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Article

Characteristics and Injury Patterns in Traumatic Brain Injury Related to E-Scooter Use in Riga, Latvia: Multicenter Case Series

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Abstract: *Background and Objectives:* In recent years Electronic scooters (E-Scooters) have gained popularity, whether for private use or as a publicly available transportation method. With introduction of these vehicles, reports of E-Scooter related accidents have surged, sparking a public debate and concern. Aim of this study was to analyse epidemiological data, characteristics and severity of traumatic brain injury (TBI) related to E-Scooter accidents. *Materials and Methods:* This retrospective case series evaluated 28 patients who were admitted to three largest neurosurgery clinics in Riga, Latvia between time period from April to October in two separate years – 2022 and 2023 after an E-Scooter related accident. Data were collected on patient demographics, time of the accident, alcohol consumption, helmet use, type of TBI, other related injuries, treatment and assessment at discharge. *Results:* A total of 28 patients were admitted with TBI related to E-Scooter use, with median age 30 years (Q1-Q3, 20.25-37.25), four individuals under age of 18, majority (64%) were male. In 23 cases the injury mechanism was fall, in 5 cases collision. None were wearing a helmet at time of injury. Alcohol intoxication was evident in over half of the patients (51.5%), with severe intoxication (>1.2ppm) in 75% cases among them. Neurological symptoms upon admission were noted in 50% of cases. All patients had intracranial trauma - 50% brain contusions, 43% traumatic subdural hematoma, almost 30% - epidural hematoma. Craniofacial fractures were evident in 71% of cases, fractures in other parts of body in 3 patients. 6 patients required emergency neurosurgical intervention. Neurological complications were noted in 2 patients, 1 patient died. *Conclusions:* E-Scooter related accidents result in a significant number of brain and other associated injuries, with notable frequency linked to alcohol influence and lack of helmet use. Prevention campaigns to raise awareness of potential risks and implementation of more strict regulations should be done.

Keywords: electric scooter; e-scooter; traffic accident; craniofacial trauma; traumatic brain injury; neurosurgery

1. Introduction

The electric scooter, or e-scooter, has gained popularity as a preferred method of short-distance transportation, whether for public or private use. Its usage has seen a significant uptick in recent years since its initial establishment in Santa Monica, California, in 2017. Introduced into our social lives under the concept of micro-mobility, the utilization of these vehicles has seen a notable increase during the Covid-19 pandemic [1]. Correspondingly, reports of e-scooter accidents have surged, sparking public debate and concern.

The frequency and severity of accidents associated with electric scooters have become a notable topic with some medical professionals arguing that the rising usage has led to an escalation in both the occurrence and seriousness of these incidents [1]. Various studies conducted in countries such as Sweden [2], the United States [3,4,5], Germany [6], Austria [7], New Zealand [8] and Turkey [9] have shed light on the impact of e-scooter-related trauma.

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Factors such as high speed, low fall height and short reaction time, coupled with the absence of adequate personal protective equipment, contribute to the heightened vulnerability of e-scooter users, particulary in terms of upper extremity and head injuries. Operating an electric scooter under the influence of alcohol is prohibited in numerous countries, yet there is limited research examining the correlation between alcohol consumption and electric scooter accidents. However, a recent study conducted in New Zealand revealed that up to 27% of accidents were linked to alcohol use [10].

The primary aim of this study was to analyse epidemiological data, characteristics and severity of traumatic brain injury (TBI) in patients hospitalized to three neurosurgery clinics in Latvia – Riga East Clinical University Hospital (RECUH), Pauls Stradiņš Clinical University Hospital (PSCUH) and Children's Clinical University Hospital (CCUH).

2. Materials and Methods

This three center retrospective case series study was based on demographic and health related data of all patients who were admitted to Departments of Neurosurgery in three university hospitals – PSCUH, CCUH, EACUH after an e-scooter related accident with recorded intracranial trauma during two selected time periods from 1 April 2022. to 31 October 2022. and 1 April 2023. to 31. October 2023. We chose these exact time periods as those were the months when it was possible to use publicly available e-scooters in Riga, Latvia, since during the winter months they are usually removed from streets. In PSCUH and RECUH patients 18 years and older are treated, in CCUH patients under the age of 18 are treated. Patients with injuries related to non-electrical scooters, and patients without noted traumatic brain injury according to ICD-10 were excluded. The patient records of the PSCUH, RECUH, CCUH were searched using the ICD-10 codes for TBI S06 and related subcategories, cause of accident was identified in individual patient records. Total of 31 patients with TBI related to e-scooter use were admitted to Departments of Neurosurgery in PSCUH, RECUH and CCUH, 3 patients were excluded, 1 patient did not have TBI, 2 patients records were incomplete.

