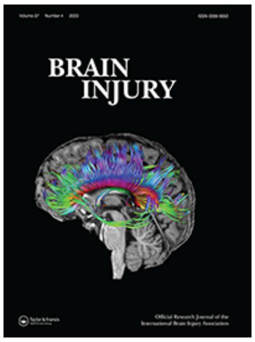

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Evaluating the influence of alcohol intoxication on the pre-hospital identification of severe head injury: a multi-center, cohort study

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ABSTRACT

Objective: To determine the influence of intoxication on the pre-hospital recognition of severely head-injured patients by Emergency Medical Services (EMS) professionals and to investigate the relationship between suspected alcohol intoxication and severe head injury.

Methods: This multi-center, retrospective, cohort study included trauma patients, aged ≥ 16 years, transported by an ambulance of the Regional Ambulance Facility Utrecht to any emergency department in the participating trauma regions.

Results: Between January 1, 2015 and December 31, 2017, 19,206 patients were included, of whom 1167 (6.0%) were suspected to have a severe head injury in the field, and 623 (3.2%) were diagnosed with such an injury at the hospital. These injuries were less frequently recognized in patients with a GCS ≥ 13 than in patients with a GCS < 13 (25.0% vs. 76.2%). Patients suspected to be intoxicated had a higher chance to suffer from severe head injury (OR 1.42, 95%-CI 1.22–1.65) and were recognized slightly more often (45.3% vs. 40.2%).

Conclusion: Severe head injuries are difficult to recognize in the field, especially in patients without a decreased GCS. Suspicion of alcohol intoxication did not seem to influence pre-hospital injury recognition, as it possibly makes a severe head injury harder to recognize and simultaneously raises caution for a severe injury.

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Background

Traumatic brain injury is a global health problem and a leading cause of mortality and morbidity (1,2). Mortality and morbidity rates of patients with severe head injuries can be decreased by specialized neurocritical care which is only available at higher-level trauma centers (3,4).

Alcohol intoxication is present in 10–18% of the trauma patients (5,6), especially in patients with head injuries (24–51%) (7). Intoxication can influence the neurological assessment by altering verbal and motor responses (which are used in clinical instruments to assess injury severity) and by mimicking signs of severe head injury (e.g., decreasing level of conscious and vomiting) (8,9). Recognizing patients with a severe head injury in the field can therefore be more challenging in intoxicated patients.

A previous study investigated the diagnostic accuracy of Emergency Medical Service (EMS) professionals' identification of patients with a head injury (10), but did not distinguish between the pre-hospital suspicion of a minor or severe head injury. Also, the influence of intoxication on the EMS professionals' on-scene decision-making was not investigated in this study. Additionally, only a limited number of studies investigated the relationship between alcohol intoxication and severe head injury, which yielded contradicting results (11,12). Therefore, it remains an open question whether alcohol intoxication is a risk factor for severe head injury. The complexity of pre-hospital triage in intoxicated patients makes these patients susceptible to undertriage and therefore undertreatment. This study aims to determine the influence of alcohol intoxication on the EMS professionals' pre-hospital assessment of patients with a severe head injury and investigates the relationship between suspected alcohol intoxication and severe head injury, in order to improve pre-hospital triage of future trauma patients with a severe head injury.

Methods

The Strengthening the Reporting of Observational Studies in Epidemiology guidelines were used for reporting in this study (13). The Medical Ethical Committee of the University Medical Center Utrecht judged this study as not subject to the Medical Research Involving Human Subjects Act (reference number 20/500747).

Study setting

In this multi-center, cohort study, one ambulance facility (i.e., Regional Ambulance Facility Utrecht [RAVU]) and

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five trauma regions participated. Ambulances of the RAVU serve the Central Netherlands Region, which has 1.34 million residents and covers 1560 km^2 (14). Patients are transported to hospitals in this region and, in some instances, to hospitals in surrounding regions. The ground ambulances of the RAVU are staffed by an EMS professional (i.e., specialized nurse able to provide advanced trauma life support) and an ambulance-driver. The Helicopter Emergency Medical Service is staffed by a specialized physician (i.e., trauma surgeon or anesthesiologist). However, due to the small distances in the Netherlands, only very few patients are transported by helicopter. All Dutch hospitals with a trauma-receiving emergency department are classified as higher-level (Level-I) or lower-level (Level-II or Level-III) trauma centers. Solely higher-level trauma centers are designated to treat severely injured patients, and lower-level trauma centers are designated to treat mildly and moderately injured patients (15). The five participating trauma regions comprise five higher-level trauma centers and 36 lower-level trauma centers. The field triage criteria of the Dutch National Protocol of Ambulance Services (NPAS) are used to guide pre-hospital patient allocation (Figure 1).

