Ir Med J; May 2022; Vol 115; No. 5; P597

May 25th, 2022

Temporal Trends in Traumatic Brain Injury

C. Forrest[1], V. Healy[2], R. Plant[3]

1. Department of Medicine, University College Cork, Ireland.
2. Department of Neurosurgery, Cork University Hospital, Ireland.
3. Department of Anaesthesia and Intensive Care, Cork University Hospital, Ireland.

Abstract

Aims

Traumatic brain injury (TBI) is a leading cause of preventable mortality and morbidity. Our aim was to examine the demographics, injury characteristics and management of TBI patients treated in an intensive care unit (ICU) in an Irish tertiary-level hospital with a neurosurgical department.

Methods

A retrospective, longitudinal study of all TBI patients treated in ICU between 2013-2018.

Results

77% (n=171) were male and median age was 46 (Q1-Q3: 28-62). The most common mechanism of injury was fall from less than two meters (<2m) followed by road traffic accident (RTA). The proportion of injuries due to RTA increased over the six-year period (p=0.006). 41.4% (n=92) of injuries had reported alcohol involvement. Patients with fall<2m had double the median age and double the rate of alcohol involvement compared to those suffering RTA (p<0.001, p<0.001). The neurosurgical intervention rate was 74% (n=165). The median duration of ICU admission and of intracranial-pressure monitoring, advanced ventilation and inotropic therapy increased over the six-year period (p=0.031, p=0.038, p=0.033, p<0.001).

Discussion

This study's findings could inform precise and impactful public prevention measures. The increasing duration of ICU admission and of other interventions should be examined further for their effect on patient outcome and resource consumption.

Introduction

Traumatic brain injury (TBI) is concisely defined "as an alteration in brain function, or other evidence of brain pathology, caused by an external force"[1]. These injuries are non-discriminatory affecting every age, race, and gender.

TBI activity in Ireland has been comprehensively examined in the 2008 Philips report which focused on the two national neurosurgical units; Beaumont Hospital, Dublin, and Cork University Hospital (CUH)[2]. According to the Major Trauma Audit conducted by the National Office of Clinical Audit in 2018, head injuries accounted for 18% of all major trauma injuries but were the cause of death in 55%[3]. As far back as 1993, head injuries have been reported as the leading cause of death in major trauma patients in Ireland[4]. However, no national study thus far has focused on TBI in an intensive care unit (ICU) serving a neurosurgical unit nor has a study looked specifically at the changing trends of TBI.

This study's main purpose is to examine the demographics, injury characteristics and critical care management of patients with TBI admitted to the ICU with an on-site neurosurgical service. A secondary aim is to uncover temporal trends by examining these parameters with regard to time.

Methods

This is a retrospective, longitudinal study of patients admitted to the ICU in CUH with TBI between 1st January 2013 and 31st December 2018. The inclusion criteria consisted of patients admitted to the ICU with TBI as defined by the Oxford Head Injury Service. The definition is "any blow to the head, even if not knocked out; including the full range of head injury, from minor to very severe; including cases who have died as a result of their injury"[5].

492 patients were initially identified by neurosurgical referral to the ICU or by referral from another speciality with a relevant 'primary Knaus diagnosis'. On review of 492 e-charts, 260 were excluded as the injury did not meet the TBI definition. 8 were duplications from readmissions. 2 were excluded based on their CT appearances. This resulted in the final study population of 222 patients. Data was collected from patient's e-charts on the electronic health-record.

Glasgow Coma Scale (GCS) scores were reported pre-hospital and/ or in-hospital prior to ICU admission. When recorded in both settings, the in-hospital score was used in accordance with the GCS score's original intended use[6]. Where a range was written, the median was used. Rotterdam CT scores were assigned by a neurosurgical specialist registrar according to the rubric reported by Maas et al[7].

Mechanisms of injury were categorised into six groups. Falls were classified into those from below (<2m) and above two meters (>2m). Any injury that involved a vehicle was classified as a road traffic accident (RTA). Recreational injuries included sports injuries and animal injuries.