All data were extracted from the physcial medical records and files stored in the clinical database system ''Ārsta birojs'' in PSCUH, RECUH and ''Andromeda''and ''Saule''in CCUH. Relevant information included age, sex, year, month, day and time of trauma, mechanism of trauma, Glasgow coma scale (GCS) score upon admission, neurological symptoms upon admission (cranial nerve deficits, motor and sensory aphasia, paresis, sensory deficits, seizures, amnesia, vertigo, other noted symptoms), alcohol intoxication (ppm), whether patient experienced loss of consciousness, amnesia, helmet status at time of trauma, seizures after trauma and during hospitalization, TBI based on ICD-10 system (concussion, diffuse traumatic brain injury, brain contusion, epidural hemorrhage, traumatic subdural hemorrhage, traumatic subarachnoid hemorrhage), craniofacial fractures (further subclassified - cranial, vault and maxillofacial fractures), other fractures (further subclassified – upper extremity, vertebral, rib and lower extremity), vertebral fracture level was noted – cervical, thoracic, lumbar and coccygeal, neurosurgical treatment received and type of neurosurgical treatment received (further subclassified – ICP monitoring, ventriculostomy, craniotomy, decompressive craniectomy, other), also decompressive craniectomy was subclassified in to – primary and secondary, information on whether patient was stationed in intensive care unit, received sedation, was intubated, length of hospital stay (days), general complications were noted (subclassified in to – wound dehiscence, wound infection, CNS infection, pneumonia, deep vein thrombosis, c. difficile infection, gastrointestinal bleeding, pressure ulcer, acute respiratory distress syndrome, sepsis, other), GCS score at discharge, neurological complications upon discharge (subclassified – cranial nerve deficits, aphasia, paresis, sensory deficits, seizures, hydrocephalus, other), disposition (home, rehabilitation center, death, lower level hospital), cause of death (related to TBI, not related to TBI).

Descriptive statistics were utilized to determine the frequencies and percentages for dichotomous variables, the mean and median values, standard deviation, and ranges of numerical variables. The distribution of continuous variables was described as the mean and standard deviation for normally distributed variables. Median and interquartile range was used to report normally distributed variables. The distribution of categorical data was reported as numbers and percentages. Data analysis was performed using the SPSS 29.0.

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3. Results

A total of 28 patients were hospitalized due to traumatic brain injury resulting from e-scooter accidents. In the specified period from april to october in two years, 17 patients were admitted in 2022 and 11 patients were admitted in 2023. The median age of patients was 30 years (Q1-Q3, 20.25-37.25) with four individuals being under the age of 18. The gender distribution showed that less than half of the patients were female (35.7%, n=10), while the majority were male (64.3%, n=18).

Between april and october the peak in hospitalizations occurred in august, constituting the highest proportion at 21.4% (n=6), while the remaining months averaged a hospitalization rate of 13.1% for patients. When comparing days of the week, it was observed that only a quarter of patients (n=7) were hospitalized from monday to thursday, while 75% were admitted from friday to sunday. Specifically, 25% (n=7) of patients were hospitalized on friday, 18% (n=5) on saturday and sunday recorded the highest number of admissions with 32% (n=9). The distribution of hospitalizations remained consistent between day hours (from 7.00 am to 6.59 pm) and night hours (from 7 pm to 6.59 am) with an equal count of 14 patients in each time period.

In 23 cases the injury mechanism was a fall while 5 cases were the result of collisions with vehicles (specifically cars in all instances). None of the patients admitted to the hospital were wearing a head helmet at the time of the injury. Loss of consciousness at the time of injury was observed in 11 patients (39.3%).

