%) had high BAC's (≥2.3 g/L), 685 (26%) moderate BAC's (1.0-2.3 g/L), 173 (6%) low BAC's (0.1-1.0 g/L) and 708 (26%) had normal BAC's (<0.1 g/L). Patients with high BAC's were predominantly male, were younger, had lower ISS scores and lower AIS-head scores compared to patients in the other BAC subgroups (Table 1). Differences in GCS between the BAC groups were more pronounced with GCS<8 in 10.8% of patients with normal BAC versus 4.6% in the patients with the highest BAC ($p<0.0001$).

TBI pattern

The most frequently diagnosed TBI in the study group was a cerebral concussion (76.5%), followed by injuries to the cerebrum (22.2%) (Table 2). The majority of patients were diagnosed with an isolated cerebral concussion (69.2%). Patients with elevated BAC's had significantly less injuries to the cerebrum, skeletal injuries, and cerebral concussions ($p<0.0001$). Also, a trend was observed between patients with different BAC's with progressively more concussions and progressively less cerebral and skeletal injuries in patients with increasing BAC's (Table 2).

Associated injuries

Patients with TBI and elevated BACs had significantly less associated severe injuries (AIS ≥ 3) in anatomical regions other than to the head compared to patients with normal BAC's (Table 1). Also, the percentage of patients with associated severe injuries decreased significantly with increasing BACs from 20.2% in the low BAC group to 8.1% in the high BAC group (Table 1).

The most frequently diagnosed severe associated injuries in all groups were thoracic injuries (lung contusions and rib fractures). Second most common were injuries to the lower extremities (mainly femur fractures) in patients in the normal BAC group, and injuries to the face (predominantly injuries to the orbita) in patients with moderate and high BAC's (Figure 1).

Table 1. Comparison of demographics, injury characteristics and clinical outcome parameters of 2,686 hospitalized patients with traumatic brain injury and quantified blood alcohol concentration.

Characteristics	Total (n=2686)	High BAC (n=1120)	Moderate BAC (n=685)	Low BAC (n=173)	Normal BAC (n=708)	p*
Gender, n (%)						
Male	2002 (74.6)	903 (80.7)	514 (75.0)	123 (71.1)	462 (65.3)	<0.0001
Age (years), mean (SD)	49.0 (18.7)	46.6 (14.9)	47.3 (19.6)	49.1 (20.1)	54.7 (21.4)	<0.0001
Age by category, n (%)						
18-25	363 (13.5)	113 (10.1)	131 (19.1)	29 (16.8)	90 (12.7)	<0.0001
26-55	1306 (48.6)	681 (60.8)	296 (43.2)	73 (42.2)	256 (36.2)	
56-75	781 (29.1)	303 (27.1)	206 (30.1)	53 (30.6)	219 (30.9)	
>75	236 (8.8)	23 (2.1)	52 (7.6)	18 (10.4)	143 (20.2)	
Mechanism of injury, n (%)						
Traffic accident	929 (35.6)	290 (27.3)	231 (34.1)	53 (31.0)	355 (50.8)	<0.0001
Low-energy fall	706 (27.0)	359 (33.7)	174 (25.7)	37 (21.6)	136 (19.5)	
High-energy fall	496 (19.0)	207 (19.5)	114 (16.8)	34 (19.9)	141 (20.2)	
Penetrating trauma	20 (0.8)	12 (1.1)	4 (0.6)	1 (0.6)	3 (0.4)	
Struck with blunt object	426 (16.3)	178 (16.7)	153 (22.6)	39 (22.8)	56 (8.0)	
Other	35 (1.3)	18 (1.7)	2 (0.3)	7 (4.1)	8 (1.1)	
ISS, median (range)	6 (4-75)	5 (4-50)	5 (4-59)	9 (4-75)	13 (4-59)	<0.0001
By category, n (%)						
ISS <16	2096 (78.0)	995 (88.8)	577 (84.2)	128 (74.0)	396 (55.9)	<0.0001
ISS ≥16	590 (22.0)	125 (11.2)	108 (15.8)	45 (26.0)	312 (44.1)	
GCS, n (%)						
<8	144 (6.8)	39 (4.6)	31 (5.8)	8 (5.9)	66 (10.8)	<0.0001
8-12	142 (6.7)	60 (7.1)	22 (4.1)	7 (5.2)	53 (8.7)	
>12	1839 (86.5)	751 (88.4)	478 (90.0)	120 (88.9)	490 (80.5)	
Head AIS, n (%)						
AIS=2	2020 (75.2)	957 (85.4)	550 (80.3)	122 (70.5)	391 (55.2)	<0.0001
AIS=3	273 (10.2)	79 (7.1)	65 (9.5)	17 (9.8)	112 (15.8)	
AIS=4	311 (11.6)	67 (6.0)	60 (8.8)	27 (15.6)	157 (22.2)	
AIS=5	82 (3.1)	17 (1.5)	10 (1.5)	7 (4.0)	48 (6.8)	
Associated injuries AIS ≥3, n (%)	414 (15.4)	91 (8.1)	91 (13.3)	35 (20.2)	197 (27.8)	<0.0001
Length of hospitalization in days, median (range)	2 (1-95)	2 (1-60)	2 (1-65)	2 (1-51)	4 (1-86)	<0.0001
IC-admittance, n (%)	395 (15.1)	87 (8.0)	64 (9.6)	34 (19.9)	210 (30.9)	<0.0001
Length of ICU stay in days, median (range)	2 (1-38)	2 (1-20)	2 (1-26)	2 (1-28)	3 (1-38)	<0.0001
In-hospital mortality, n (%)	69 (2.6)	6 (0.5)	9 (1.3)	7 (4.1)	47 (6.7)	<0.0001

BAC, Blood Alcohol Concentration (normal (<0.1 g/L), low (0.1-1.0 g/L), moderate (1.0-2.3 g/L) and high (≥2.3 g/L)); SD, standard deviation; ISS, Injury Severity Score; GCS, Glasgow Coma Scale; AIS, Abbreviated Injury Scale
*ANOVA for normally distributed continuous data, Kruskal-Wallis test for skewed continuous data and Chi- square test for categorical data
Results are presented as numbers (%) of patients with that specific injury. Patients may have multiple traumatic brain injury locations or types. BAC, Blood Alcohol Concentration (normal (<0.1 g/L), low (0.1-1.0 g/L), moderate (1.0-2.3 g/L) and high (≥2.3 g/L)).

Table 2. Anatomical location and type of traumatic brain injury in hospital-admitted trauma patients with available quantified blood alcohol concentrations.

	Total (n=2686)	High BAC (n=1120)	Moderate BAC (n=685)	Low BAC (n=173)	Normal BAC (n=708)	p
Brain stem	3 (0.1)	1 (0.1)	0 (0)	0(0)	2 (0.3)	0.41
Cerebellum	60 (2.2)	24 (2.1)	12 (1.8)	4 (2.3)	20 (2.8)	0.59
Cerebrum	597 (22.2)	139 (12.4)	118 (17.2)	48 (27.7)	292 (41.2)	<0.0001
Contusion	286 (10.6)	68 (6.1)	61 (8.9)	22 (12.7)	135 (19.1)	<0.0001
Hematoma epi- or extradural	75 (2.8)	12 (1.1)	10 (1.5)	10 (5.8)	43 (6.1)	<0.0001
Hematoma intracerebral	47 (1.7)	6 (0.5)	11 (1.6)	4 (2.3)	26 (3.7)	<0.0001
Hematoma subdural	267 (9.9)	63 (5.6)	47 (6.9)	24 (13.9)	133 (18.8)	<0.0001
Subarachnoid haemorrhage	239 (8.9)	60 (5.4)	44 (6.4)	16 (9.2)	119 (16.8)	<0.0001
Skeletal	313 (11.7)	77 (6.9)	65 (9.5)	17 (9.8)	154 (21.8)	<0.0001
Base fracture	80 (3.0)	13 (1.2)	19 (2.8)	7 (4.0)	41 (5.8)	<0.0001
Vault fracture	151 (5.6)	43 (3.8)	28 (4.1)	6 (3.5)	74 (10.5)	<0.0001
Close vault fracture	58 (2.2)	10 (0.9)	13 (1.9)	3 (1.7)	32 (4.5)	<0.0001
Cerebral concussion	2055 (76.5)	960 (85.7)	567 (82.8)	124 (71.7)	404 (57.1)	<0.0001

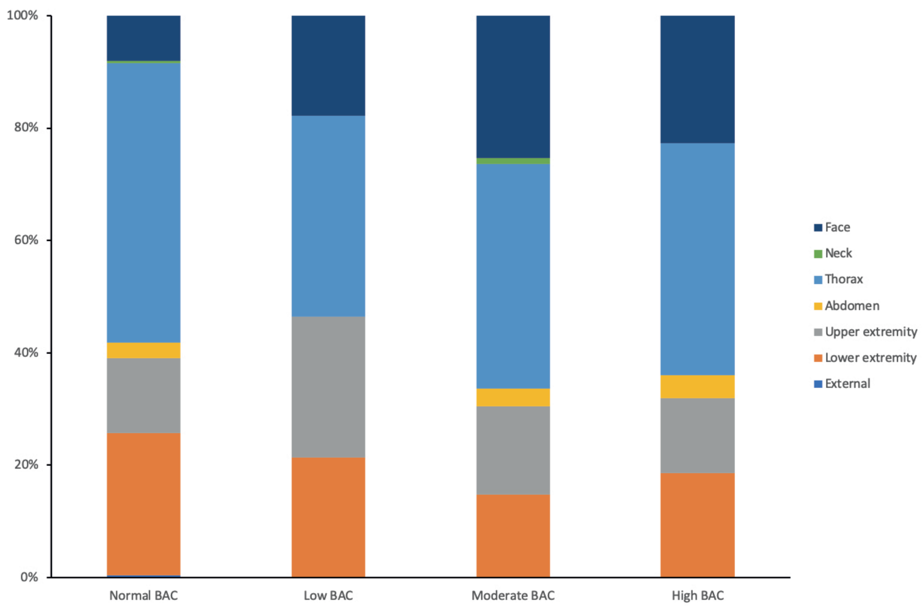

Figure. 1 Distribution of associated injuries per anatomical region (according to the AIS classification) in alcohol intoxicated and not-alcohol intoxicated trauma patients with traumatic brain injury. The External category comprises of burns

Clinical outcome

The median length of hospitalization in the total group was 2 days (range 1-95) and was highest in the group with normal BAC's (median 4 days, range 1-86; Table 1). Also, ICU admittance and ICU length of stay were highest in the patients with normal BAC's (Table 1). When adjusted for age, gender, AIS-head and presence of associated severe injuries, the risk of ICU-admittance for patients with moderate and high BACs was significantly lower compared to patients with normal BAC's (resp. AOR 0.36, 95% CI 0.25 to 0.52 and AOR 0.40, 95% CI 0.29 to 0.57) (Table 3).