Patients

All trauma patients aged 16 years and older, who were transported by a ground ambulance of the RAVU to any trauma-receiving emergency department in the participating trauma regions, were considered eligible for inclusion. Patients transported to a hospital in a nonparticipating (i.e., non-adjacent) trauma region were excluded.

Data collection

A previously developed selection tool with an accuracy of 98.9% (95%-CI, 98.3–99.2) (16), was used to identify trauma patients in the pre-hospital records of the RAVU. Pre-hospital records, written by the EMS professionals, were prospectively collected and contained, amongst others, patient demographics, transportation details (e.g., destination), vital parameters, and a free text in which the suspicion of an alcohol intoxication, the suspected injuries, and the cause of injury were described. Members of the research group retrospectively evaluated whether the EMS professional suspected a severe head injury and intoxication by systematically analyzing the full pre-hospital records without knowledge of the patient's outcomes. Suspicion of a severe head injury was defined as the suspicion by the EMS professional of any injury corresponding with a score ≥ 3 in the head region of the Abbreviated Injury Scale (AIS) (e.g., intra-cranial hemorrhage, skull-base fracture, or penetrating head injury). The AIS coding system classifies injuries by body region (i.e., head, face, neck, thorax, abdomen, spine, upper extremity, lower extremity, and unspecified) and severity (i.e., minor [AIS 1] up to maximum injury [AIS 6]) (17). Suspicion of alcohol intoxication was considered present if EMS professionals described that they suspected alcohol intoxication, which they based on clinical findings, such as alcohol fetor or patient behavior and/or by asking patients whether they consumed alcohol. No additional diagnostic measurements, such as a breath analyzer or blood alcohol test, were used in the field. As assessing alcohol intoxication is part of the routine pre-hospital assessment, no suspicion of an intoxication was assumed in case intoxication was not documented by the EMS professional.

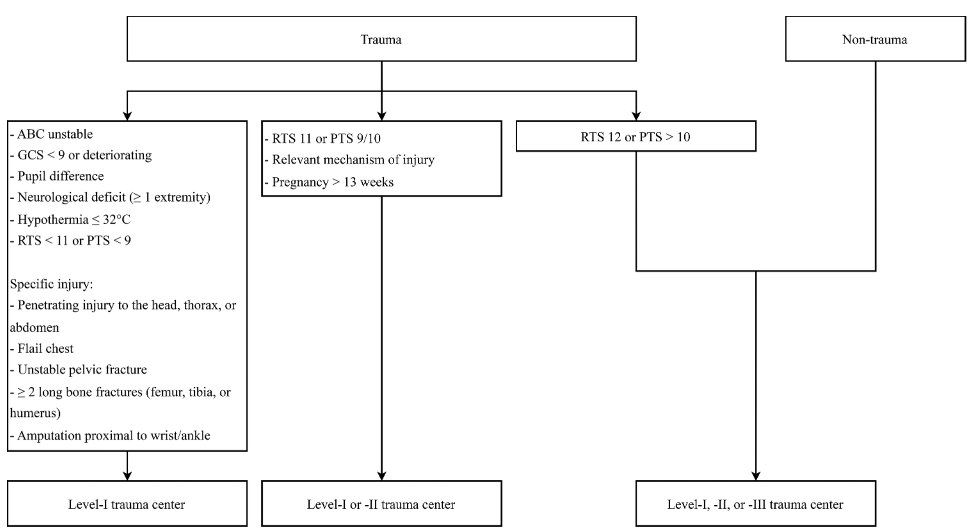

Figure 1. Field triage criteria of the Dutch National Protocol of Ambulance Services (NPAS).In areas with long expected transport times, it may, in case of severe hemodynamic instability, be preferred to first transport the patient to the nearest hospital that is able to provide an adequate trauma response, if rendez-vous (i.e., meeting during transport) with a specialized physician is not possible.
Abbreviations: GCS, Glasgow Coma Scale; RTS, Revised Trauma Score; PTS, Pediatric Trauma Score.