Data was collected in line with European General Data Protection Regulation. This project received ethical approval from Clinical Research Ethics Committee of the Cork Teaching Hospitals. Statistical analysis consisted of Kruskal-Wallis test for non-parametric testing, Dunn's pairwise comparisons with Bonferroni correction for post-hoc testing, Pearson Chi-squared or Fisher's Exact test for categorical data. A $p<0.05$ was considered statistically significant for all variables.

Results

Demographics and Injury Characteristics

The mean number admitted to the ICU with TBI annually was 37.0 (SD:±8.8). Overall, the male to female ratio was 3.4:1 and the median age 46.0 years (Q1-Q3:28-62). However, the age group '19-35 years' accounted for the highest percentage of injuries overall and in every year (Table 1).

Severe injuries, classified as a GCS score of 3-8, accounted for over half of admissions (55.4%). In comparison, 40.1% had a Rotterdam score of 4 or more. The most common mechanism of injury was fall<2m (29.7%) followed by RTA (26.1%). Over the study period, the proportion of injuries due to RTA increased ($p=0.006$) while other mechanisms did not change. When all falls, regardless of height, were combined they accounted for over half of all injuries (51.3%) (Table 1).

Overall, alcohol involvement was reported in 41.4% of injuries (Table 1). However, when alcohol involvement was stratified according to mechanism of injury, its involvement varied considerable ($p<0.001$). Post-hoc analysis revealed that alcohol involvement was reported in significantly more assault injuries (77.8%) and fall<2m injuries (53.0%) compared to RTA injuries (24.1%) ($p<0.001$, $p<0.001$).

Median age also differed across mechanisms of injury ($p<0.001$). Post-hoc analysis showed the median age of those suffering a fall<2m was significantly higher (66 years) compared to those with a RTA injury (29 years) or an assault injury (33 years) ($p<0.001$, $p<0.001$). Furthermore, the frequencies of mechanisms varied greatly across the age groups as evident in Figure 1.

Table 1: Patient demographics and injury characteristics.