In-hospital mortality was highest in patients with normal BAC's (Table 1). Although the association between alcohol intoxication and in-hospital mortality was less strong after adjustment for confounding, the adjusted risk of death after admission to the hospital remained lower in patients with high levels of BAC (AOR 0.36, 95% CI 0.14 to 0.97) (Table 3).

Table 3. Predictive value of BAC's for in-hospital mortality and ICU admittance in patients with traumatic brain injury.

	Risk of in-hospital mortality[1]		*Risk of ICU admittance*[2]	
	Crude OR (95% CI)	Adjusted OR[3] (95% CI)	Crude OR (95% CI)	Adjusted OR[3] (95% CI)
High BAC	0.08 (0.03-0.18)	0.36 (0.14-0.97)	0.19 (0.15-0.25)	0.40 (0.29-0.57)
Moderate BAC	0.19 (0.09-0.38)	0.60 (0.26-1.38)	0.24 (0.17-0.32)	0.36 (0.25-0.52)
Low BAC	0.60 (0.26-1.34)	1.39 (0.54-3.57)	0.56 (0.37-0.84)	0.72 (0.43-1.19)
Normal BAC	ref	ref	ref	ref

BAC, Blood Alcohol Concentration (normal (<0.1 g/L), low (0.1-1.0 g/L), moderate (1.0-2.3 g/L) and high (≥2.3 g/L));
ICU, Intensive Care Unit; OR, odds ratio; CI, confidence interval.
[1] Results are based on 2672/2686 (99.5%) of patients with available BAC.
[2] Results are based on 2608/2686 (97.1%) of patients with available BAC.
[3] Adjusted for age group, gender, AIS head and presence of associated severe injury (AIS≥3).

Outcome in the TBI patients without isolated concussion

All statistical analyses were performed again to determine if the results were comparable when the patients with isolated cerebral concussions were excluded. After exclusion, 827 patients (30.8%) without isolated concussions and with reported BAC's were analysed; 368 patients with normal BAC's, 61 with low BAC's, 174 with moderate BAC's and 224 with high BAC's. Clinical and demographical characteristics were comparable to the results for the total group described above. The estimated association of different levels of BAC's with in-hospital mortality was somewhat lower than those in the total group and not statistically significant for all BAC levels (for high BAC: AOR 0.46, 95% CI 0.17-1.26). Also, patients with moderate or high BACs without isolated concussion were less likely to be admitted to the ICU (for moderate BAC: AOR 0.41, 95% CI 0.26-0.64; for high BAC: AOR 0.48, 95% CI 0.31-0.74).

DISCUSSION

The aim of the study was to examine the controversial topic of alcohol intoxication at the time of injury and its assumed protective effect on the short-term outcome in TBI patients. Also, the TBI pattern was examined in relation to different BACs at the time of injury.

The findings of this study are in line with previous studies reporting possible protective effects of alcohol consumption in relation to TBI: Patients with high BAC's were predominantly male, were younger, had lower ISS scores and lower AIS-head scores compared to patients in the other BAC subgroups of TBI patients. Increasing BACs were associated with less severe TBI, less concomitant injuries, less ICU admissions and a higher survival.

TBI pattern

Cerebral injuries (contusions, subdural hematomas and subarachnoid haemorrhage) and concussions were the most frequently diagnosed TBI's in our study population. However, with rising BAC's these were diagnosed less often. These findings are in accordance with results of previous studies. Talving et al. [17] found that in patients with isolated severe TBI, blood alcohol levels were not associated with overall head injury severity. Lustenberg et al. [18] showed that in their study population subarachnoid, intraparenchymal and subdural hematoma were the most frequent injuries, followed by skull fractures. Their group with alcohol intoxicated patients showed significantly less skull fractures than the non-intoxicated patients, which was also the case in our study. Again another study pointed out that acute alcohol intoxication was not associated with type and number of diffuse axonal injury lesions and intraventricular bleedings [19].

Effect on mortality

The occurrence of associated injuries have been found to be associated with higher mortality and longer hospital and ICU stay in patients with TBI [20]. Our study showed a significantly lower risk for in-hospital mortality in all intoxicated patients and especially in patients with high levels of BAC. Berry et al. classified BAC's according to the same categories as used in our study [9]. Despite the fact that they did not include patients with moderate TBI (AIS=2) nor those with associated severe injuries (AIS≥ 3), they also found that high levels of BAC were independently associated with an improved survival.

Talvin et al. published similar effects on survival [17]. Several other studies compared intoxicated with non-intoxicated patients and also found lower risks of mortality in intoxicated patient groups [21–23]. However, some other studies did not find these effects of alcohol on mortality [24–26]. For example, Chen et al. concluded that the possible protective effect of alcohol no longer existed after correction for residual confounding variables such as causes and intents of TBI and injury severity scores (ISS). The adjusted in-hospital mortality even appeared to increase [27]. It should be noted again that all previous studies only evaluated patients with severe TBI (AIShead≥3) and are not completely comparable with our study. A recently conducted meta-analysis evaluated mortality in relation to TBI and alcohol intoxication in 15 studies, including the previously mentioned studies. It showed no significant difference in mortality between alcohol intoxicated and not-intoxicated patients nor between low levels and high levels of BAC [28]. Unfortunately, due to the small sample sizes of some studies and only few of the included studies examined comparable outcomes, the reliability of this meta-analysis is limited [20].

Effect on length of hospital stay, ICU admittance and ICU length of stay

Rising levels of BAC, were associated with a shorter length of hospital stay when compared to the group with normal BAC's. This finding is in line with Berry et al. [9] who described a statistically significant difference in length of hospital stay for different alcohol concentration categories; patients with high BAC's had less hospitalization days than patients with normal BAC's. Nevertheless, other studies, as well as the recently published meta-analysis, showed no differences in length of hospital stay [17,22,23,26,28].

The shorter time at the ICU of patients with moderate and high BAC's may be explained by the fact that especially in patients with high BAC's the alcohol intoxication affects the initial level of consciousness. In cases where alcohol intoxication is the cause of decreased consciousness, this will normalize over limited time as the BAC decreases. When patients have recovered consciousness, ICU-admittance will no longer be necessary. In the literature only one study showed a significant difference between the different BAC's, with a trend towards less ICU-admittances and shorter length of stay in the high BAC group [9]. The recently conducted meta-analysis included studies with patients aged >16 and without penetrating TBI, and showed a shorter length of ICU stay in intoxicated patients [28]. This was mainly due to the study conducted by Salim et al. [22] that had a large study size and found that ICU length of stay was shorter in the intoxicated group.

Explanation of the effects found

Different potential mechanisms have been proposed to account for the protective effects of alcohol on TBI. A recent study showed that alcohol intoxication may have protective effects in TBI at behavioural and histological level. It suggests that when alcohol intoxication is present at the moment right before trauma, it significantly decreases the trauma-induced transcriptional responses of hippocampal neurons [29]. Another possible mechanism is the inhibition of N-Methyl-D-aspartic acid receptors (NMDAr). NMDAr is associated with neuronal cell death due to a chain reaction that occurs when NMDAr overactivation leads to a major release of excitatory neurotransmitters [11]. Alcohol acts as a NMDAr antagonist and inhibits this process. Another popular theory is that alcohol blunts the adrenergic response that occurs when a person sustains a TBI [10,11,30–32]. Obviously, the exact mechanism by which alcohol may enhance survival is not yet fully understood at this time. Further studies that provide further insight in this mechanism, may also be of use in the development of therapeutic agents for the treatment of TBI.

Limitations

The limitations that result from a retrospective research set up all do apply. Especially the fact that we obtained 2,686 BAC serum levels from 5,794 TBI patients has potentially introduced a bias. We did however also analyse the group of TBI patients of which we did not have BAC's (data not presented) and found that alcohol intoxication is associated with less severe TBI, shorter length of hospitalization and ICU admission, and higher survival.

Every effort was made to code injuries accurately in our trauma registry, but because of the retrospective design of the study a possible selection bias may have been introduced concerning the interpretation of injury patterns and injury severity, therefore, influencing the AIS and ISS coding. Also, it was impossible to retrieve all the missing GCS data because of the retrospective design of our study. Thus, it can be assumed that some of our findings are the result of residual confounding.

Another issue to consider is the fact that we did not distinguish between acute alcohol intoxication and chronic alcohol consumption, nor was a history of alcohol use or abuse documented. Trauma patients with behavioural and biochemical evidence of chronic alcohol abuse have been associated with higher complication rates, worse outcomes and longer length of stay compared to acutely intoxicated patients [33]. It is plausible that patients with chronic alcohol abuse and TBI also have a higher complication rate, worse outcomes, and longer length of stay when compared to acutely intoxicated patients as has been described with other injuries. Their presence in the current study would attenuate the clear effects found and exclusion of these patients probably would magnify these effects.

CONCLUSIONS

The current study results suggest that increasing levels of BAC in patients with moderate and severe TBI are independently, i.e., after correcting for confounding variables, associated with lower injury severity, shorter length of hospital and ICU stay and improved survival. Controversy remains and further clinical and basic research is necessary into the pathophysiological mechanisms to help explain the outcomes found.

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7

Reduced Quality of Life, Fatigue, and Societal Participation After Polytrauma.