The regional Dutch trauma registries register data on injuries and outcomes of all admitted trauma patients in their region (18). Qualified data-managers of the registries collected all injuries diagnosed at the emergency department or clinical ward within the first 30 days post-trauma and designated the AIS codes (17). Severe head injury was, in line with previous research (10), defined as an injury in the head region of the Abbreviated Injury Scale (AIS) with a score ≥ 3. Trauma patients who were not admitted and thus not registered by the regional trauma registries were assumed not to have a severe injury. This assumption was validated with data from a previous study (19). The pre-hospital and in-hospital data were combined using a previously designed linkage tool with an externally validated accuracy of 100.0% (95%-CI, 100.0–100.0) (16).

Outcomes

The primary objective was to determine the influence of suspicion of alcohol intoxication on the diagnostic accuracy of EMS professionals' assessment of a severe head injury. Subgroup analyses of patients with a GCS score < 13 and GCS score ≥ 13 in intoxicated and in non-intoxicated patients were performed. A recognized injury was defined as an in-hospital diagnosed severe head injury that was suspected at the scene of injury by the EMS professional. An unrecognized injury was defined as an in-hospital diagnosed severe head injury that was not suspected at the scene of injury.

The secondary objective was to determine the relationship between suspicion of alcohol intoxication and severe head injury, quantified in an odds ratio (OR) with a 95%-confidence interval (CI).

Missing data

Missing data were analyzed and appeared to be missing at random. Multi-level, multiple imputation was used to impute the missing values of the GCS (13.6%). Amongst others, patients' characteristics, vital signs, and outcomes were used to create 48 imputed datasets, based on 20 iterations per set, using the R-package micemd (12 datasets per processor core) (16). If applicable, analyses were performed in each imputed dataset and pooled following the Rubin's rules (20). Confidence intervals were calculated using the Agresti-Coull method (21).

Statistical analysis

We used the $\chi 2$ or Mann-Whitney *U* test to compare groups unless specified otherwise and considered p-values <0.05 as statistically significant. The diagnostic accuracy of the EMS professionals' assessment of a severe head injury was presented in sensitivity, specificity, positive predictive value, negative predictive value, and percentages of recognized and unrecognized severe head injuries.

To determine the relationship between alcohol intoxication and severe head injury, the covariates age, gender, anticoagulation use, violence, fall, fall ≥ 2 meters, high-energy motor vehicle collision, and high-energy pedestrian or cyclist versus motor vehicle, were balanced with Entropy balancing (22–26). Entropy balancing is a weighting method seen as a generalization of propensity score weighting with an additional reweighting scheme that reweights covariates until appropriate balance is obtained, resulting in standardized mean differences approximating zero (23,25). We used restricted cubic splines for the covariate age and observed the covariates' balancing quality using the cobalt software package (27). If the standardized mean difference was < 0.1, the covariates were presumed thoroughly balanced (**Table A1**) (28). A generalized linear model (GLM) was fit with the inverse probability weights (IPW) of the balanced covariates. To evaluate the robustness of our results, an additional GLM-fit with the confounders was used for the studied relationships as these generally had 10 or more events per confounder (29,30). The results were presented in unadjusted and adjusted odds ratios with CI. All statistical analyses were conducted using R statistical software (R version 3.6.1) (31).

Results

A total of 21,129 trauma patients were transported to an emergency department by EMS professionals of the RAVU between January 1, 2015 and December 31, 2017. Of these patients, 19,206 (90.9%) were 16 years and older and transported to a participating hospital. The patient inclusion is summarized in Figure 2.

Patient characteristics

Table 1 displays the baseline characteristics of the included patients. Approximately 1 out of 10 (1944 [10.1%]) included patients were suspected to be under the influence of alcohol. These patients were younger than the non-intoxicated patients (median age of 47.1 years vs. 63.5 years; $p < 0.001$), were predominantly male (1387 [71.3%] vs. 7760 [45.0%]; $p < 0.001$) and were more likely to have a Revised Trauma Score (RTS) < 12 (194 [10.0%] vs. 844 [4.9%]; $p < 0.001$). Intoxicated patients were more often diagnosed with a severe head injury in the hospital (95 [4.9%] vs. 528 [3.1%]; $p < 0.001$), were more often suspected to have a severe head injury in the field (181 [9.3%] vs. 995 [5.8%]; $p < 0.001$) and were more likely to have a GCS score < 13 (185 [9.5%] vs. 547 [3.2%]; $p < 0.001$). Intoxicated patients were more often transported to a higher-level trauma center (429 [22.1%] vs. 2985 [17.3%]; $p < 0.001$), were more often admitted to the Intensive Care Unit (ICU) (86 [4.4%] vs. 429 [2.5%]; $p < 0.001$), and had a lower 30-day mortality (7 [0.4%] vs. 315 [1.8%]; $p < 0.001$).