	Total	2013	2014	2015	2016	2017	2018	*p*
Number of patients	222	27	35	48	46	28	38	
Male sex (%)	171 (77.0)	19 (70.4)	26 (74.3)	39 (81.3)	36 (78.3)	25 (89.3)	26 (68.4)	0.379
Median age (Q1-Q3)	46.0 (28-62)	41.0 (24-61)	47.0 (28-62)	53.5 (33-65)	42.5 (28-58)	52.0 (32-69)	32.5 (19-56)	0.165
Age groups (%)								
0-18 years	14 (6.3)	1 (3.7)	2 (5.7)	0 (0)	2 (4.3)	0 (0)	9 (23.7)	<0.01
19-35 years	71 (32.0)	10 (37.0)	12 (34.3)	15 (31.3)	14 (30.4)	9 (32.1)	11 (28.9)	0.987
36-50 years	42 (18.9)	5 (18.5)	7 (20.0)	7 (14.6)	11 (23.9)	5 (17.9)	7 (18.4)	0.925
51-65 years	47 (21.2)	6 (22.2)	6 (17.1)	14 (29.2)	11 (23.9)	5 (17.9)	5 (13.2)	0.542
66 + years	48 (21.6)	5 (18.5)	8 (22.9)	12 (25.0)	8 (17.4)	9 (32.1)	6 (15.8)	0.610
Injury severity (%)								
Severe (GCS 3-8)	123 (55.4)	14 (51.9)	24 (68.6)	25 (52.1)	26 (56.5)	15 (53.6)	19 (50.0)	0.651
Moderate (GCS 9-12)	43 (19.4)	7 (25.9)	6 (17.1)	8 (16.7)	7 (15.2)	8 (28.6)	7 (18.4)	0.680
Mild (GCS 13-15)	28 (12.6)	2 (7.4)	3 (8.6)	8 (16.7)	7 (15.2)	3 (10.7)	5 (13.2)	0.809
No GCS reported	28 (12.6)	4 (14.8)	2 (5.7)	7 (14.6)	6 (13.0)	2 (7.1)	7 (18.4)	0.589
Rotterdam Score (%)								
1	4 (1.8)	0 (0)	1 (2.9)	2 (4.2)	0 (0)	0 (0)	1 (2.6)	0.588
2	67 (30.2)	6 (22.2)	10 (28.6)	12 (25.0)	18 (39.1)	9 (32.1)	12 (31.6)	0.654
3	59 (26.6)	11 (40.7)	8 (22.9)	8 (16.7)	14 (30.4)	8 (28.6)	10 (26.3)	0.321
4	58 (26.1)	3 (11.1)	13 (37.1)	16 (33.3)	9 (19.6)	8 (28.6)	9 (23.7)	0.163
5	27 (12.2)	6 (22.2)	2 (5.7)	8 (16.7)	4 (8.7)	2 (7.1)	5 (13.2)	0.281
6	4 (1.8)	0 (0)	0 (0)	1 (2.1)	1 (2.2)	1 (3.6)	1 (2.6)	0.871
Not available	3 (1.4)	1 (3.7)	1 (2.9)	1 (2.1)	0 (0)	0 (0)	0 (0)	0.632
Median APACHE II score (Q1-Q3)	16.5 (13-21)	16.0 (14-20)	18.0 (13-23)	16.0 (14-19)	17.0 (12-18)	19.0 (15-27)	15.5 (10-25)	0.363
Median ICNARC score (Q1-Q3)	18.0 (15-21)	19.0 (16-24)	16.0 (13-26)	16.0 (14-19)	18.0 (15-20)	18.0 (14-22)	18.5 (15-21)	0.518
Mechanism of injury (%)								
Fall < 2m	66 (29.7)	8 (29.6)	15 (42.9)	17 (35.4)	9 (19.6)	9 (32.1)	8 (21.1)	0.196
Fall > 2m	48 (21.6)	7 (25.9)	6 (17.1)	14 (29.2)	12 (26.1)	6 (21.4)	3 (7.9)	0.214
RTA	58 (26.1)	5 (18.5)	3 (8.6)	10 (20.8)	19 (41.3)	6 (21.4)	15 (39.5)	0.006
Assault	27 (12.2)	4 (14.8)	5 (14.3)	3 (6.3)	4 (8.7)	4 (14.3)	7 (18.4)	0.560
Recreational	17 (7.7)	2 (7.4)	3 (8.6)	2 (4.2)	2 (4.3)	3 (10.7)	5 (13.2)	0.611
Other	6 (2.7)	1 (3.7)	3 (8.6)	2 (4.2)	0 (0)	0 (0)	0 (0)	0.146
Alcohol involvement (%)	92 (41.4)	9 (33.3)	21 (60.0)	21 (43.8)	20 (43.5)	7 (25.0)	14 (36.9)	0.096

Abbreviations: Q1-Q3 – first quartile and third quartile values, GCS – Glasgow coma scale, APACHE II – acute physiology and chronic health evaluation II, ICNARC – intensive care national audit and research centre, < 2m – less than two meters, > 2 m – over two meters, RTA – road traffic accident