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ABSTRACT

Background

This cross-sectional study analysed associations between and determinants for Health-Related Quality of Life (HRQoL), fatigue and societal participation in polytrauma patients.

Summary of Background Data

More polytrauma patients survive their injuries, often resulting in long-term disabilities. HRQoL is therefore an important outcome of trauma care. Fatigue and societal participation may be related to HRQoL. Also, their relation to severe injuries has not been studied to date.

Methods

283 polytrauma patients (ISS≥16) admitted to the Dutch level 1 Trauma Centre West were analysed. HRQoL was measured by the Physical Component Summary (PCS) and Mental Component Summary (MCS) scores of the SF-36, fatigue by the Multidimensional Fatigue Inventory and societal participation by the Utrecht Scale for Evaluation of Rehabilitation-Participation. Age, gender, comorbidity, injury pattern, injury severity and time since trauma were analysed as potential determinants.

Results

122 patients (43%) responded after a median follow-up of 15 (10-23) months after polytrauma. 44% reported reduced physical health (PCS<45) and 47% reduced mental health (MCS<45). HRQoL was highly correlated with all fatigue and participation subscales. Severe head injury was associated with worse mental health. Female patients reported more general and mental fatigue and were less satisfied with their ability to perform daily activities. Patients with pre-existing comorbidity experienced worse physical health, more fatigue, and reduced societal participation.

Conclusions

One to two years after the trauma, polytrauma patients report reduced HRQoL, which is associated with more fatigue and reduced societal participation. Trauma rehabilitation strategies should focus on early recognition of reduced HRQoL, fatigue and societal participation and facilitate early intervention to improve these outcomes.

INTRODUCTION

Trauma is an important cause of death and contributes significantly to the global burden of disease. Trauma affects people of all ages and particularly the young, resulting in a considerable number of life years lost due to premature death and large numbers of years lived with disability[1]. The introduction of the Advanced Trauma Life Support (ATLS®) program, all-inclusive trauma systems and centralization of trauma care have gradually resulted in reduced trauma-related mortality in the Netherlands and many other countries[2]. Subsequently, an increasing number of trauma patients survive with long-term morbidity and often face severe and prolonged deficits in health-related quality of life (HRQoL). HRQoL has therefore become an increasingly important outcome measure to evaluate further enhancement of trauma care.

Long-term effects of major trauma on physical and mental health have been extensively reported[3-11]. Fatigue, another important aspect of well-being, has only been described after specific types of traumatic injuries such as traumatic brain injury[12, 13] and spinal cord injury[14-17]. In these patient groups, fatigue was associated with a negative impact on societal participation and resulted in restricted physical and social activities. Fatigue and reduced societal participation in multiple injured trauma patients after recovery have not been previously reported on and also their association with reduced HRQoL has not been described in the literature.

The objective of the study was to analyse these relations and to identify patient and injury characteristics associated with HRQoL, fatigue and societal participation in severely injured patients one to two years after the trauma.

MATERIALS AND METHODS

Study Design

In the regional trauma registry of the Dutch Trauma Centre West (DTCW) we identified all severely injured patients (Injury Severity Score [ISS] ≥16), who had been admitted to two level-I trauma centre locations of the DTCW, between July 2011 and July 2012. Minors (<18 years), deceased patients, patients with self-inflicted injuries, non-Dutch residents and patients who had been lost to follow-up after discharge from the hospital were excluded from the study. In April 2013, selected patients received a letter by mail to invite them to participate in a survey including questionnaires concerning HRQoL, fatigue and societal participation. Patients who did not respond were contacted by telephone and encouraged to participate and complete the questionnaires or, in case of missing phone numbers, were sent reminders by mail to encourage participation. The institutional Medical Ethics Review Board approved the study (protocol no. P13.061).

Demographic and clinical data

Data retrieved from the trauma registry included gender, age, anatomic injury diagnoses and injury severity according to the Abbreviated Injury Scale (AIS) version 2005 update 2008[18], the initial Emergency Department Glasgow Coma Scale (GCS)[19] and mortality. Severe injury (AIS ≥ 3) was categorized using the anatomical regions defined in the AIS (head, face, neck thorax, abdomen, spine, extremities and external). The trauma patients were divided into two categories: polytrauma and severe polytrauma patients. Polytrauma was defined as an Injury Severity Score (ISS) ≥16), and severe polytrauma as ISS ≥ 25[20]. Data on pre-existing diseases were obtained from the Electronic Medical Records. Comorbidity was scored using the Charlson Comorbidity Index[21], which includes disorders defined according to the International Classification of Diseases 10 (ICD10). All data were documented directly after trauma or after discharge from the hospital.

HRQoL, fatigue and societal participation

HRQoL was measured using the Short Form Health Survey (SF-36), a validated questionnaire including 36 items covering eight health domains: physical functioning, role limitations due to physical health problems, bodily pain, vitality, social functioning, role limitations due to emotional problems, general health, and emotional well-being [22]. The eight scales can be summarized into two scores: The Physical Component Summary (PCS) score and the Mental Component Summary (MCS) score. PCS and MCS scores range from 0 to 100 with higher scores reflecting better health. These scores are standardized to the general Dutch population by age and gender so that a score of 50 reflects the expected HRQoL of the Dutch population. Reduced HRQoL was defined as a score of 45 or lower since a difference of five points in PCS and MCS scores is considered clinically relevant [23].

Fatigue was measured using the Multidimensional Fatigue Inventory (MFI-20)[24]. This questionnaire evaluates five dimensions of fatigue: general fatigue, physical fatigue, mental fatigue, reduced motivation, and reduced activity. Scores on each scale vary from 4 to 20, with higher scores indicating higher levels of fatigue for each dimension.

Social participation was measured using the Utrecht Scale for Evaluation of Rehabilitation-Participation (USER-P)[25]. This instrument measures three aspects of participation: frequency of leisure and societal activities, restriction in daily activities and satisfaction with the ability to perform daily activities. Scores range from 0 to 100, with higher scores indicating higher levels of participation.

Data Analysis

Characteristics of respondents and non-respondents, and patients with or without reduced HRQoL, were compared using the unpaired t-test for continuous data, and the Chi-square test for categorical data. The average PCS and MCS scores in our study group were compared with the reference score of 50 (standard deviation [SD] 10) for the general Dutch population using a one-sample t-test. Scores on the fatigue and societal participation scales were compared between patients with and without reduced HRQoL using an unpaired t-test. Furthermore, it was assessed whether patient- and injury characteristics (age, gender, presence of comorbidity, severe injury to the head, neck, trunk (thorax and abdomen), extremities and severe polytrauma) and length of follow-up since trauma were associated with HRQoL, societal participation and fatigue using linear regression analysis. Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS Inc., Chicago, IL), version 20. P-values < 0.05 were considered statistically significant.

RESULTS

Study group

Of the 372 identified polytrauma patients, 89 patients were excluded: 51 patients had died due to their injuries, 10 patients were minors, 9 patients had inflicted the injuries themselves, 2 patients were living abroad, and 17 patients were lost to follow-up. So, 283 met the inclusion criteria and were contacted for participation. Of these, 122 patients filled out the questionnaire (response rate of 43.1%). Respondents and non-respondents were comparable with respect to patient and injury characteristics, although respondents more often had severe injuries to the lower extremities (Table 1). The median follow-up of the respondents was 15.0 months (range 10-23).

Health-Related Quality of Life

The PCS and MCS scores could be computed for 114 patients (8 missing). Compared with the general Dutch population of the same gender and age, the polytrauma study group scored on average 4.2 PCS points (95% confidence interval [CI] 2.0-6.4) lower for physical health and 5.4 MCS points (95% CI 3.3-7.6) lower for mental health ($p<0.001$ for both comparisons). Fifty patients (43.9%) reported reduced physical health (PCS<45) and 53 patients (46.5%) reported reduced mental health (MCS<45).

Relation between reduced HRQoL and fatigue/societal participation

Polytrauma patients with reduced physical and/or mental health scored higher on all dimensions of the MFI-20 ($p<0.001$), indicating that they experienced more general, physical, and mental fatigue, and more reduced activity and reduced motivation than polytrauma patients without reduced HRQoL (Table 2). Furthermore, polytrauma patients with reduced HRQoL scored lower on all USER-P subscales (p<0.001), indicating that they participated less frequently in social activities, were less satisfied with their societal participation and experienced more restrictions in their daily activities (Table 2).

Table 1. Demographics and clinical characteristics of polytrauma patients by study participation.

	Total (*n*=283)	Respondents (*n*=122)	Non-respondents (*n*=161)	*P*
Male, n (%)	192 (67.8)	81 (66.4)	111 (68.9)	0.65
Age in years, mean (SD)	56.2 (21.1)	57.9 (19.2)	55.0 (22.4)	0.24
CCI, mean (SD)	0.5 (0.9)	0.4 (0.8)	0.5 (1.0)	0.35
ISS, mean (SD)	22.2 (7.3)	21.6 (6.2)	22.6 (8.1)	0.25
Number of severe injuries, mean (SD)	1.9 (1.1)	1.9 (1.2)	1.9 (1.1)	0.96
Severe injury (AIS ≥3), n (%)				
Head/Face	175 (61.8)	71 (58.2)	104 (64.6)	0.27
Thorax	96 (33.9)	40 (32.8)	56 (34.8)	0.73
Abdomen	19 (6.7)	9 (7.4)	10 (6.2)	0.70
Spine	30 (10.6)	12 (9.8)	18 (11.2)	0.72
Upper extremities	18 (6.4)	8 (6.6)	10 (6.2)	0.91
Lower extremities	37 (13.1)	22 (18.0)	15 (9.3)	0.03
External	7 (2.5)	3 (2.5)	4 (2.5)	1.00
GCS[I], mean (SD)	13.1 (3.3)	13.4 (3.1)	13.0 (3.5)	0.42

SD: standard deviation; CCI: Charlson Comorbidity Index; ISS: Injury Severity score; AIS: Abbreviated Injury Scale.
[I]GCS: Glasgow Coma Scale

Table 2. Associations between reduced health-related quality of life and fatigue and societal participation after polytrauma.