Diagnostic accuracy

Table 2 shows outcomes regarding the head-injury assessments by EMS professionals in patients in whom alcohol intoxication was suspected or not suspected. The sensitivity and specificity of the pre-hospital assessment of severe head injury were 45.3% (95%-CI, 35.0–55.8) and 92.5% (91.2–93.7) in intoxicated patients, and 40.2% (35.9–44.5) and 95.3% (95.0–95.6) in non-intoxicated patients, respectively. The assessment of a severe head injury was more difficult in patients with a GCS ≥ 13 for both intoxicated (sensitivity: 27.9% [95%-CI, 17.2% –

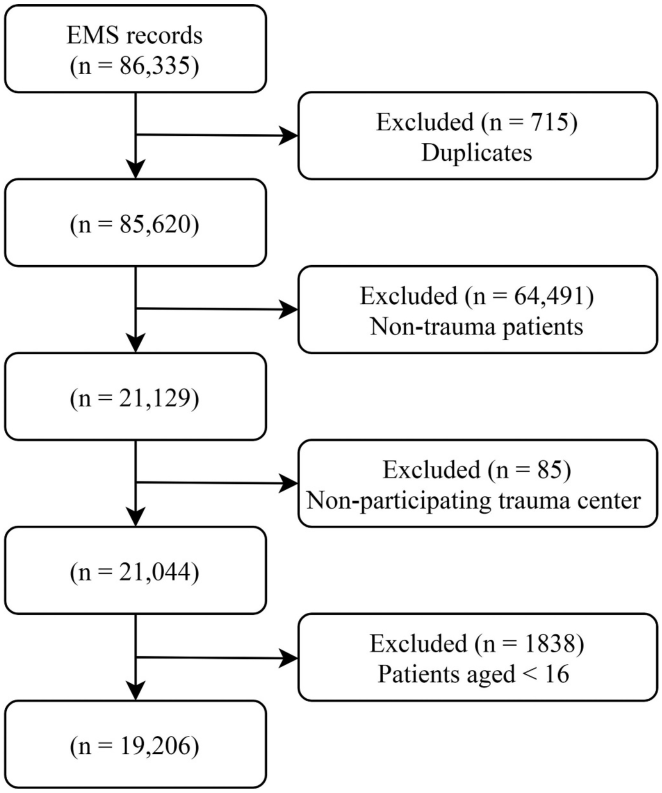

Figure 2. Patient flow.
Abbreviation: EMS, Emergency Medical Services

40.8%]; specificity: 94.5% [93.3–95.5]) and non-intoxicated patients (sensitivity: 23.3% [19.1–28.1]; specificity: 95.9% [95.6–96.2]). Table 3 displays that 137 (37.2%) patients with an unrecognized severe head injury were transported to a higher-level trauma center versus 219 (85.9%) patients in which a severe head injury was recognized ($p < 0.001$). Intoxicated patients with a severe head injury were more often transported to a higher-level trauma center than non-intoxicated patients (60 [63.2%] vs. 296 [56.1%]; $p < 0.001$)).

Relationship between suspected intoxication and severe head injury

Table 4 displays the relationship between suspected intoxication and severe head injury. Intoxication was significantly associated with severe head injury (unadjusted odds ratio of 1.63 [95%-CI, 1.30–2.04]). A comparable relationship was found after adjustment for confounding in the GLM with IPW (OR: 1.42; 95%-CI, 1.22–1.65) and in the regular GLM (OR: 1.66; 95%-CI, 1.31–2.10). A similar relationship was found (in GLMs with IPW) in sensitivity analyses of patients who sustained their injuries in traffic (OR: 1.46; 95%-CI, 1.16–1.83) or due to a fall (OR: 1.51; 95%-CI, 1.22–1.87).

Discussion

This multi-center, retrospective, cohort study was, to our knowledge, the first study that investigated the influence of suspicion of alcohol intoxication on the diagnostic accuracy of EMS professionals' assessment of a severe head injury and evaluated the relationship between alcohol intoxication and severe head injury. We found that assessing a severe head injury is challenging in both intoxicated and non-intoxicated patients (sensitivity: 45% vs. 40%, specificity: 92% vs. 95%), and seemed to be even more challenging in patients with a GCS ≥ 13 (sensitivity: 28% vs. 23%, specificity: 95% vs. 96%). Patients with a recognized severe head injury were more often transported to a higher-level trauma center than patients with an unrecognized severe head injury (219 [86%] vs. 137 [37%]). Additionally, we found that patients suspected of an intoxication had a significantly higher chance to have a severe head injury than non-intoxicated patients (adjusted OR of 1.42 [95%-CI, 1.22–1.65]); the same relationship was found in subgroups of patients who sustained their injuries in traffic or due to a fall.