Alcohol intoxication was identified in over half of the patients (n=16, 51.1%). Notably, alcohol intoxication was exclusively present in patients aged 18 and above, with no instances observed in the pediatric population. Among the cases with alcohol intoxication mild levels (<0.5 ppm) were found in 3 patients, moderate levels (0.5-1.2 ppm) in 1 patient and severe levels (>1.2 ppm) in 12 patients, constituting 75% of all patients who were directly under the influence of alcohol. Overall, 66.7% of all adult patients were diagnosed with alcohol intoxication.

Table 1. Patients and traffic accidents characteristics.

	n (%)
Age in years (mean)	30
Under 18 years of age	4 (14.3%)
Over 18 years of age	24 (85.7%)
Sex	
Male	18 (64.3%)
Female	10 (35.7%)
Mechanism of injury	
Fall	23 (82.2%)
Collision with car	5 (17.8%)
Time of injury	
Daytime (7.00 am to 6.59 pm)	14 (50.0%)
Nightime (7.00 pm to 6.59 am)	14 (50.0%)
Helmet use	
No helmet	28 (100.0%)
Wearing a helmet	0 (0.0%)
Alcohol intoxication	
No intoxication	12 (42.9%)
<0.5 ppm	3 (10.7%)
0,5-1,2 ppm	1 (3.6%)
>1.2 ppm	12 (42.9%)

When evaluating patients at the Emergency Department of the hospital, neurological symptoms were observed in 50% of cases. According to the Glasgow Coma Scale (GCS), 27 patients had mild head injuries with GCS scores ranging from 13 to 15 and among them 19 patients achieved the maximum GCS score of 15 points. Only one patient had severe head injury with a GCS score of 3.

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Amnesia was the most frequently observed neurological symptom during the pre-hospital or hospital stages, affecting 9 out of 14 patients (32.1%). Other neurological symptoms included vertigo in 5 patients, cranial nerve palsies in 4 patients, seizures during the prehospital or hospital stage in 3 patients, motor aphasia in 2 patients, sensory aphasia in 1 patient, paresis in 1 patient, and nystagmus in 1 patient. No patients exhibited sensory deficits.

Table 2. Neurological symptoms at the Emergency Department and other symptoms.

	n (%)
GCS for traumatic brain injury	
Mild (13-15)	27 (96.4%)
Moderate (9-12)	0 (0.0%)
Severe (3-8)	1 (3.6%)
Neurological symptoms	14 (50.0%)
Cranial nerve palsies	4 (14.3%)
Motor aphasia	2 (7.14%)
Sensor aphasia	1 (3.6%)
Paresis	1 (3.6%)
Sensor deficits	0 (0.0%)
Seizure (pre-hospital or hospital stage)	3 (10.7%)
Amnesia (pre-hospital or hospital stage)	9 (32.1%)
Vertigo	5 (17.9%)
Nystagmus	1 (3.6%)
Other symptoms	
Loss of consciousness at the moment of injury	11 (39.3%)

All patients included in the study had traumatic brain injury: 50% had brain contusion, 42.9% had traumatic subdural hematoma, 28.6% had epidural hematoma, 17.8% had traumatic subarachnoid hematoma and 17.8% had concussion. Craniofacial fractures were found in 20 patients (71%), who had combined fractures in different regions of the skull - 50% had cranial vault fractures, 46.4% had skull base fractures and 46.4% had facial bone fractures.

Fractures impacting other body regions were observed in 3 patients, involving upper extremity fractures (7.1%), rib fractures (7.1%) and vertebral fractures (7.1%). No lower extremity fractures were detected in any patient. Vertebral fractures of the spine were identified in two patients (7.1%), with one experiencing a cervical spine fracture and the other having a lumbar spine fracture. Additionally, soft tissue lesions like skin abrasions were prevalent in the majority of patients (n=18, 64.3%).