Dimension	PCS < 45 (*n* = 50)	PCS ≥ 45 (*n* = 64)	*P*	MCS < 45 (*n* = 53)	MCS ≥ 45 (*n* = 61)	*P*
General Fatigue	14.8 (3.9)	8.4 (4.2)	<0.001	14.5 (3.7)	8.3 (4.4)	<0.001
Physical Fatigue	15.4 (3.7)	7.8 (3.8)	<0.001	14.3 (4.4)	8.4 (4.6)	<0.001
Reduced Activity	13.8 (3.9)	8.2 (3.9)	<0.001	13.5 (4.2)	8.2 (3.7)	<0.001
Reduced Motivation	12.4 (4.3)	7.9 (3.8)	<0.001	12.9 (3.9)	7.2 (3.3)	<0.001
Mental Fatigue	11.8 (5.3)	8.2 (4.5)	<0.001	12.8 (4.7)	7.2 (3.9)	<0.001
USER-P Frequency	23.8 (13.2)	38.3 (10.7)	<0.001	25.2 (13.4)	37.5 (11.7)	<0.001
USER-P Restriction	64.1 (21.1)	96.2 (7.6)	<0.001	72.5 (23.3)	92.3 (14.9)	<0.001
USER-P Satisfaction	57.9 (19.4)	84.8 (14.6)	<0.001	58.2 (17.8)	86.9 (14.1)	<0.001

All results are presented as mean scores (standard deviation).
General Fatigue, Physical Fatigue, Reduced Activity, Reduced Motivation and Mental Fatigue are the five scales of the Multidimensional Fatigue Inventory (MFI-20).
USER-P Frequency (measuring the frequency of leisure and societal activities), USER-P Restriction (measuring restriction in daily activities) and USER-P Satisfaction (measuring satisfaction with the ability to perform daily activities) are the three scales of the Utrecht Scale for Evaluation of Rehabilitation-Participation (USER-P).
The Physical Component Summary (PCS) score and Mental Component Summary (MCS) score are summary measures that are based on the scores of the eight scales of the Short Form Health Survey (SF-36).

Determinants of HRQoL

Pre-existing comorbidity was associated with worse physical health (on average 12.9 points lower PCS scores, 95% CI 7.9-17.9; p<0.001) (Table 3). Severe head injury was associated with worse mental health (on average 6.8 points lower MCS scores, 95% CI 0.6-13.1; p=0.03). PCS and MCS scores were not associated with severe injury to the trunk or to the extremities, severe polytrauma and time since the trauma. The models explained 25.6% and 8.0% of the variance in PCS and MCS scores.

Table 3. Associations between patient and injury characteristics* and health-related quality of life in polytrauma patients, assessed by linear regression analysis.

Characteristic	PCS	MCS
Presence of comorbidity	**-12.9 (-17.9; -7.9)**	-0.9 (-6.1;4.3)
Severe injury† to the		
Head	2.8 (-3.2;8.9)	**-6.8 (-13.1; -0.6)**
Neck, thorax, abdomen or spine	-0.5 (-6.3;5.4)	-2.6 (-8.6;3.5)
Extremities	-4.5 (-10.0;1.0)	-2.1 (-7.8;3.6)
Severe polytrauma‡	-1.6 (-7.2;4.0)	-0.1 (-5.9;5.7)
Time since trauma, per month increase	0.1 (-0.6;0.7)	0.4 (-0.2;1.0)

Data are presented as regression coefficients with their 95% confidence interval. Statistically significant regression coefficients (p<0.05) are presented in bold.
The Physical Component Summary (PCS) score and Mental Component Summary (MCS) score are summary measures that are based on the scores of the eight scales of the Short Form Health Survey (SF-36).
* Not including age and gender, since PCS and MCS scores are standardized by these characteristics
† Abbreviated Injury Score ≥ 3
‡ Injury Severity Score ≥ 25

Determinants of fatigue

Female patients reported more general fatigue (on average 2.3 points higher scores, 95% CI 0.3-4.4; p=0.03) and more mental fatigue (on average 2.3 points higher scores, 95% CI 0.1-4.5; p=0.04) than male patients (Table 4). Patients with comorbidity had higher scores on most fatigue subscales indicating more general fatigue (5.0 points higher scores, 95% CI 2.7-7.4; p<0.001), more physical fatigue (4.8 points higher scores, 95% CI 2.3-7.3; p<0.001), more reduced activity (3.3 points higher scores, 95% CI 1.0-5.6; p=0.006), more reduced motivation (2.3 points higher scores, 95% CI 0.1-4.6; p=0.006). Age, severe polytrauma, location of severe injury and time since trauma were not associated with any of the domains of fatigue (Table 4). The percentage of variance explained by the models ranged from 10.7% for mental fatigue to 22.0% for general fatigue.

Determinants of societal participation

Gender and the presence of comorbidity were associated with some dimensions of societal participation (Table 5).

Table 4. Associations between patient and injury characteristics and fatigue in polytrauma patients, assessed by linear regression analysis.

Characteristic	General Fatigue	Physical Fatigue	Reduced Activity	Reduced Motivation	Mental Fatigue
Age, per year increase	-0.03 (-0.08;0.02)	0.01 (-0.04;0.07)	0.01 (-0.05;0.06)	0.01 (-0.04;0.06)	-0.03 (-0.09;0.03)
Female gender	**2.3 (0.3;4.4)**	1.9 (-0.4;4.1)	1.5 (-0.5;3.6)	1.2 (-0.8;3.2)	**2.3 (0.1;4.5)**
Presence of comorbidity	**5.0 (2.7;7.4)**	**4.8 (2.3;7.3)**	**3.3 (1.0;5.6)**	**2.3 (0.1;4.6)**	2.1 (-0.4;4.5)
Severe injury* to the					
Head	-0.6 (-3.1;2.0)	-0.9 (-3.7;1.8)	0.4 (-2.1;3.0)	0.7 (-1.8;3.2)	1.2 (-1.6;3.9)
Neck, thorax, abdomen or spine	0.7 (-1.8;3.1)	0.3 (-2.3;2.9)	-0.5 (-3.0;1.9)	-0.8 (-3.2;1.6)	0.7 (-1.9;3.2)
Extremities	1.0 (-1.3;3.4)	1.3 (-1.3;3.8)	0.8 (-1.5;3.1)	1.1 (-1.2;3.4)	0.6 (-1.9;3.1)
Severe polytrauma†	0.6 (-1.8;3.0)	1.0 (-1.3;3.8)	1.8 (-0.6;4.1)	1.7 (-0.6;4.0)	1.2 (-1.3;3.7)
Time since trauma, per month increase	-0.02 (-0.28;0.25)	-0.1 (-1.6;3.5)	-0.03 (-0.29;0.23)	-0.1 (-0.4;0.1)	-0.09 (-0.36;0.19)

Data are presented as regression coefficients with their 95% confidence interval. Statistically significant regression coefficients (p<0.05) are presented in bold. Fatigue was measured using the Multidimensional Fatigue Inventory (MFI-20).
* Abbreviated Injury Score ≥ 3
† Injury Severity Score ≥ 25

Table 5. Associations between patient and injury characteristics and social participation in polytrauma patients, assessed by linear regression analysis.

Characteristic	USER-P Frequency	USER-P Restrictions	USER-P Satisfaction
Age, per year increase	-0.1 (-0.2;0.1)	0.0 (-0.3;0.2)	-0.03 (-0.27;0.22)
Female gender	-0.2 (-5.9;5.5)	**-13.5 (-22.8;-4.2)**	-6.7 (-15.9;2.5)
Presence of comorbidity	-5.3 (-11.9;1.3)	**-21.0 (-31.6;-10.3)**	**-14.9 (-25.7;-4.0)**
Severe injury* to the			
Head	-2.5 (-9.5;4.5)	-2.4 (-14.0;9.3)	-9.3 (-20.3;1.8)
Neck, thorax, abdomen or spine	0.5 (-6.2;7.3)	-9.1 (-20.1;1.9)	-2.9 (-13.5;7.8)
Extremities	-2.9 (-9.4;3.5)	-4.5 (-15.7;6.7)	-5.5 (-16.0;5.0)
Severe polytrauma†	-3.1 (-9.6;3.5)	5.2 (-6.3;16.6)	1.5 (-9.1;12.1)
Time since trauma, per month increase	0.6 (-0.1;1.4)	0.2 (-1.0;1.3)	0.6 (-0.6;1.7)

Data are presented as regression coefficients with their 95% confidence interval. Statistically significant regression coefficients (p<0.05) are presented in bold.
USER-P Frequency (measuring the frequency of leisure and societal activities), USER-P Restriction (measuring restriction in daily activities) and USER-P Satisfaction (measuring satisfaction with the ability to perform daily activities) are the three scales of the Utrecht Scale for Evaluation of Rehabilitation-Participation (USER-P).
*Abbreviated Injury Score ≥ 3
† Injury Severity Score ≥ 25

Female patients reported more restrictions in social participation than male patients with on average 13.5 points lower scores (95% CI 4.2-22.8; p=0.005). Compared to patients without comorbidity, the patients with comorbidity experienced more restrictions in social participation (scores on average 21.0 points lower, 95% CI 10.3-31.6;

p<0.0001) as well as less satisfaction with social participation (scores on average 14.9 points lower, 95% 4.0-25.7; p=0.008). Age, severe polytrauma, location of severe injury and time since trauma were not associated with any of the dimensions of societal participation. The percentage of variance explained by the models was 12.4% for frequency of leisure and societal activities, 28.7% for restrictions in daily activities, and 17.4% for satisfaction with the ability to perform daily activities.

DISCUSSION

The aim of this study was to analyse HRQoL, fatigue and societal participation after polytrauma in relation to specific patient and injury characteristics.

One to two years after being severely injured, almost half of the participants in our study reported reduced physical and/or mental health compared to the general Dutch population of the same age and gender. Reduced HRQoL was strongly associated with increased fatigue and reduced societal participation. Within this group of polytrauma patients, the injury severity and location of severe injuries were not associated with HRQoL, fatigue and societal participation, except that mental health was worse in patients who had suffered severe head injury. Female patients and patients with comorbidity were found to be at risk for decreased HRQoL, more fatigue and lower societal participation.