Pre-hospital recognition of severe head injuries has been previously investigated in a study of our research group, which found that 79% of the patients with a severe head injury were suspected of having a head injury (10). However, this study did not distinguish between the pre-hospital suspicion of a minor head injury and the pre-hospital suspicion of more severe head injuries. Epstein et al. found that alcohol intoxication was associated with a higher rate of misdiagnosis of clinically significant traumatic brain injury (TBI) among patients intubated in the field due to suspected TBI (32). In the current study, we found that the recognition of a severe head injury was limited in both intoxicated and non-intoxicated patients and that the unrecognized patients were often transported to lower-level trauma centers. However, it seemed that patients suspected to be intoxicated were slightly more often recognized to have a severe head injury and were more often transported to a higher-level trauma center, probably due to EMS professionals being more cautious for severe injuries in intoxicated patients. Nevertheless, patients suspected to be intoxicated had a significantly lower 30-day mortality rate, probably as they were relatively young. Previous studies found that intoxication can lower the GCS score in head-injured patients (8,33,34), making it challenging to discern whether the lowered GCS score was caused by intoxication or intracranial injuries. However, these studies state that the found decrease of the GCS score in intoxicated patients (i.e., approximately one point) was not clinically significant (33,34). Therefore, attributing signs of severe head injury to intoxication can delay treatment urge and lead to inadequate transportation to a lower-level trauma-center. In patients with a severe head injury, this would result in unnecessary inter-hospital transfers and a further delay of specialized trauma-care (3,4).

Previous studies described the relationship between intoxication and head-injury severity (11,12), but no conclusions could be drawn for a general trauma population. Cunningham et al. found a positive relationship between alcohol intoxication and severe head injury in motor vehicle crash victims, adjusted for crash severity, and stated that their results were probably not statistically significant due to a small sample size (11). Talving et al. found no association between alcohol intoxication and head injury severity (comparing AIS 3 with AIS > 3), but did solely include patients with severe traumatic brain injuries (12). Both studies were not aimed at pre-hospital decision-making and therefore not able to investigate whether

Table 1. Baseline characteristics.

	All patients n = 19,206	Alcohol intoxication suspected n = 1944	No alcohol intoxication suspected n = 1944	p value
Demographics	**Median (IQR)**	**Median (IQR)**	**Median (IQR)**	
Age (years)	61.2 (37.1-79.7)	47.1 (28.4-62.4)	63.5 (38.8-81.1)	<0.001
	N (%)	**N (%)**	**N (%)**	
Age > 65 (years)	8733 (45.5)	404 (20.8)	8329 (48.3)	<0.001
Male gender	9147 (47.6)	1387 (71.3)	7760 (45.0)	<0.001
Anticoagulant use	1980 (10.3)	150 (7.7)	1830 (10.6)	<0.001
Type of trauma	**N (%)**	**N (%)**	**N (%)**	
Private	10,538 (54.9)	979 (50.4)	9559 (55.4)	<0.001
Traffic	6606 (34.4)	709 (36.5)	5897 (34.2)	0.045
Sport	833 (4.3)	5 (0.3)	828 (4.8)	<0.001*
Industrial	357 (1.9)	1 (0.1)	356 (2.1)	<0.001*
Violence	595 (3.1)	201 (10.3)	394 (2.3)	<0.001
Self-mutilation	262 (1.4)	46 (2.4)	216 (1.3)	<0.001
Unknown	15 (0.1)	3 (0.2)	12 (0.1)	0.189
Pre-hospital assessment	**N (%)**	**N (%)**	**N (%)**	
Systolic blood pressure < 90 mmHg	247 (1.3)	29 (1.5)	218 (1.3)	0.456
Respiratory rate > 29/min or < 10/min	315 (1.6)	24 (1.2)	291 (1.7)	0.164
Glasgow Coma Scale score < 13	732 (3.8)	185 (9.5)	547 (3.2)	<0.001
Revised Trauma Score < 12	1038 (5.4)	194 (10.0)	844 (4.9)	<0.001
Suspicion of severe head injury	1176 (6.1)	181 (9.3)	995 (5.8)	<0.001
Severe injuries (AIS score ≥ 3)	**N (%)**	**N (%)**	**N (%)**	
Head	623 (3.2)	95 (4.9)	528 (3.1)	<0.001
Face	10 (0.1)	1 (0.1)	9 (0.1)	1.000*
Neck	15 (0.1)	1 (0.1)	14 (0.1)	1.000*
Thorax	513 (2.7)	62 (3.2)	451 (2.6)	0.155
Abdomen	71 (0.4)	8 (0.4)	63 (0.4)	0.902
Spine	141 (0.7)	14 (0.7)	127 (0.7)	1.000
Upper extremity	111 (0.6)	11 (0.6)	100 (0.6)	1.000
Lower extremity	2473 (12.9)	76 (3.9)	2397 (13.9)	<0.001
Injury severity	**N (%)**	**N (%)**	**N (%)**	
Severely injured (ISS ≥ 16)	576 (3.0)	64 (3.3)	512 (3.0)	0.466
Clinical characteristics	**N (%)**	**N (%)**	**N (%)**	
Transport to a higher-level trauma center	3414 (17.8)	429 (22.1)	2985 (17.3)	<0.001
Hospital admission	6661 (34.7)	693 (35.6)	5968 (34.6)	0.358
ICU admission	515 (2.7)	86 (4.4)	429 (2.5)	<0.001
24-h mortality	60 (0.3)	3 (0.2)	57 (0.3)	0.280*
30-day mortality	322 (1.7)	7 (0.4)	315 (1.8)	<0.001