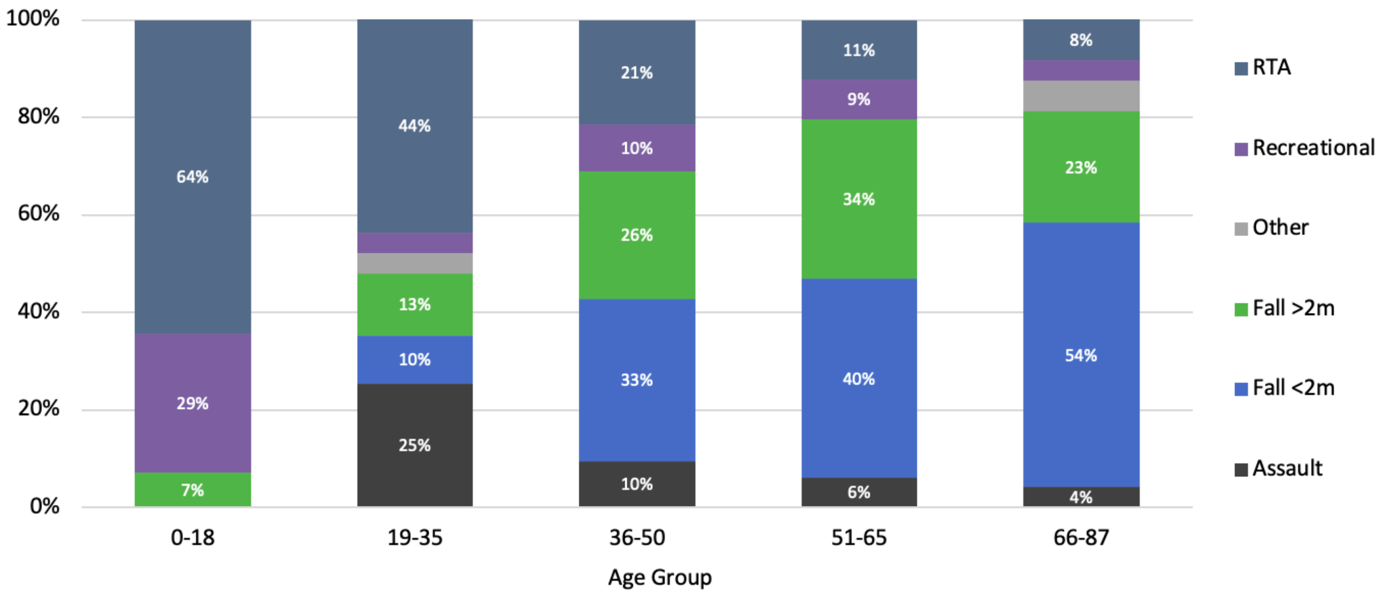

Figure 2: Mechanism of injury by age group.

Critical Care Management

As evident in Table 2, the overall median length of stay (LoS) in ICU was 8.4 days (Q1-Q3:4-14). Advanced ventilation was the longest ICU intervention (median:6.5 days), followed by intracranial pressure (ICP) monitoring (4 days) and inotropic therapy (3 days).

A number of critical care management parameters have changed over the six-year study period as demonstrated in Figure 2. The median LoS in ICU has increased (p=0.031), as well as the median number of days patients received advanced ventilation, ICP monitoring with a Codman® bolt and inotropic therapy (p=0.033, p=0.038, p=<0.001) (Table 2).

The majority of patients (64.0%) received ICP monitoring. Over half (51.8%) underwent neurosurgery with a further 22.5% receiving ICP monitoring alone. Therefore, almost three quarters (74.3%) had a neurosurgical procedure (Table 2).

Figure 2: Median duration of ICU length of stay, advanced ventilation, intracranial pressure monitoring and inotropic therapy over study period.

