PREDICTIVE VALUE OF THE NEUROPSYCHOLOGICAL IMPAIRMENT SCALE IN PATIENTS WITH TRAUMATIC BRAIN INJURY

TRAVMATİK BEYİN HASARI OLAN HASTALARDA NÖROPSİKOLOJİK BOZULMA ÖLÇEĞİNİN PREDİKTİF DEĞERİNİN BELİRLENMESİ

Sophia MANSOURIPOUR[1] , Alireza ALA[1] , Elham AFSAR[1] , Alireza BIHAMTA[1] , Erfan GOLSHAN SHALI[1] ,
Pouneh HAMIAN-ROOMIANI[1] , Pouya VAKILIPOUR[1] , Samad SHAMS VAHDATI[1,2]

[1]Tabriz University of Medical Sciences, Emergency and Trauma Care Research Center, Tabriz, Iran
[2]Islamic Azad University, Faculty of Medicine, Tabriz Branch, İran

ORCID IDs of the authors: S.M. 0009-0005-9872-2443; A.A. 0000-0001-8231-2937; E.A. 0000-0001-5963-4145; A.B. 0009-0007-5831-1249;
E.G.S. 0009-0005-4657-3175; P.H.R. 0000-0002-1546-8648; P.V. 0000-0003-2244-043X; S.S.V. 0000-0002-4831-6691

ABSTRACT

Objective: Various studies have used different measures to predict the outcome of patients with traumatic brain injury, including the Glasgow Coma Scale (GCS), Disability Rating Scale, and length of hospital stay, among others. This study was conducted to determine the predictive significance of the Neuropsychological Impairment Scale (NIS) concerning the mortality rate, recovery, and discharge outcomes of patients who have been presented to the emergency department.

Material and Method: This descriptive–analytical cross-sectional study was conducted on 100 individuals aged ≥18 years who have experienced traumatic brain injuries. A checklist was prepared incorporating items from the NIS and patient information such as age, gender, and injury mechanism details. The checklist was completed during bedside examinations.

Result: The prevalence of traumatic brain injuries was higher in men (78%) in the age group of 21–40 years. The average age of patients was 41.63 years. Falling from a height was identified as the predominant cause of brain trauma, followed by two-car accidents. The mean primary GCS score was 13.47 for men and 14.63 for women. Hospitalization occurred in 67% of cases, followed by discharge in 30% and surgical intervention in 3% of cases. An inverse correlation was observed between the examined sample's NIS standard score and the initial GCS score.

Conclusion: An inverse relationship between NIS and initial GCS scores suggests that lower NIS scores are associated with better outcomes, indicating its utility as a predictive factor.

Keywords: Traumatic brain injury, Neuropsychological Impairment Scale, Glasgow Coma Scale

ÖZET

Amaç: Glasgow Koma Ölçeği (GKÖ), Engellilik Derecelendirme Ölçeği ve hastanede kalış süresi (HKS) dahil olmak üzere travmatik beyin hasarı olan hastaların sonuçlarını tahmin etmek için çeşitli çalışmalarda farklı ölçümler kullanılmıştır. Bu çalışma, acil servise travmatik beyin hasarı nedeniyle başvuran hastaların ölüm oranı, iyileşme ve taburculuk sonuçları açısından Nöropsikolojik Bozukluk Ölçeği'nin (NBÖ) prediktif değerinin belirlemesi amaçlanmaktadır.

Gereç ve Yöntem: Tanımlayıcı-analitik kesitsel yöntem kullanılarak yapılan bu araştırma, travmatik beyin hasarı geçirmiş 18 yaş ve üzeri 100 kişiden oluşan bir çalışma grubunu içermektedir. Araştırma, NBÖ maddeleri, yaş, cinsiyet ve yaralanma mekanizması ayrıntıları gibi hasta bilgilerini içeren bir kontrol listesi ile yapıldı. Kontrol listesi, yatak başı muayeneleri sırasında tamamlandı.

Bulgular: Bulgular, 21 ila 40 yaş grubundaki erkeklerde (%78) travmatik beyin hasarı prevalansının daha yüksek olduğunu göstermektedir. Hastaların ortalama yaşı 41,63 yıldır. Yüksekten düşme, beyin travmasının en önemli nedeni olarak ortaya çıkmakta ve bunu araç içi trafik kazaları takip etmekteydi. Ortalama birincil GKÖ skoru erkekler için 13,47, kadınlar için 14,63'tü. Vakaların %67'sinde hastaneye yatış, %30'unda taburcu edilme ve %3'ünde cerrahi müdahale yapıldı. Çalışmada, incelenen örneğin NBÖ standartı ile başlangıçtaki GKÖ puanı arasında ters korelasyon olduğu saptandı.