Systolic blood pressure missed in 12.2%, respiratory rate in 11.9%, and Glasgow Coma Scale in 13.6% of the patients.
Abbreviations: AIS, Abbreviated Injury Scale; ISS, Injury Severity Score; IQR, Interquartile range.
*Fisher's exact test

intoxication is a pre-hospital risk factor for a severe head injury.

This study has several strengths. First, all trauma patients transported by an ambulance of the RAVU to both higher-level and lower-level trauma-centers of the participating trauma regions were included, resulting in an appropriate ambulance transported trauma population. Second, a comparable relationship between intoxication and severe head injury was found in subgroups of patients who sustained their injuries in traffic or due to a fall, which supports the validity of the found relationship. Third, we used two different methods (i.e., a GLM with IPW and a GLM-fit with unbalanced confounders) to confirm the robustness of our results and used entropy balancing to weight the covariates. The reweighting scheme of entropy balancing reweights the covariates until balance is achieved, ensuring a high degree of covariate balancing. Therefore, the degree of balance is equal and frequently superior to conventional balancing methods, such as propensity score weighting (23,25).

This study also has some limitations. First, the actual prevalence of alcohol intoxication and therefore the accuracy of the pre-hospital suspicion of intoxication could not be determined as definitive alcohol levels were not available in the hospital data and retrieving this data manually was impossible due to the performed anonymization, which was needed to link the pre-hospital and hospital data. We used the EMS professionals' clinical assessment to assess whether a patient was suspected of alcohol intoxication as in the Netherlands EMS professionals do not have access to additional resources (e.g., blood-alcohol test). This approach was, in our opinion, appropriate for the studied objectives as assessing alcohol intoxication is part of the routine EMS professionals' assessment, but could, however, influence the generalizability of our results. Second, we did not assess the severity of the alcohol intoxications. Therefore, it is possible that a minor intoxication did not equally contribute to the studied diagnostic accuracy and relationship as a severe intoxication. As the alcohol consumption varies worldwide (35), differences in intoxication severity between countries are likely and could make our results less generalizable. In addition, most countries' trauma systems are derivatives from the American trauma system (36), but they differ per country. The pre-hospital setting in other countries could therefore differ from the setting we investigated. Third, missing data were analyzed and appeared to be missing at random, it is, however, possible that the missing data

Table 2. Diagnostic accuracy of severe head injury assessment.