HRQoL, Fatigue and Societal Participation

Although the mean PCS and MCS scores of the polytrauma patients were statistically lower compared to those of the general Dutch population of similar age and gender, the clinical significance of these differences on a group level was marginal (respectively 4.2 and 5.4 on average). Differences found with the general population in overall HRQoL are in concordance with earlier studies in different countries, for instance in Denmark[3], Sweden[4], Norway[5], Germany[6] and the Netherlands[11]. But, considering the fact that more than half of the patients in our study did not report reduced HRQoL together with the marginal clinical significant difference in PCS and MCS, it seems that many polytrauma patients in contrast to the previous stated studies recover fully from their injuries.

Our study showed that both reduced physical health and reduced mental health were strongly associated with all dimensions of fatigue and societal participation. Fatigue is often found in patients with various chronic diseases and is perceived by patients to have a major impact on their quality of life[26]. The results of this study confirm our assumption that reduced HRQoL, and fatigue have a large impact on the ability of polytrauma patients to participate in social activities. Although not measured in our study, it is also known from other studies that up to 30% of polytrauma patients in working ages are unable to return to work after recovery of their injuries[6,7,27]. It is important to recognize that, beside physical disabilities, psychological factors such as depressive symptoms and posttraumatic stress disorder (PTSD) are common in trauma patients. These psychological factors can limit societal participation and prevent a return to work[28-31]. Physicians should be aware of these symptoms so that psychological intervention can be started early if needed[32].

Determinants of HRQoL, fatigue and societal participation

There is a vast body of literature describing various determinants of reduced HRQoL after polytrauma. Several studies have identified demographic determinants such as age[4, 33-36], gender[11,27], educational level[11,36], social economic status[35], living with a partner[11,35]; clinical determinants such as pre-existing comorbidity [9,11,33,34]; and injury-related determinants such as injury severity[11,27,33-35] and injury location[15,33,35-38]. In this study, we focused on injury severity, the anatomical site of the injuries, and basic patient characteristics (gender, age, pre-existing comorbidity) as potential determinants because the socioeconomic status and educational level at the time of the hospital admission were not available in the analysed data.

Only pre-existing comorbidity was identified as a determinant for worse physical health, and only severe head injury was a determinant for worse mental health. Both determinants were associated with a clinically relevant decrease in scores of 7 and 13 points, respectively. The fact that varying determinants of HRQoL are found in the present and previous studies, indicates that influences on HRQoL after trauma are multifactorial and that most probably many of the determinants of reduced HRQoL are correlated. In previous studies, the length of the patient's follow-up since trauma also differed between one and five years, which may explain some of the variations in determinants found in the literature.

Although persistent fatigue is a frequent complaint after traumatic head injury[12,13,39] and spinal cord injury[14,17], determinants of fatigue in the general polytrauma population have not previously been described. Fatigue is a multidimensional concept which was studied using the MFI-20 which measures fatigue on five subscales. These five include general fatigue which refers to daily functioning, physical functional fatigue which refers to physical tiredness, mental fatigue which refers to cognitive symptoms of fatigue, reduced motivation which refers to the lack of motivation to start any activity, and reduced activity[24]. We found that scores on all subscales of the MFI were equally high for polytrauma patients with severe injury to the head, trunk (including neck, thorax, abdomen and spine) or extremities. Unfortunately, in our study, there were only twelve patients with severe spinal injury, which was a too small number to be studied as a separate group. Similarly, to injury location, fatigue scores also did not relate to the overall injury severity level (ISS). From these results, we tentatively conclude that fatigue is equally present in all types of polytrauma patients, irrespective of injury severity and anatomical injury site. Pre-existing comorbidity was found to be a determinant of most aspects of fatigue except for mental fatigue.

The female patients in our polytrauma population scored on average respectively 2.3 points higher than the male patients on both the subscales for general and mental fatigue, which is in line with a previous study conducted by Cantor[13]. The effect seems to be clinically meaningful and is similar to that described in patients with cancer-related fatigue[40]. General fatigue relates to general remarks made by a person concerning his or her functioning, while the MFI-20 mental subscale reflects fatigue related to “mental ability to do things” and “mental condition” that causes a feeling of decreased ability to manage daily activities. Female patients are known to report significantly worse long-term well-being after major trauma than male patients[11, 27]. They are at risk for worse functional and psychological outcomes, independent of age, injury severity and trauma mechanism[41]. The underlying mechanism is not well understood, although psychological factors may play a role, as female patients seem to be more susceptible to depression and post-traumatic stress after major trauma than male patients[42]. This may explain why the female patients in our study reported more general fatigue and mental fatigue. The female patients also seemed to score more fatigue on the other three subscales (physical fatigue, reduced motivation and reduced activity), but these effects were not as large and not statistically significant.

Societal participation other than return to work has rarely been studied as an outcome measure after trauma. In the present study, societal participation was measured using the Utrecht Scale for Evaluation of Rehabilitation-Participation (USER-Participation). This instrument measures both objective participation (the frequency of leisure and societal activities) and subjective participation (experienced restriction in daily activities and satisfaction with the ability to perform daily activities). Patients with pre-existing comorbidity experienced more restrictions in social participation due to their condition and were also less satisfied with their level of social participation. Female patients did not report less participation in leisure and social activities than male patients, but they did feel notably more restricted in participating in daily activities. The explanation for these seemingly contradictory results for the objective and subjective levels of social participation is not clear and can only be speculated upon. As women are more at risk for psychological morbidity than men after severe trauma[42], the perception of being able to participate after recovering from their injuries may be more adversely affected in females than in male patients[42]. This assumption is strengthened by the fact that the female patients also seemed to feel less satisfied with their ability to participate socially, although this finding was not statistically significant.

LIMITATIONS

This study has several limitations. First, the study had a cross-sectional design so causal relationships could not be established. Moreover, the actual levels of HRQoL, fatigue and societal participation of the patients before their injuries were not measured so changes from baseline could not be taken into account.

Second, the response rate in our study was low, which may have resulted in a bias. The questionnaire sent to the polytrauma population was lengthy because it included specific instruments for measuring HRQoL, as well as fatigue and societal participation. Therefore, the length of the used questionnaire could not be shortened, which may have discouraged study participation, especially in specific subgroups such as patients struggling with fatigue after polytrauma and patients with cognitive limitations after severe head injury. Also, the order of the instruments within the questionnaire was not randomized. Although selection and information bias cannot be ruled out entirely, our study group of polytrauma patients seemed representative since the respondents and non-respondents were comparable regarding patient and injury characteristics, which renders the risk of bias to be low.

Third, it can be assumed that the time elapsed between trauma and participation in our survey was relatively short i.e., between 10 and 23 months. However, the length of follow-up since trauma did not have a measurable effect on any of the outcomes in the study. Also, it has been demonstrated that after one year of follow-up hardly any improvement in functioning is seen, so one year seems sufficient to gain insight into HRQoL after severe injuries[5,21].

Last, although every effort was made to code injuries accurately in our regional trauma registry, a possible selection bias might have been introduced concerning the interpretation of injury pattern and injury outcome; therefore, influencing the AIS and ISS coding.

CONCLUSIONS

Between one and two years after the trauma, nearly half of all polytrauma patients still suffer from a reduced HRQoL, which is associated with more fatigue and reduced societal participation. It can be assumed that female polytrauma patients and patients with comorbidities have higher risks for reduced HRQoL, more fatigue and lower societal participation compared to other polytrauma patients.

Despite the previously stated limitations, this study underlines the importance of early identification of polytrauma patients at risk for suboptimal physical and/or mental recovery. Increased awareness of signs and symptoms, both in-hospital and after discharge, of reduced HRQoL, fatigue and societal participation after polytrauma can help achieve improved guidance by clinicians and rehabilitation specialists.

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DISCUSSION

8

General discussion

The number of road traffic accident (RTA) fatalities continues to increase worldwide. According to the World Health Organisation's "Global Status Report on Road Safety", it reached 1.35 million in 2016 alone. This means that around the world more people die as a result of road traffic injuries than from infectious diseases like HIV/AIDS, tuberculosis or diarrhoeal diseases[1]. Like with many causes of mortality the key to reduction of mortality due to traffic accidents lies mostly in prevention, which in the case of traffic accidents implies road safety. Road (un)safety affects all people in both high-income and low-income countries, every day. Almost everyone participates in daily traffic, wants to travel safely and expects to return home unharmed. Road safety is therefore an important social issue.

In a densely populated country like the Netherlands, it is quite a challenge to ensure that all road users, whether travelling by car, bicycle, motorcycle or on foot, can safely participate in traffic. Nevertheless, the importance of road safety is often underestimated by these participants.

It is only when things go wrong in traffic that people face the consequences of hazardous behaviour and experience both the physical and mental impact on their lives as a result of traffic unsafety. Not to mention the medical costs, loss of production, handling costs and congestion costs because of traffic accidents, which result in substantial social and economic burden. Traffic accident-related social and economic costs are estimated to exceed € 14 billion per year, equalling 2% of the Dutch gross domestic product (GDP)[2]. In this context, the importance of safe traffic for society is also high[3]. The Dutch government together with road safety institutes and pre- and in-hospital care institutions should adopt a new approach to structurally improve road safety and traffic accident outcome. Only by working together, safety and outcome can both be improved.

The primary aim of this thesis was to analyse injury patterns, injury severity and mortality for different types of road traffic participants involved in accidents in the Netherlands.