Table 3. E-scooter-related injuries.

	n (%)
Traumatic brain injury (patients)	28 (100.0%)
Concussion	5 (17.8%)
Contusion	14 (50.0%)
Epidural hematoma	8 (28.6%)
Traumatic subdural hematoma	12 (42.9%)
Traumatic subarachnoidal hematoma	5 (17.8%)
Craniofacial factures (patients)	20 (71.0%)
Cranial vault	14 (50.0%)
Base of the skull	13 (46.4%)
Facial bones	13 (46.4%)
Fractures (non-head) (patients)	3 (10.7%)
Upper extremities	2 (7.1%)
Lower extremities	0 (0.0%)
Ribs	2 (7.1%)

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Vertebrae of the spine	2 (7.1%)
Vertebral fractures (patients)	2 (7.1%)
Cervical	1 (3.6%)
Thoracic	0 (0.0%)
Lumbar	1 (3.6%)
Sacral	0 (0.0%)
Soft tissue injuries (abrasions, skin lesions) (patients)	18 (64.3%)

Over one-fifth of patients (n=6, 21.4%) required specific neurosurgical intervention –craniotomy was performed to evacuate the hematoma but one of these patients also underwent a secondary decompressive craniectomy. Among them two patients were admitted to the Intensive Care Unit and received sedation, while the patient undergoing decompressive craniectomy being the only one requiring intubation outside of the operative setting.

The hospitalization duration ranged from a minimum of 2 days to a maximum of 45 days, with a median length of stay at 5.5 days. Among the discharged patients (n=27) for further treatment, 25 patients had a GCS score of 15 points and 2 patients had a GCS score of 14 points. A comparison of GCS scores at admission and discharge revealed that 6 patients initially scored below 15 points but achieved the maximum GCS score of 15 points upon discharge. Additionally, one patient consistently scored 14 points at both admission and discharge and one patient demonstrated improvement from a GCS score of 13 at admission to 14 at the time of discharge.

Neurological complications were noted in 2 patients, both during their inpatient stay and at the time of discharge. One patient experienced cranial nerve palsies and both patients exhibited motor aphasia. Notably, these were the only individuals with a GCS score of 14 at the time of discharge.

Following the outcome, 26 patients were released to their homes, 1 patient was moved to a lower-level hospital for additional care and 1 patient passed away.

Table 4. Data of patients.

n	Sex	Age	Time of the day	Month	Mechanism of injury	Alcohol	Alcohol level in blood (ppm)	Outcome treatment
1	m	30	n	august	fall	yes	>1.2	conservative
2	m	48	n	july	fall	no	-	conservative
3	m	38	n	october	fall	yes	>1.2	conservative
4	m	48	d	july	fall	yes	>1.2	conservative
5	m	35	n	august	fall	yes	>1.2	conservative
6	f	28	d	october	fall	no	-	conservative
7	m	41	n	october	fall	yes	>1.2	conservative
8	f	29	n	september	fall	yes	>1.2	conservative
9	f	29	d	august	fall	no	-	conservative
10	m	51	n	april	fall	yes	>1.2	conservative
11	f	19	n	july	fall	yes	>1.2	conservative
12	f	15	d	april	collision	no	-	conservative
13	f	15	d	october	fall	no	-	craniotomy
14	f	13	d	september	collision	no	-	conservative
15	m	12	n	august	fall	no	-	craniotomy
16	m	35	n	september	fall	yes	>1.2	conservative

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17	f	35	d	june	fall	no	-	conservative
18	m	31	n	april	fall	yes	>1.2	craniotomy
19	m	30	n	may	fall	yes	>1.2	1) craniotomy, 2) decompressive craniectomy. Fatal outcome
20	m	64	n	august	fall	yes	<0.5	craniotomy
21	m	38	d	september	collision	no	-	conservative
22	m	35	d	august	fall	yes	<0.5	conservative
23	m	31	d	may	fall	no	-	conservative
24	m	30	d	may	fall	yes	0.5-1.2	craniotomy
25	f	21	n	april	fall	yes	>1.2	conservative
26	m	18	n	june	collision	no	-	conservative
27	m	20	d	may	fall	yes	<0.5	conservative
28	f	24	n	june	collision	no	-	conservative

Abbreviations: m – male, f – female, d – daytime (7.00 am to 6.59 pm), n – nightime (7.00 pm to 6.59 am).

4. Discussion

The rising popularity of e-scooters is accompanied by a growing number of e-scooter-related injuries. This study represents the first examination of e-scooter accidents in Latvia. Our objective was to analyze epidemiological data, as well as the characteristics and severity of traumatic brain injuries in patients admitted to three neurosurgery clinics in Latvia. Additionally, we compared these findings with existing data from other countries.