Sonuç: Çalışma sonuçları, NBÖ skoru ile başlangıç GKÖ skoru arasındaki ters ilişki, daha düşük NBÖ değerlerinin daha iyi sonuçlarla ilişkili olduğunu ve bunun öngörücü bir faktör olarak kullanılabileceğini göstermektedir.

Anahtar Kelimeler: Travmatik beyin hasarı, Nöropsikolojik Bozukluk Ölçeği, Glasgow Koma Ölçeği

INTRODUCTION

Traumatic brain injury (TBI) is a prominent global contributor to disability and mortality, often referred to as a silent epidemic. It is caused by an external force that changes brain function or is another evidence of brain pathology (1, 2).

Worldwide, the annual occurrence of TBI is approximated to range from 27 to 69 million cases. Numerous individuals who survive experience substantial disabilities, causing a substantial social and economic burden. In 2010, the financial consequences of TBIs in the United States amounted to $76.5 billion (3).

In 2014, the Society for Patient Control and Prevention conducted a study on 2.53 million patients who sought emergency care for TBIs. The findings revealed 288,000 hospitalizations and 56,800 fatalities within this group, encompassing both children and adults. Remarkably, adults aged ≥75 years exhibited the highest rate of emergency visits, with 1682 individuals per 100,000. This was followed closely by children aged 0–4 years, with 1618.6 individuals per 100,000, whereas the age group of 15–24 years recorded the lowest number of visits (4).

In Europe, the occurrence of hospitalization after TBI is approximately 262 instances per 100,000 injuries, and the annual fatality rate is approximately 15 cases per 100,000 injuries (5). TBI extends beyond a pathophysiological event, encompassing a range of intricate issues that induce both functional and structural harm through primary and secondary mechanisms of damage (6).

The lesions formed are not confined to the site of the initial trauma but expand progressively. Hence, the initial damage occurs at the moment of impact, and over hours, weeks, months, and ultimately throughout one's life, the secondary damage is triggered by the host's response to the initial injury (7).

The primary damage arises from the immediate impact mechanism on the brain tissue caused by an external force, encompassing contusion, blood vessel damage, bleeding, and nerve damage (8, 9).

Secondary damage occurs from minutes to months after the primary injury, involving a sequence of molecular, cellular, and metabolic events that culminate in brain cell death, tissue damage, and atrophy (10).

Therefore, identifying individuals at risk of unfavorable neuropsychological outcomes after TBI holds significant importance. This study was conducted to evaluate the predictive value of the Neuropsychological Impairment Scale (NIS) in terms of mortality rate, recovery, and discharge of patients who have been admitted to the emergency department at Imam Reza Hospital in Tabriz due to TBI.

MATERIALS and METHODS

This descriptive–analytical cross-sectional investigation included a sample of 100 individuals aged ≥18 years who had experienced TBIs. Ethical approval and the research code were obtained from the Tabriz University of Medical Sciences's Research and Ethical Committee (Date: 04.07.2023, No: R.IAU.TABRIZ.REC.1402.142). Participants were recruited from among those seeking medical attention at the emergency department of Imam Reza Hospital in Tabriz between the beginning of July and the end of August 2023.

Inclusion criteria were patients with TBIs during the specified time frame. Exclusion criteria encompassed individuals who refused to participate or had preexisting physical or mental disabilities before the traumatic injury.

After the acquisition of required approvals, 100 eligible patients were included in this study. These involved individuals aged 18 years and older who visited the emergency department of Imam Reza Hospital in Tabriz between the specified dates. Those who did not wish to participate or had preexisting physical or mental disabilities (before the traumatic event) were excluded from the study.

Subsequently, a checklist was prepared incorporating items from the NIS and patient information such as age, gender, and injury mechanism details. The checklist was completed during bedside examinations and investigations, and subsequent reviews were conducted to align the collected data with the study objectives.

Statistical analysis

The collected data were processed using the SPSS ver.26 (IBM Corp., Armonk, NY, USA) statistical software. Normality of the data was evaluated using the Smirnov–Kolmogorov test. Qualitative data were expressed as frequency (percentage). Quantitative data were expressed as mean (standard deviation) when the data exhibited a normal distribution; otherwise, the median (interquartile range 25–75) value was used. Qualitative data were analyzed using the χ^2 test in two groups, and if certain conditions were met, Fisher's exact test was used.