Policies and measures taken in the past have led to many successes and greatly reduced the number of road traffic accident victims. Unfortunately, it became apparent that the number of seriously injured road accident victims is increasing and the decline in the number of road deaths has stagnated over recent years. Increased numbers of elderly victims in general and both bicycle and motorized mobility scooter victims seem to have contributed substantially to this development[3,4]. This is consistent with the findings described in this thesis (**Chapter 2)**, that bicyclists were the largest and eldest group of in-hospital deceased traffic accident victims. Although 88% of all deceased RTA victims with severe trauma (ISS≥ 16) in **Chapter 2** were transported to a level-I trauma centre, 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). According to national guidelines set up by the Dutch Trauma Association, patients with severe trauma should directly be transported to a level-I trauma centre, but the above presented findings may reflect the fact that injury severity often is difficult to determine in the prehospital phase, especially in elderly victims. To prevent under-triage in the elderly, one may consider referring all acute elderly trauma patients (>65 years), with at least one AIS>3 injury, to a level-I trauma center[5]. As RTA victims aged over 75 years in this study were the largest group, with the lowest mean ISS and the most favourable 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 [6,7]. Also, the majority of the victims described in **Chapter 2** sustained severe head trauma and showed an almost three times higher frequency of severe head trauma than all RTA victims together in the Netherlands[8]. Thus, it can be assumed that the 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 light-mopeds and bicycles, even though bicycling is the most common form of transportation[9]. Because of increasing road congestion in the Netherlands, however, the motorized two-wheeled vehicle (MTV) is becoming a more important method of transportation. In the 1970s extensive helmet laws for both motorcyclists and moped riders were introduced. Light-moped riders, on the other hand, are not obliged to wear a helmet, which makes this a popular way of transportation for both young and elderly people in the Netherlands. The three categories of MTVs offered a unique possibility to compare and analyse the effects of accidents with different types of MTV and their specific drivers on injury severity and mortality (**Chapter 3)**. It was found that driving a light-moped is associated with a high risk to sustain severe trauma and dying when admitted to a hospital after a crash, compared to the better-protected motorcyclist and moped rider. Severe head injury was most common in light-moped riders, both fatally and nonfatally injured, and lowest in motorcyclists. This may imply that a large proportion of head injuries in light-moped riders is related to their heads being unprotected; the head injuries are likely to have been prevented or to be less severe with the usage of protective helmets. The protective effect of helmets in MTVs has been confirmed in many studies[10-15] This underscores the importance of implementation of strict legislation concerning helmet usage for all types of motorized two-wheelers in the Netherlands.

This thesis also clearly presents that injury patterns differ between different road user groups. In **Chapter 5** it was determined that pedestrians were the most vulnerable group of road traffic accident victims. They had the highest risk to sustain severe traumatic brain injury (TBI), resulting in the longest hospitalization compared to other groups. These findings are in accordance with other European epidemiological studies, which also demonstrated that pedestrians are vulnerable participants in daily traffic, having the most severe TBI with the worst outcome[16-19]. Both the high incidence of specific types of severe TBI and the frequent combination of multiple severe injuries in pedestrians may be due to their unprotected traffic participation and relatively high age. Possible measures to increase pedestrian safety are pedestrian-friendly car fronts and truck side shields, supplying more pedestrian crossings with traffic lights and the forced reduction of speed of other traffic in crowded pedestrian areas by installing elevations (raised junctions) or by completely excluding motorised traffic[20].

Our analysis showed that the overall injury severity in fatally injured road traffic accident victims is inversely related to age and that younger victims had a higher prevalence of severe (AIS≥3) injuries to the head and thorax. On the other hand, in-hospital deceased elderly trauma patients showed lower overall injury severity compared to younger deceased trauma patients. This underlines that the elderly are very vulnerable road users, mostly due to pre-existing comorbidities and functional decline in daily life[21,22]. The vulnerability of these patients aged over 75 years in combination with better vital signs at initial presentation than in younger accident victims **(Chapter 2)** can easily obscure severe injuries. It may bias the clinicians' interpretation of injury severity during admission and the impact of the injury severity on the chance of survival. In elderly pedestrians and cyclists, clinicians should therefore be extra suspicious of (combinations of) potentially lethal injuries to the head and thorax, that do not seem life-threatening at the time of admission.

Another vulnerable group of road users prone to under-triage after road traffic accidents are motorized mobility scooter (MMS) victims **(chapter 4)**. With its low speed, the mobility scooter may seem a relatively safe mode of transport, but safe use can be affected negatively by chronic illnesses and polypharmacy, especially among older users, and by changes in physical and cognitive skills. As a consequence, accidents involving these road users often result in unpredictable injury patterns and therefore it can be difficult for both ambulance and hospital staff to adequately assess the severity of these injuries after such an accident.[5,23,24] More and more accidents involving mobility scooters occur in our country and there are several specific reasons why these accidents may occur; the driver loses balance after contact with an obstacle or on an uneven surface and falls over, the driver makes a mistake when operating the mobility scooter, or the mobility scooter is hit by another road user. [25] In 2010, 3% of all people who died in a traffic accident were driving a mobility scooter. In 2018, 44 mobility scooter users died after traffic accidents, which is more than 6% of all traffic accident victims. Also, approximately 1200 mobility scooter drivers ended up in hospital with an injury[26]. It was striking that in the study described in **chapter 4**, five MMS accident victims who died after a low-energy trauma were all older than 75 years and four out of these five had not suffered severe injuries (ISS < 16). This emphasises that age and related factors, such as the presence of chronic diseases and polypharmacy, influence the risk of death in victims of mobility scooter accidents [27-29]. Therefore, it is important to involve various medical disciplines (trauma surgeon, neurologist and geriatrician) during the early phase of in-hospital care and treatment of this group of patients, especially to prevent underestimation of injuries. Regarding injury prevention, multiple measures should be taken to reduce the number of serious and fatal accidents involving these vulnerable traffic participants. One might consider regulations to equip mobility scooters with steering angle protection and to improve the stability of the mobility scooter.[25] Also, in spatial planning one might consider widening narrow bike paths and rearranging tight curves or removing, flattening or marking kerbstones along cycle paths to prevent mobility scooters from falling over and the introduction of driving skills training for mobility scooter users.

In this thesis associations between blood alcohol concentrations, TBI patterns and patient outcome, and between patient and injury characteristics and HRQoL, fatigue and societal participation in polytrauma patients were also studied. In these two separate areas of research, traumatic brain injury (TBI) in particular constitutes a significant public health problem[30-32]. A considerable number of patients with TBI is also diagnosed with alcohol intoxication[32]. The influence of different levels of blood alcohol concentrations (BAC) on the outcome of this patient population remains to be clarified. The study described in **chapter 6** examined this controversial issue of alcohol intoxication at the time of injury and its assumed protective effect on short-term outcome in TBI patients. The findings of this study are in line with some previous studies on this issue and suggest that in trauma patients with TBI, higher blood alcohol concentrations are associated with less severe TBI, fewer ICU admissions and a higher survival rate[33-38]. However, other studies did not find these effects of alcohol intoxication. Some even found an increased effect on in-hospital mortality for patients with TBI after correction for confounding variables such as cause of TBI and injury severity[38,39]. Unfortunately, all of these studies are not completely comparable with our study because of heterogeneous outcomes, the retrospective nature of our study and our failure to distinguish between acute alcohol intoxication and chronic alcohol consumption[40]. Obviously, the exact pathophysiological mechanism by which alcohol may or may not enhance survival is not yet fully understood at this time and further clinical studies and basic research is needed to provide insights into these mechanisms.

This thesis points out that road traffic accidents related to trauma contribute significantly to the global burden of disease. The trauma mechanisms and injury affect people of all ages, resulting in considerable numbers of life years lost due to premature death and large numbers of years lived with disability[41]. As a result of the introduction of an all-inclusive trauma system and centralization of trauma care in the Netherlands, an increasing number of trauma patients survive with long-term morbidity and often face severe and prolonged deficits in health-related quality of life (HRQoL), fatigue and societal participation[42]. These aspects, therefore, have become increasingly important outcome measures to evaluate further enhancement of trauma care. The study in **chapter 7** showed that one to two years after the trauma, polytrauma patients still report reduced HRQoL, associated with more fatigue and reduced societal participation. Although persistent fatigue is a frequent complaint after TBI[43-45], determinants of fatigue in the general polytrauma population have not been described well previously. We found that scores for fatigue on all subscales on the multidimensional fatigue inventory (MFI-20) were equally high for polytrauma patients with severe injuries to the head, trunk or extremities. Also, patients with pre-existing comorbidities and female patients experienced more restrictions in social participation compared with other polytrauma patients. However, because more than half of the patients in our study did not report any reduced HRQoL, it seems that many polytrauma patients in contrast to other studies[46-50] recover fully from their injuries. Nevertheless, trauma rehabilitation strategies should focus on early recognition of reduced HRQoL, fatigue and societal participation and facilitate early intervention to improve these outcomes.

Final Consideration

All road users should reach their destination safely. After decades of declining figures, the number of road traffic accident (RTA) fatalities is stagnating in the Netherlands, whilst the number of road traffic-related injuries has been increasing for years. But traffic is changing. Especially in the cities, it is getting busier and busier on both the roads and bicycle paths. Also, there are new (quieter) vehicles, such as electric bicycles and cars. Also, people increasingly participate in traffic at an older age. Thus, changing circumstances call for new measures. The introduction and implementation of new road traffic accident prevention measures as well as improving existing governmental protective and preventive measures, such as further prevention of head trauma, traffic education, alcohol education, improved infrastructure, improved vehicle safety standards and better enforcement of traffic rules, are essential to promote traffic safety in the Netherlands. Ultimately, the aim is to decrease the number of RTA fatalities in all road user groups.

If pre-hospital and hospital care providers are aware of the specific crash and patient characteristics, this will improve the vigilance for specific types of injury after RTA's, stimulate the development of focused diagnostic strategies in the early phases of trauma care and, consequently, help to achieve better outcomes for these specific trauma patients.

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9

Summary

Road traffic accidents (RTA) contribute significantly to the global burden of trauma. The World Health Organization indicates that approximately 1.3 million people die each year on the world's roads and between 20 and 50 million sustain non-fatal injuries. The introduction of extensive traffic safety laws, preventive governmental programs and substantial changes in (the organisation of) pre- and in-hospital trauma care have resulted in a gradual decrease in road traffic injuries and fatalities in the 1990s and onward in the Netherlands. Since 2006, however, the number of seriously injured road traffic participants has been increasing despite these government measures to improve road safety. In 2018, an estimated 21,700 people were seriously injured in traffic in the Netherlands, approximately 1,000 more than in 2017.