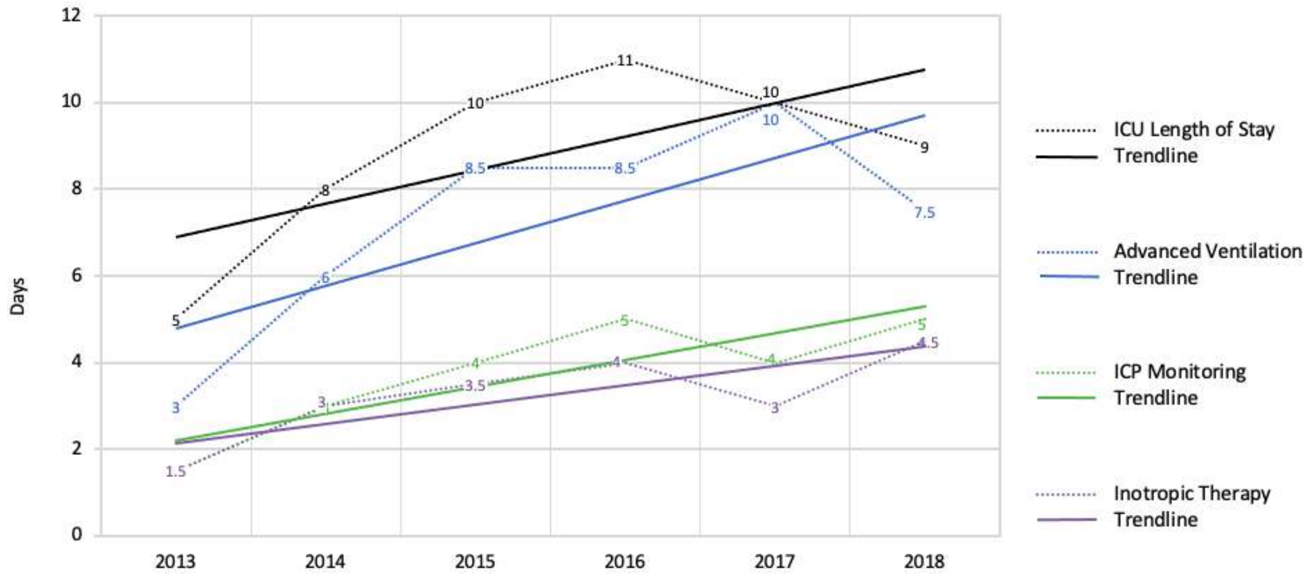

Table 2: Critical care management.

	Total	2013	2014	2015	2016	2017	2018	*p*
Number of patients	222	27	35	48	46	28	38	
Median ICU LoS in days (Q1-Q3)	8.4 (4-14)	5.0 (2-7)	8.0 (2-15)	10.0 (4-14)	11.0 (5-16)	10.0 (4-16)	9 (5-15)	0.031
Median days of advanced ventilation (Q1-Q3)	6.5 (3-12)	3.0 (2-6)	6.0 (2-11)	8.5 (3-14)	8.5 (5-13)	10.0 (4-14)	7.5 (3-12)	0.033
ICP monitoring (%)	142 (64.0)	11 (40.7)	20 (57.1)	36 (75)	31 (67.4)	20 (71.4)	24 (63.2)	0.063
Median days of ICP monitoring (Q1-Q3)	4.0 (0-7)	1.5 (0-4)	3.0 (0-7)	4.0 (0.5-9)	5.0 (0-7)	4.0 (0-11)	5.0 (0-8)	0.038
Number of craniotomies	78	9	15	24	11	10	9	0.091
Number of decompressive craniectomies	41	5	8	9	6	4	9	0.762
Neurosurgical Operative Status (%)								
Non-operative	57 (25.7)	11 (40.7)	8 (22.9)	9 (18.8)	11 (23.9)	8 (28.6)	10 (26.3)	
ICP only	50 (22.5)	2 (7.4)	6 (17.1)	8 (16.7)	18 (39.1)	6 (21.4)	10 (26.3)	0.088
Operative	115 (51.8)	14 (51.9)	21 (60.0)	31 (64.6)	17 (37.0)	14 (50.0)	18 (47.4)	
Median days of inotropic therapy (Q1-Q3)	3.0 (1-6)	1.5 (0-3)	3 (0.5-6)	3.5 (1-5)	4.0 (2-7)	3.0 (2-8)	4.5 (1-7)	<0.001

Abbreviations: ICU – intensive care unit, LoS – length of stay, Q1-Q3 – first quartile and third quartile values, ICP – intracranial pressure

Critical Care Outcome

Finally, 49 patients died while in ICU resulting in an overall ICU mortality rate of 22.1%. Of those who died, the median age was 57.5 years (Q1-Q3:29.5-69). Organ donation occurred in 13 incidences. Median discharge GCS score was 13 (Q1-Q3:11-14) and the majority of patients (n=153) were discharged to another ward within CUH.