In numerous studies, it is consistently highlighted that injuries related to e-scooter usage predominantly affect men [2,3,4,6,7,9,11,12,13,14]. Our findings align with this trend, revealing that 64.3% of hospitalized patients were men, whereas only 35.7% were women. This pattern is also reflected in cases where patients were under the influence of alcohol at the time of injury – 13 of the patients were men, and only 3 were women. This suggests a higher likelihood of men using e-scooters while intoxicated, potentially contributing to the notable male predominance observed. It's worth noting that Blomberg et al. (2019) stand out, reporting in their study that 57.1% of all e-scooter-related injury patients were female. Similar findings were reported by Büyükceran et al. (2023), where their study revealed that 50.5% of patients were female, while 49.5% were male.

Taking into account the time of day, other studies by various authors note an increased occurrence of e-scooter accidents during evening and nighttime hours, contrary to our findings [7,12,15]. Moftakhar et al. (2021) observed that 58.3% of all e-scooter-related admissions took place between 8:00 pm and 7:59 am. Trivedi et al. (2019) reported that 75% of accidents happened between 3 pm and 7 am. These findings do not align with the outcomes of our study, where half of the patients were hospitalized during the day (7:00 am to 6:59 pm) and the other half during the night (7:00 pm to 6:59 am).

In this study, there were only 4 pediatric patients (under 18 years of age) with a mean age of 13.8 years (range 12-15 years). Several studies have specifically delved into the pediatric population concerning e-scooter injuries [13,14,16]. For instance, Cohen et al. (2022) noted that children exhibit a higher incidence of fractures and polytrauma related to e-scooters when compared to adults, although they experience fewer facial injuries despite a similar rate of head trauma. In another study, Morgan et al. (2022) reported findings on 10 patients, among whom 5 necessitated orthopedic surgery. However, Büyükceran et al. (2023) incorporated 49.4% of patients below 18 years and 50.6% of patients aged 18 and above in their research. Their findings indicated that pediatric patients were

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more prone to upper extremity injuries, whereas adults were more predisposed to lower extremity injuries.

It is crucial to highlight the importance of employing protective gear while riding e-scooters. Numerous studies attest to the limited use of helmets in the context of e-scooter usage [2,4,5,6,9,11,12,13,14,15,17,18]. This observation is consistent with the data obtained in our study, where none of the participants, including pediatric patients, were wearing helmets at the time of injury. In our study, a direct comparison of outcomes between patients wearing and not wearing helmets was not possible. However, there are studies that have assessed the effectiveness of helmets through simulations with human body models. The results of these studies suggest that protective helmets can mitigate the force of impact during injuries, thus reducing the risk of head injuries [19,20,21]. It is worth noting that as of January 1, 2024, amendments to the Road Traffic Regulations of the Republic of Latvia mandate that all e-scooter drivers under the age of 17 must wear a protective helmet. However, for individuals beyond this age, the use of a protective helmet is only recommended.

Our study has certain limitations worth noting. We exclusively considered patients admitted to the neurosurgery department, overlooking the inclusion of individuals who received outpatient treatment for e-scooter-related head injuries. The inclusion of outpatients would allow for comparisons across different severities of head injuries and an exploration of the correlation with helmet usage. Furthermore, a prospective study with an extended data collection period could encompass a larger patient population for a more comprehensive analysis.

5. Conclusions

Electric scooters have become a prevalent means of transportation in many urban areas. Accidents involving e-scooters lead to a substantial number of brain and other associated injuries, with notable frequency linked to alcohol influence and lack of helmet use. It is imperative to conduct prevention campaigns to enhance awareness of potential risks and advocate for the implementation of stricter regulations.

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Informed Consent Statement: Patient consent was waived because no personal information, images, or any identifying patient data were included.

Data Availability Statement: Data are available upon request due to ethical restrictions. All the data included in this study are available upon request from the corresponding author. The data are not publicly available and are stored in the patient medical record repository at Pauls Stradins Clinical University Hospital, Childrens's Clinical University Hospital, Riga East Clinical University Hospital according to where the individual patient was treated.

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