In **Chapter 1** the discussion about outcome and injury patterns after RTAs in the Netherlands is introduced. The primary aim of this thesis was to analyse injury patterns, injury severity and mortality for different types of road traffic participants involved in accidents in the Netherlands. Secondly, the association between blood alcohol concentrations, TBI patterns and patient outcome was analysed. Finally, patient and injury characteristics associated with HRQoL, fatigue and societal participation in polytrauma patients were identified.

Further reduction of RTA fatalities is a key priority in the European Union. Since data on injury patterns related to mortality in RTAs are scarce, **Chapter 2** describes the injury patterns and injury severity of in-hospital deceased RTA victims in the Netherlands. A total of 497 RTA victims deceased during the period 2015 – 2016 were analysed. Most of them were bicyclists and all deceased motorcyclists suffered severe trauma (Injury Severity Score ≥ 16). Head trauma was most frequently diagnosed in pedestrians and bicyclists. Therefore, further prevention of head trauma is needed to reduce RTA fatalities, especially among bicyclists. Trauma to the thorax was most frequently found in motorcyclists and motorists. Remarkable was that more than 10% of the severely injured (Injury Severity Score ≥ 16) RTA victims were not transported directly to a level I trauma centre and that the majority of this group was older than 75 years. Thus, under-triage of the severity of the injury 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.

RTAs involving motorized two-wheeled vehicle (MTV) riders often result in severe morbidity and mortality. The three categories of MTVs (motorcycles, mopeds and light-mopeds) in the Netherlands offered the possibility to compare the relation of different types of MTV and their specific driver groups, with injury severity and mortality in hospital-admitted MTV crash victims. **Chapter 3** presents an analysis of injury severity and mortality among 33,495 MTV crash victims. Overall, in light-moped riders, not only severe head injuries were most common, but also the prevalence of severe trauma and mortality was highest compared with motorcyclists and moped riders. The young motorcycle riders and elderly light-moped riders are two vulnerable groups in daily MTV traffic, with high chances of severe injury and mortality, upon hospitalization. These differences in age and also the use of different types of MTVs are of significant clinical and societal importance. Apart from the influence of the type of MTV on injury severity and mortality, this study pointed out that - despite previous protective measures - continuing improvement of the safety of all MTV users is urgent and the introduction of mandatory helmet usage in light-moped riders should be considered.

It is well known that the elderly are over-represented in both RTA fatalities and seriously injured road users. As the Dutch population is ageing, the increased desire for self-reliance and autonomy of older people will probably strengthen this trend. The Netherlands Social Support Act (WMO) dictates that municipalities give mobility scooters on loan to persons with limited physical capabilities who want to remain mobile. As a result of this desire for mobility, the number of mobility scooters is expected to grow among this specific group of persons to around 600,000 in 2030. **Chapter 4** describes the characteristics and clinical outcomes of 242 victims of motorized mobility scooter (MMS) crashes which were included in the trauma registry of the Trauma Centre West-Netherlands (TCW). In this study, both low-energy and high-energy crashes involving the MMS resulted in serious injuries and sometimes death. Especially elderly MMS users sustained severe trauma in this study. Consequently, improved awareness of MMS patient characteristics by multidisciplinary medical teams may help to avoid underestimation of the injury severity in this vulnerable population.

The objective of the study described in **Chapter 5**, was to analyse and determine the incidence, risk factors, hospital triage, and outcome of patients with severe traumatic brain injuries (sTBIs) caused by road traffic accidents. This study shows that especially age, Glasgow Coma Scale, and type of haemorrhage were independent prognostic factors for in-hospital mortality after sTBI. Between different types of road users, in-hospital mortality ranged from 4.2% in moped riders to 14.1% in motorists. However, pedestrians had the highest risk to sustain sTBI and, more specifically, intracranial haemorrhage. In general, specific brain injury patterns have been distinguished for specific road user groups, and independent prognostic risk factors for sTBI were identified.

The second part of this thesis focuses on the impact of alcohol intoxication on injury patterns and short-term outcome in patients with traumatic brain injuries (TBI). **Chapter 6** presents the association of different levels of blood alcohol concentrations

(BAC) with TBI characteristics and outcome. Adult patients with moderate to severe TBI (Abbreviated Injury Scale $\geq$ 2) and measured BAC admitted to hospitals in the Trauma Centre West-Netherlands (TCW) region during a 5 year period were analysed. In concordance with recent literature suggesting a neuroprotective effect of alcohol on TBI, possibly associated with less morbidity and mortality, this study found that in patients with moderate to severe TBI, increasing BACs were associated with less severe TBI, fewer ICU admissions and higher survival.

The introduction of all-inclusive trauma systems and centralization of trauma care has gradually resulted in reduced trauma-related mortality in the Netherlands. As a result, an increasing number of trauma patients survive their injuries and often face severe and prolonged deficits in health-related quality of life (HRQoL). HRQoL has therefore become an increasingly important outcome measure to evaluate further enhancement of trauma care. However, little is known about the relation between fatigue and reduced societal participation in severely injured trauma patients after recovery with the occurrence of reduced HRQoL. With this in mind, the last part of this thesis focuses on the associations between and determinants for HRQoL, fatigue and societal participation in polytrauma patients. **Chapter 7** describes the analysis of 283 polytrauma patients (Injury Severity Score$\geq$16) admitted to two level-I trauma centre locations in the Trauma Centre West-Netherlands region. HRQoL was measured using the Short Form Health Survey (SF-36), and fatigue and societal participation were respectively measured using the Multidimensional Fatigue Inventory and the Utrecht Scale for Evaluation of Rehabilitation-Participation. One to two years after the trauma, polytrauma patients reported reduced HRQoL, which was also associated with more fatigue and reduced societal participation. Also, severe head injury was associated with worse mental health and female patients reported more general and mental fatigue and were less satisfied with their ability to perform daily activities. Thus, trauma rehabilitation strategies for polytrauma patients might focus on early recognition of reduced HRQoL, fatigue and societal participation and facilitate early intervention to improve these outcomes.

The general discussion in **chapter 8** presents an overview of the clinical implications of the main findings, future perspectives as well as issues that remain to be studied relating to factors influencing both injury patterns and injury outcome of RTA victims and polytrauma patients.

APPENDICES

10

Dutch summary

Elk jaar sterven volgens de Wereldgezondheidsorganisatie wereldwijd ongeveer 1,3 miljoen mensen aan de gevolgen van verkeersongevallen. Daarnaast lopen tussen de 20 en 50 miljoen verkeersdeelnemers ernstig letsel op. De invoering van uitgebreide verkeersveiligheidswetten, preventieve overheidsprogramma's en substantiële veranderingen in (de organisatie van) de prehospitale en hospitale traumazorg hebben vanaf de jaren negentig in Nederland geleid tot een geleidelijke daling van het aantal gewonden en doden als gevolg van verkeersongevallen. Sinds 2006 neemt het aantal ernstig gewonde verkeersdeelnemers echter weer toe, ondanks diverse overheidsmaatregelen om de verkeersveiligheid te verbeteren. In 2018 raakten in Nederland naar schatting 21,700 mensen ernstig gewond in het verkeer, ongeveer 1,000 meer dan in 2017.

Het primaire doel van dit proefschrift is het analyseren van letselpatronen, letselernst en mortaliteit voor verschillende typen verkeersdeelnemers die betrokken zijn geweest bij ongevallen in Nederland. Ten tweede wordt het verband tussen concentraties alcohol in het bloed, typen traumatisch hersenletsel en patiëntuitkomsten geanalyseerd. Tenslotte zijn patiënt- en letselkenmerken geanalyseerd die invloed hebben op de kwaliteit van leven, vermoeidheid en maatschappelijke participatie van polytrauma patiënten.

In **hoofdstuk 1** wordt als introductie de historische ontwikkeling van verkeersongevallen in Nederland besproken. Tevens wordt zowel de rol van alcohol bij het oplopen van hersenletsel als de invloed van ernstig letsel op de kwaliteit van leven besproken.

Het verder terugdringen van het aantal dodelijke verkeersslachtoffers is een topprioriteit van de Europese Unie. Omdat gegevens over letselpatronen in relatie tot mortaliteit na verkeersongevallen schaars zijn, beschrijft **hoofdstuk 2** de letselpatronen en letselernst van in ziekenhuis overleden verkeersslachtoffers in Nederland. In totaal zijn de kenmerken van 497 verkeersslachtoffers geanalyseerd die gedurende de periode 2015 - 2016 zijn overleden. De meesten van hen waren fietsers en alle overleden motorrijders waren ernstig gewond (Injury Severity Score (ISS) ≥ 16). Traumatisch hersenletsel werd het vaakst gediagnosticeerd bij voetgangers en fietsers. Daaruit kan geconcludeerd worden dat verdere preventie van hersenletsel nodig is om het aantal verkeersdoden, vooral onder fietsers, te verminderen. Letsels aan de borstkas werden het vaakst gediagnosticeerd bij motorrijders en automobilisten. Opvallend was dat meer dan 10% van de ernstig gewonde (ISS ≥ 16) verkeersslachtoffers niet direct naar een level I traumacentrum zijn vervoerd en dat de meerderheid van deze groep ouder was dan 75 jaar. Onderschatting van de ernst van het letsel bij oudere verkeersslachtoffers ligt dus voor de hand en extra aandacht hiervoor gedurende de eerste fasen van de traumazorg, vooral tijdens de prehospitale behandeling en opvang op de Spoed Eisende Hulp, lijkt noodzakelijk.

Verkeersongevallen waarbij bestuurders van gemotoriseerde tweewielers betrokken zijn, leiden vaak tot ernstige morbiditeit en mortaliteit. In Nederland zijn er drie categorieën gemotoriseerde tweewielers (motorfietsen, bromfietsen en snorfietsen). Hierdoor is het mogelijk om het verband tussen deze drie groepen, en de karakteristieken van de ongevalsslachtoffers, hun letsel(ernst) en mortaliteit te bepalen.