	Alcohol intoxication suspected			No alcohol intoxication suspected		
	Severe head injury suspected	No severe head injury suspected	Total	Severe head injury suspected	No severe head injury suspected	Total
All patients	**n = 181**	**n = 1763**	**n = 1944**	**n = 995**	**n = 16,267**	**n = 17,262**
AIS score	N (%)	N (%)	N	N (%)	N (%)	N
0-2	138 (7.5)	1711 (92.5)	1849	783 (4.7)	15,951 (95.3)	16,734
≥ 3	43 (45.3)	52 (54.7)	95	212 (40.2)	316 (59.8)	528
	Value	95% CI		Value	95% CI	
Sensitivity	0.45	0.35-0.56		0.40	0.36-0.44	
Specificity	0.93	0.91-0.94		0.95	0.95-0.96	
Positive predictive value	0.24	0.18-0.31		0.21	0.19-0.24	
Negative predictive value	0.97	0.96-0.98		0.98	0.98-0.98	
Positive likelihood ratio	6.06	4.61-7.97		8.58	7.58-9.72	
Negative likelihood ratio	0.59	0.49-0.71		0.63	0.59-0.67	
GCS < 13	**n = 71**	**n = 125**	**n = 196**	**n = 243**	**n = 407**	**n = 650**
AIS score	N (%)	N (%)	N	N (%)	N (%)	N
0-2	45 (27.8)	117 (72.2)	162	115 (23.9)	367 (76.1)	482
≥ 3	26 (76.5)	8 (23.5)	34	128 (76.2)	40 (23.8)	168
	Value	95% CI		Value		
Sensitivity	0.76	0.59-0.89		0.76	0.69-0.82	
Specificity	0.72	0.65-0.79		0.76	0.72-0.80	
Positive predictive value	0.37	0.25-0.49		0.53	0.46-0.59	
Negative predictive value	0.94	0.88-0.97		0.90	0.87-0.93	
Positive likelihood ratio	2.75	2.02-3.76		3.19	2.67-3.83	
Negative likelihood ratio	0.33	0.18-0.60		0.31	0.24-0.41	
GCS ≥ 13	**n = 110**	**n = 1638**	**n = 1748**	**n = 752**	**n = 15,860**	**n = 16,612**
AIS score	N (%)	N (%)	N	N (%)	N (%)	N
0-2	93 (5.5)	1594 (94.5)	1687	668 (4.1)	15,584 (95.9)	16,252
≥ 3	17 (27.9)	44 (72.1)	61	84 (23.3)	276 (76.2)	360
	Value	95% CI		Value	95% CI	
Sensitivity	0.28	0.17-0.41		0.23	0.19-0.28	
Specificity	0.95	0.94-0.96		0.96	0.96-0.96	
Positive predictive value	0.15	0.09-0.24		0.11	0.09-0.14	
Negative predictive value	0.97	0.97-0.98		0.98	0.98-0.98	
Positive likelihood ratio	5.33	3.40-8.36		5.68	4.64-6.94	
Negative likelihood ratio	0.76	0.65-0.89		0.80	0.76-0.85	

The Glasgow Coma Scale was missing in 13.6% of the patients and was multiply imputed. Values derived from multiply imputed variables were rounded to zero decimals.
Abbreviations: AIS, Abbreviated Injury Scale; GCS, Glasgow Coma Scale.

from the patients with a missing GCS may be more or less severe than similar patients, possibly affecting our results. Finally, although we corrected the association between alcohol intoxication and a severe head injury for, based on clinical reasoning, all available confounders, the presence of unmeasured confounding can never be ruled out. Moreover, the GCS was not incorporated in the model because it is influenced by both intoxication and head injury severity and should be considered a collider. The addition of GCS to the model could introduce collider bias and distorts the association of interest (37,38).

Our results should raise awareness about the fact that severe head injuries are frequently not recognized at the scene of injury and that alcohol-intoxicated patients seem to have a higher chance to suffer from a severe head injury. This could aid EMS professionals in their clinical decision-making and help them identify severe head injuries at the scene of injury

Table 3. Triage in patients with a severe head injury (AIS score ≥ 3).

	Patients with a severe head injury n = 623	Patients with an **unrecognized** severe head injury n = 368	Patients with a **recognized** severe head injury n = 255	*p* value
All patients	**N (%)**	**N (%)**	**N (%)**	
Higher-level trauma center	356 (57.1)	137 (37.2)	219 (85.9)	<0.001
Lower-level trauma center	267 (42.9)	231 (62.8)	36 (14.1)	<0.001
Alcohol intoxication suspected	**N (%)**	**N (%)**	**N (%)**	
Higher-level trauma center	60 (63.2)	24 (46.2)	36 (83.7)	<0.001
Lower-level trauma center	35 (36.8)	28 (53.8)	7 (16.3)	<0.001
No alcohol intoxication suspected	**N (%)**	**N (%)**	**N (%)**	
Higher-level trauma center	296 (56.1)	113 (35.8)	183 (86.3)	<0.001
Lower-level trauma center	232 (43.9)	203 (64.2)	29 (13.7)	<0.001

Abbreviations: AIS, Abbreviated Injury Scale

Table 4. Unadjusted and adjusted odds ratios for severe head injury (AIS ≥ 3).