Discussion

Traumatic brain injury (TBI) is a significant cause of premature mortality and life-long disability. Comprehensive research regarding these avoidable injuries can inform precise prevention measures. A reduction in the number of patients suffering injuries that require care in the intensive care unit (ICU) can only be achieved with specific knowledge regarding TBI in this setting.

Over the six-year study period, the average number admitted annually to the ICU with TBI was 37. Over three quarters were male which is in keeping with Irish and international studies[2,8-10]. The median age of those with TBI requiring ICU admission was 46 years. This is higher than 43 years as reported in the 2008 Philips report and 28 years as described in a 1996 Irish study[2,11]. Research has shown that the median age has increased over the past two decades[2,12,13].

Understanding the age profile of TBI is important as older age is a well-established, independent predictor of worse outcome[14,15]. However, this study found that the most common age group was 19 to 35 year-olds. Almost one in three patients fell into this group. Despite an increasing average age, TBI remains an injury primarily of the young. This has societal consequences because of life years lost to death and disability[16]. Therefore, preventative measures should focus on this population.

The severity of TBI is most frequently assessed using Glasgow Coma Scale (GCS) scores. The GCS has high inter-observer variability and is often unreliable due to confounding factors such as eye trauma, intoxication or medications[17]. When the GCS was designed in 1974, it was intended for use in the hospital setting[6]. However since then, it has been widely implemented in the pre-hospital environment. Not all GCS scores in this study correspond directly to the original definition and, as a result, have limited validity[18]. However, this study found that over half of those admitted to the ICU had severe TBI classified by GCS score and this finding was consistent both overall and in each individual year. A low initial GCS score is a poor prognostic factor and GCS scores have been shown to have a linear relationship with mortality[19].

Due to the limitations of GCS scores, CT scores can also be utilised. The Rotterdam CT score, first described in 2006, is a classification which evaluates the prognosis of those with moderate or severe TBI. In adults, the mortality at six months is 0% with a score of 1, 7% with 2, 16% with 3, 26% with 4, 53% with 5 and 61% with 6[7]. Katar et al. calculated a mean Rotterdam score as 1.51 for mild TBI (GCS 13-15), 2.22 for moderate (GCS 9-12) and 4.33 for severe injuries (GCS 3-8), however this was in a paediatric population[20].

This study found that 40.1% of patients had a Rotterdam CT score of 4 or more which may equate with a severe injury as classified by a GCS 3-8. This percentage differs from the 55.4% with a severe injury based on GCS. The difference may be due to a number of factors, one of which is the application of the Rotterdam CT score to all patients, including those deemed as having a mild traumatic brain injury. Furthermore, 41.4% of injuries in this study involved alcohol. Research has shown that alcohol's influence significantly reduces GCS scores in patients with Rotterdam CT scores of 1-3[21]. In light of this, the classification of injury severity with initial GCS score versus CT brain findings is one that warrants further investigation.

With regards to cause of injury, fall from less than two metres (<2m) accounted for nearly one in three patients admitted to the ICU. When all falls, regardless of height, were combined they accounted for over half of all injuries. These findings echo other studies examining TBI in Ireland[2,3,8]. International literature demonstrates an increasing number of TBI due to falls particularly in high income countries or those with an aging population[12,22,23]. The common use of antiplatelet and anticoagulant medications in older patients may impact TBI in this cohort and should be investigated further. As our population ages, falls will become a greater problem. Increasing public awareness about the risk of serious brain injury from a fall, even from low heights, should be prioritised.

RTA was responsible for over a quarter of injuries which mirrors multiple national and international studies conducted in high-income countries[2,8,22,24]. In this study, the proportion of injuries due to RTA increased over the six-year period. However, this is at odds with national research. The 2008 Philips report found that the incidence of TBI amongst road users had decreased in the past decade[2]. In Ireland, road fatalities have decreased by 66% over the past thirty years despite a 66% increase in the number of cars on the roads[25]. Further research should be conducted to examine the potential relationship between decreasing annual fatal collisions and increasing TBI caused by RTA.