Hoofdstuk 3 bespreekt de karakteristieken en uitkomsten van 33.495 slachtoffers van een verkeersongeval met gemotoriseerde tweewielers. Het blijkt dat bij snorfietsers niet alleen ernstig hoofdletsel het meest voorkomt, maar dat ook het meeste polytrauma (ISS ≥ 16) en hoogste mortaliteit uit ongevallen met deze verkeersdeelnemers voorkomt. Vaker dan bij in ziekenhuizen opgenomen motorrijders en bromfietsers. Daarnaast laat deze studie zien dat jonge motorrijders en oudere snorfietsers twee kwetsbare groepen zijn in het dagelijkse verkeer, met een hoge kans op ernstig letsel en sterfte tijdens een ziekenhuisopname. Deze verschillen in leeftijd en ook het gebruik van verschillende typen gemotoriseerde tweewieler zijn van significant klinisch en maatschappelijk belang. Afgezien van de invloed van het type voertuig op de ernst van het letsel en de mortaliteit, wijst deze studie erop dat - ondanks eerdere beschermende maatregelen - voortdurende verbetering van de veiligheid van alle gemotoriseerde tweewieler gebruikers hoog op de agenda dient te staan en de invoering van verplicht helmgebruik bij bestuurders van snorfietser moet worden overwogen.

Het is alom bekend dat vanwege de vergrijzing ouderen oververtegenwoordigd zijn in zowel het aantal dodelijke als in het aantal ernstig gewonde verkeersslachtoffers. Echter, met deze vergrijzing van de Nederlandse bevolking neemt ook de drang naar meer zelfredzaamheid en autonomie toe, waardoor het aantal oudere verkeersslachtoffers waarschijnlijk zal toenemen. De Wet Maatschappelijke Ondersteuning (WMO) schrijft voor dat gemeenten scootmobielen in bruikleen te kunnen geven aan personen met beperkte fysieke mogelijkheden die mobiel willen blijven. Als gevolg van deze mobiliteitswens wordt verwacht dat het aantal scootmobielen onder deze specifieke groep personen zal groeien tot ongeveer 600.000 in 2030. In **hoofdstuk 4** zijn de demografische kenmerken en klinische uitkomsten van 242 slachtoffers van ongevallen met gemotoriseerde scootmobielen bestudeerd. De gegevens zijn afkomstig uit het traumaregister van het Traumacentrum West-Nederland (TCW). De resultaten laten zien dat zowel laag- als hoogenergetische ongevallen waarbij scootmobiel gebruikers betrokken waren, regelmatig resulteerden in ernstige verwondingen en overlijden. In deze studie liepen vooral oudere gebruikers ernstig letsel op. Het verkrijgen van een beter inzicht in specifieke patiënt karakteristieken van deze populatie is essentieel. Daarnaast lijkt het verstandig deze groep multidisciplinair te behandelen, waardoor onderschatting van de ernst van letsels bij deze kwetsbare populatie voorkomen kan worden.

Hoofdstuk 5 bespreekt de kenmerken en uitkomsten van patiënten met ernstig traumatisch hersenletsel veroorzaakt door verkeersongevallen. Deze studie heeft laten zien dat vooral de leeftijd van het slachtoffer, de score van de Glasgow Coma Scale en het type hersenletsel onafhankelijke prognostische factoren zijn voor sterfte in het ziekenhuis na ernstig traumatisch hersenletsel. Tussen de verschillende types weggebruikers varieerde de sterfte in het ziekenhuis van 4,2% bij bromfietsers tot 14,1% bij automobilisten. Voetgangers hadden echter het hoogste risico om ernstig hersenletsel op te lopen en, meer specifiek, een intracraniële bloeding. In het algemeen zijn dus specifieke hersenletselpatronen onderscheiden voor specifieke groepen weggebruikers, en werden onafhankelijke prognostische risicofactoren voor ernstig traumatisch hersenletsel geïdentificeerd.

Het tweede deel van dit proefschrift richt zich op de invloed van intoxicaties met alcohol op zowel letselpatronen als op de korte termijneffecten op patiënten met traumatisch hersenletsel. **Hoofdstuk 6** laat het verband zien tussen verschillende bloedalcohol concentraties (BAC) en traumatisch hersenletsel en de uitkomsten daarvan voor patiënten. Voor deze studie zijn alle in de Traumacentrum West-Nederland (TCW) regio opgenomen volwassen patiënten met matig tot ernstig traumatisch hersenletsel (Abbreviated Injury Scale (AIS) ≥ 2) en beschikbare BAC bestudeerd. Deze studie toonde aan dat bij patiënten met matig tot ernstig traumatisch hersenletsel, stijgende alcohol concentraties in het bloed geassocieerd waren met minder ernstig hersenletsel, minder IC-opnames en een hogere overleving. Dit 'neuro-protectief effect' is in overeenstemming met recente literatuur waarin gesuggereerd wordt dat stijgende alcohol concentraties in het bloed worden geassocieerd met minder morbiditeit en mortaliteit onder patiënten met traumatisch hersenletsel.

De centralisatie van de zorg voor trauma patiënten door de invoer van 11 regionale traumacentra heeft geleidelijk tot een betere kwaliteit van opvang en behandeling van traumapatiënten in Nederland geleid. Als gevolg hiervan overleeft een toenemend aantal traumapatiënten hun verwondingen en worden zij vaker geconfronteerd met ernstige en langdurige beperkingen in hun kwaliteit van leven. Kwaliteit van leven is daarom een steeds belangrijkere uitkomstmaat geworden om verdere verbetering van de traumazorg te evalueren. Er is echter weinig bekend over de mogelijke correlatie tussen aan de ene kant vermoeidheid en verminderde maatschappelijke deelname bij ernstig gewonde traumapatiënten en aan de andere kant een verminderde kwaliteit van leven. Met dit in het achterhoofd richt **hoofdstuk 7** van dit proefschrift zich op de relaties tussen determinanten voor verminderde kwaliteit van leven, vermoeidheid en maatschappelijke deelname bij polytrauma patiënten. In deze studie zijn 283 polytrauma patiënten (ISS ≥ 16) beschreven die na het ongeval zijn opgenomen in twee level-I traumacentrum locaties in de regio Traumacentrum West-Nederland. Kwaliteit van leven werd gemeten met de Short Form Health Survey (SF-36), vermoeidheid en maatschappelijke participatie werden respectievelijk gemeten met de Multidimensional Fatigue Inventory en de Utrechtse Schaal voor Evaluatie van Revalidatie-Participatie. Eén tot twee jaar na het ongeval rapporteerden polytrauma patiënten een verminderde kwaliteit van leven, welke ook een verband had met meer vermoeidheid en een verminderde maatschappelijke deelname. Ook werd ernstig traumatisch hersenletsel geassocieerd met een slechtere mentale gezondheid en rapporteerden vrouwelijke patiënten meer algemene en mentale vermoeidheid en waren ze minder tevreden met hun vermogen om dagelijkse activiteiten uit te voeren. Behandeling tijdens de revalidatie van polytrauma patiënten zou zich dus meer kunnen richten op het vroegtijdig herkennen van een verminderde kwaliteit van leven, toegenomen vermoeidheid en verminderde maatschappelijke deelname en het faciliteren van vroegtijdige interventies om deze uitkomsten juist te verbeteren.

De algemene discussie van het proefschrift (**hoofdstuk 8)** geeft een overzicht van de klinische implicaties van de belangrijkste bevindingen, toekomstperspectieven en kwesties die nog onderzocht moeten worden, met betrekking tot factoren die zowel de letselpatronen als de letseluitkomsten van verkeersslachtoffers en polytrauma patiënten beïnvloeden.

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List of Publications

Dang Q, **Leijdesdorff HA**, Hoogendoorn JM, Emmink BL. Factors Affecting Hospital Length of Stay in Geriatric Patients With a Surgically Treated Fragility Ankle Fracture. *J Foot Ankle Surg. 2021 Oct 6:S1067-2516(21)00380-X.*

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Curriculum Vitae

Alexander Leijdesdorff was born on July 20th 1982 in Willemstad, Curacao. After graduating from the Willem de Zwijger College in Bussum in 2001, he started his medical studies at the University of Amsterdam in 2002. During his study, he worked at Bio Implant Services in Leiden during which he was responsible for cornea and cardiac valve explantation procedures. Before starting his clinical internships, he went to Ho-Chi-Minh City Vietnam for three months to participate in a scientific internship at the National Hospital of Odonto-Stomatology, which is the main hospital responsible for the care of maxillofacial trauma in Southern Vietnam, under the supervision of dr. L. Dubois.

After finishing his medical studies in 2009 he started working as a resident Surgery, not in training at the Department of Surgery at Onze Lieve Vrouwe Gasthuis in Amsterdam (dr. M. Gerhards). In the same year, he started his scientific work on road traffic accidents together with Prof. dr. I.B. Schipper.

In 2011 he started his General Surgical training in Gelre Ziekenhuizen in Apeldoorn (dr. W. H. Bouma and dr. P. van Duijvendijk), followed by a year of training in the Academic Medical Centre Amsterdam (prof. dr. O.R.C. Busch). Further training in Trauma Surgery followed in 2015 in the Academic Medical Centre Amsterdam (prof. dr. J.C. Goslings) and in 2016 in the MCH (Medisch Centrum Haaglanden) (dr. S.J. Rhemrev).

Following his surgical training in 2017, he was appointed as a fellow in Orthopaedic Trauma at Liverpool Hospital, New South Wales, Australia under the supervision of prof. Ian Harris. At the beginning of 2018, he returned to the Haaglanden Medical Centre where he still works as a permanent Trauma Surgeon.

During his career, he developed a special interest in the education and training of medical students, interns and residents. And from May 2022 he will become the acting Surgical Training Program Director of the Department of Surgery of the Haaglanden Medical Centre.

Alexander lives happily together with his wife Wendy in the Hague, the Netherlands and they are proud parents of three sons (Flint, Toby and Feys).

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