	Unadjusted	Adjusted, GLM and IPW	Adjusted, GLM
	Odds ratio (95% CI)	**Odds ratio (95% CI)**	**Odds ratio (95% CI)**
All patients[a]			
No Alcohol intoxication suspected	Reference	Reference	Reference
Alcohol intoxication suspected	1.63 (1.30-2.04)	1.42 (1.22-1.65)	1.66 (1.31-2.10)
Patients injured in traffic[b]			
No Alcohol intoxication suspected	Reference	Reference	Reference
Alcohol intoxication suspected	1.24 (0.87-1.78)	1.46 (1.16-1.83)	1.38 (0.98-2.06)[d]
Patients injured by a fall[c]			
No Alcohol intoxication suspected	Reference	Reference	Reference
Alcohol intoxication suspected	2.26 (1.68-3.04)	1.51 (1.22-1.87)	2.04 (1.48-2.81)

[a]Adjusted for: age, gender, anticoagulation use, violence, fall, fall ≥ 2 meter, high energy motor vehicle collision, high energy pedestrian or cyclist vs. motor vehicle.
[b]Adjusted for: age, gender, anticoagulation use, high energy car collision, high energy motorcycle collision, high energy pedestrian or cyclist vs. motor vehicle.
[c]Adjusted for: age, gender, anticoagulation use, violence, fall ≥ 2 meter.
[d]Model possibly being overspecified as less than 10 events per confounder present.
Abbreviations: OR, odds ratio; CI, confidence interval; GLM, generalized linear model; IPW, inverse probability weighting.

more adequately. Further research is necessary to investigate other predictive factors of severe head injury in a general trauma population, as the currently used pre-hospital predictive tool, the GCS, is not designed to predict injury severity on its own (39). Such predictors could be combined in a pre-hospital clinical prediction model or an advanced pre-hospital protocol, which could aid EMS professionals to determine the right transportation and treatment course. Until then, we advise to be careful when assessing patients with a head injury at the scene of injury and to be aware that intoxicated patients are at risk for having a severe head injury.

Conclusion

This study found that severe head injuries are difficult to recognize at the scene of injury, especially in patients without a decreased GCS. Suspicion of alcohol intoxication did not seem to influence pre-hospital injury recognition, as it possibly makes a severe head injury harder to recognize and simultaneously raises caution for a severe injury. This study has also demonstrated that patients suspected to have an alcohol-intoxication have a higher chance of suffering from a severe head injury. This knowledge can contribute to improve the pre-hospital assessment and triage of patients with a severe head injury. Further research is needed to assess the value of adding intoxication to pre-hospital protocols or create a prediction model to aid EMS professionals in their on-scene decision-making.

Disclosure statement

There are no conflicts of interest to declare.

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Data and material availability

The data that supports the findings of the current study are not publicly available due to the sensitive nature of the collected data but are available upon a reasonable request that needs to be approved of the participating Emergency Medical Services and trauma regions, provided that appropriate ethical approval is sought. R-scripts are available upon request.

Collaborative group

Members of the Pre-hospital Trauma Triage Research Collaborative (PTTRC) whom participated in this study are: Dennis den Hartog (Erasmus University Medical Center), Jens A. Halm (Amsterdam University Medical Center), Georgios F. Giannakópoulos (Amsterdam University Medical Center), and Michael J.R. Edwards (Radboud University Medical Center).

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Table A1. Covariate balance.

Variables	Unadjusted SMD	Adjusted SMD
All patients		
Age	-0.5946	-0
Age′	-0.7450	-0
Gender	0.2639	0
Anticoagulation use	-0.0289	-0
Violence	0.0806	0
Fall	-0.0586	-0
Fall ≥ 2 meters	0.0176	-0
High energy motor vehicle collision	-0.0153	-0
High energy pedestrian or cyclist vs. motor vehicle	-0.0027	-0
Patients injured in traffic		
Age	-0.2858	-0
Age′	-0.3926	-0
Gender	0.1973	0
Anticoagulation use	-0.0131	-0
High energy car collision	-0.0094	-0
High energy motorcycle collision	-0.0141	0
High energy pedestrian or cyclist vs. motor vehicle	-0.0377	-0
Patients injured due to a fall		
Age	-0.8530	-0
Age′	-1.0452	-0
Gender	0.2988	0
Anticoagulation use	-0.0303	-0
Violence	0.0302	0
Fall ≥ 2 meter	0.0443	-0

Abbreviation: SMD, Standardized mean differences.