The median age of those suffering a fall from <2m was double that of those suffering a RTA. Alcohol involvement was reported in twice as many falls from <2m (53.7%) than in RTA injuries (23.7%). Therefore, people who suffered a fall from <2m were twice as old and had twice the level of alcohol involvement compared to those with TBI caused by RTA. These differences could form the basis for specific and targeted public prevention measures.

Alcohol is a known contributor to TBI, particularly in high-income countries such as Ireland however comparison of alcohol involvement in TBI across different studies can be limited by varying study methods. This study found an overall involvement rate of 41.4%. In comparison, two Irish studies found it to be involved in 25% of TBI although both studies were conducted in the non-ICU setting[2,8]. This raises the question as to whether alcohol involvement is a predictor of subsequent ICU admission and warrants further investigation.

Our study found that the median length of stay in ICU increased over the study period. Similarly, the median duration of ventilation, intracranial pressure monitoring and inotropic therapy increased over the six years. It is logical that the longer patients spend in the unit, the longer they receive a number of interventions. However, this has effects on resource consumption and reduces patient turnover which has implications for availability of critical care beds. Further research should examine the effect of increasing durations of ICU admission and interventions on patient outcome and resource consumption.

The strength of this study lies in its originality. This study is the first to use the ICU electronic health-record system to examine TBI activity in the unit. It is also, to our knowledge, the first study that examines TBI exclusively in an Irish ICU which serves a neurosurgical unit.

This study is limited by the fact it was performed retrospectively and is sensitive to selection bias. This study is primarily descriptive and limited conclusions can be drawn about relationships between findings. Instead, it can form hypotheses and suggest future research questions. Furthermore, the study's timeframe incorporates the transitional period around the 2016 update to the Brain Trauma Foundation guidelines. Therefore it cannot assess the impact of these guidelines on trends. Finally, there are numerous areas beyond this study's scope which warrant investigation. These include the use of prehospital tranexamic acid, injury severity scores, incidence of rebleeds and haematoma progression, median cerebral perfusion pressure, EEG monitoring, polytrauma status and long-term outcomes.

TBI requiring ICU admission is a grave scenario for those suffering such injuries. This study allows us to understand this heterogenous population, to appreciate the differences between mechanisms of injury and to identify changing patterns in patients' management. Its findings are ICU-specific and Ireland-specific, and they should be considered when planning national prevention measures and campaigns.

Declaration of Conflicts of Interest:
The authors have no conflict of interest to declare.

Corresponding Author:
Clara Forrest
Department of Medicine,
University College Cork,
Ireland.
E-Mail: claraforrest1@hotmail.com

References:

1. Menon DK, Schwab K, Wright DW, Maas AI. Position statement: definition of traumatic brain injury. Arch Phys Med Rehabil. 2010;91(11):1637-40.
2. Traumatic Brain Injury Research Group. *Phillips Report: National Report on Traumatic Brain Injury in the Republic of Ireland.* Beaumont Hospital, 2008.

3. National Office of Clinical Audit. *Major Trauma Audit: National Report 2018*. Dublin, 2018.
4. Caldwell MT, McGovern EM. Fatal trauma: a five year review in a Dublin hospital. Ir J Med Sci. 1993;162(8):309-12.
5. Moss NE, Powers D, Wade DT. The Oxfordshire Head Injury Register. Disabil Rehabil. 1996;18(4):169-73.
6. Teasdale G, Jennett B. Assessment of coma and impaired consciousness. A practical scale. Lancet. 1974;2(7872):81-4.
7. Maas AI, Hukkelhoven CW, Marshall LF, Steyerberg EW. Prediction of outcome in traumatic brain injury with computed tomographic characteristics: a comparison between the computed tomographic classification and combinations of computed tomographic predictors. Neurosurgery. 2005 Dec;57(6):1173-82; discussion 1173-82.
8. Owens PW, Lynch NP, O'Leary DP, Lowery AJ, Kerin MJ. Six-year review of traumatic brain injury in a regional trauma unit: demographics, contributing factors and service provision in Ireland. Brain Inj. 2018;32(7):900-6.
9. Peeters W, van den Brande R, Polinder S, Brazinova A, Steyerberg EW, Lingsma HF, et al. Epidemiology of traumatic brain injury in Europe. Acta Neurochir (Wien). 2015;157(10):1683-96.
10. Hirschberg R, Weiss D, Zafonte R. Traumatic brain injury and gender: What is known and what is not. Future Neurology. 2008;3:483-9.
11. O'Brien DP, Phillips JP. Head injuries in the Republic of Ireland: a neurosurgical audit. Ir Med J. 1996;89(6):216-8.
12. Salottolo K, Carrick M, Stewart Levy A, Morgan BC, Slone DS, Bar-Or D. The epidemiology, prognosis, and trends of severe traumatic brain injury with presenting Glasgow Coma Scale of 3. J Crit Care. 2017;38:197-201.
13. Stocchetti N, Carbonara M, Citerio G, Ercole A, Skrifvars MB, Smielewski P, et al. Severe traumatic brain injury: targeted management in the intensive care unit. The Lancet Neurology. 2017;16(6):452-64.
14. Thompson HJ, McCormick WC, Kagan SH. Traumatic brain injury in older adults: epidemiology, outcomes, and future implications. J Am Geriatr Soc. 2006;54(10):1590-5.
15. Stocchetti N, Paternò R, Citerio G, Beretta L, Colombo A. Traumatic brain injury in an aging population. J Neurotrauma. 2012;29(6):1119-25.
16. Polinder S, Meerding WJ, Mulder S, Petridou E, van Beeck E. Assessing the burden of injury in six European countries. Bull World Health Organ. 2007;85(1):27-34.
17. Gill MR, Reiley DG, Green SM. Interrater reliability of Glasgow Coma Scale scores in the emergency department. Ann Emerg Med. 2004;43(2):215-23.
18. Zuercher M, Ummenhofer W, Baltussen A, Walder B. The use of Glasgow Coma Scale in injury assessment: a critical review. Brain Inj. 2009;23(5):371-84.
19. Perel P, Arango M, Clayton T, Edwards P, Komolafe E, Poccock S, et al. Predicting outcome after traumatic brain injury: practical prognostic models based on large cohort of international patients. Bmj. 2008;336(7641):425-9.
20. Katar S, Aydin Ozturk P, Ozel M, Arac S, Evran S, Cevik S, Baran O. The Use of Rotterdam CT Score for Prediction of Outcomes in Pediatric Traumatic Brain Injury Patients Admitted to Emergency Service. Pediatr Neurosurg. 2020;55(5):237-243.

21. Rundhaug NP, Moen KG, Skandsen T, Schirmer-Mikalsen K, Lund SB, Hara S, Vik A. Moderate and severe traumatic brain injury: effect of blood alcohol concentration on Glasgow Coma Scale score and relation to computed tomography findings. J Neurosurg. 2015 Jan;122(1):211-8.
22. Jonsdottir GM, Lund SH, Snorradottir B, Karason S, Olafsson IH, Reynisson K, et al. A population-based study on epidemiology of intensive care unit treated traumatic brain injury in Iceland. Acta Anaesthesiologica Scandinavica. 2017;61(4):408-17.
23. Feigin VL, Theadom A, Barker-Collo S, Starkey NJ, McPherson K, Kahan M, et al. Incidence of traumatic brain injury in New Zealand: a population-based study. Lancet Neurol. 2013;12(1):53-64.
24. Roozenbeek B, Maas AI, Menon DK. Changing patterns in the epidemiology of traumatic brain injury. Nat Rev Neurol. 9. England2013. p. 231-6.
25. Road Safety Authority of Ireland. *Road Safety Strategy 2013-2020*. Ballina, 2013.