Moreover, the independent t-test was used for analyzing quantitative data in two groups if the data followed a normal distribution. One-way ANOVA was used to determine whether any significant differences existed in the mean values of a continuous dependent variable across the groups. A p value of <0.05 was considered statistically significant.

RESULTS

In this cross-sectional study employing a descriptive–analytical approach and involving 100 patients with TBI, the obtained statistical outcomes are as follows.

Of the 100 patients with TBI, 78 (78%) were men, and 22 (22%) were women. Regarding age distribution, the mean age of all patients with TBI was 41.36 (range: 18–87) years, and 12% were aged <20 years, 47% were aged 21–40 years, 20% were aged 41–60 years, and 21% were aged ≥61 years, Table 1).

As shown in Table 2, the predominant form of trauma was falling from an elevated position, which accounted for 28% of cases, followed by two-car accidents that accounted for 20% of cases. Regarding the outcome, a majority of patients with TBI underwent hospitalization (67%), followed by discharge (30%), whereas 3% of patients unfortunately died due to the injury (Table 1).

The distribution of male and female patients across the various age groups did not show a significant difference (p=0.247). In all the four age categories under examination, the number of men exceeded that of women, indicating no variance in gender distribution across age groups.

Regarding the nature of trauma, there was no significant difference in distribution between men and wom-

en (p=0.063). The prevalent type of trauma for men was falling from a height, which accounted for 21 patients, whereas it was two-car accidents for women, which accounted for 9 patients.

The distribution of men and women based on the outcome showed a remarkable difference (p=0.020). Specifically, the outcomes of hospitalization, discharge, and death for men were 85.1%, 60%, and 100%, respectively (Table 2).

According to the findings of the independent samples t-test that compared the mean ages of two separate groups, there was no statistically significant difference in the average age of male and female patients (p=0.055). The mean ages were 39.46 (±18.47) years for male patients and 48.09 (±18.28) years for female patients (Table 3).

The results of one-way ANOVA that compared the mean values across several independent groups revealed a significant difference in the average age among various types of trauma (p=0.022). The trauma type with the lowest average age was a "car with a motorcycle accident." Further analysis using the least significant difference (LSD) post hoc test revealed significant differences in the average age between "two-car accident" and "accident with pedestrian" traumas (p=0.024), as well as between "accident with pedestrian" and "car with motorcycle accident" traumas (p=0.006).

Moreover, there were significant differences between the average ages of "accident with pedestrian" and "motorcycle rollover" traumas (p=0.006) and "accident with pedestrian" and "other" traumas (p=0.022), as well as between "car with motorcycle accident" and "falling from a height" traumas (p=0.014). Furthermore, the differences in mean age were significant between "falling from a height" and "motorcycle rollover" traumas (p=0.013), as well as between "falling from a height" and "falling from a level height" traumas (p=0.049). Conversely, there was no significant difference in the average age across the outcomes of hospitalization, discharge, and death (p=0.0665).

Nonetheless, it is worth noting that the average age in the death outcome was higher than that in the outcomes of discharge and hospitalization (Table 3).

The independent samples t-test revealed a significant difference in the average NIS score between male (6.17±5.38) and female (3.37±3.66) patients (p=0.035).

The one-way ANOVA revealed a statistically significant difference in the mean NIS scores across various types of trauma (p=0.011). The mean NIS for car rollover trauma was remarkably lower than that for other traumas, amounting to 4.38. Further analysis using the two-by-two mean

Table 1: Frequency distribution of patients with TBI according to gender and age group

Variable	Variable category	Frequency (%)
Gender	Male	78
	Female	22
Age group (years)	<20	12
	21-40	47
	41-60	20
	>61	21
Trauma type	Two-car accident	20
	Accidents with pedestrians	9
	Car with motorcycle accident	7
	Falling from a height	28
	Car rollover	9
	Motorcycle rollover	8
	Motorcycle with pedestrian accident	3
	Falling from a level height	16
Outcome	Hospitalized	67
	Discharged	30
	Deceased	3

Table 2: Comparison of the frequency distribution of gender across age groups, types of trauma, and primary Glasgow Coma Scale (GCS) based on the results obtained from Fisher's exact test

Variable	Variable category	Gender		p value
		Male n (%)	Female n (%)	
Age group (years)	<20	11 (91.7)	1 (8.3)	0.247
	21-40	38 (80.9)	9 (19.1)	
	41-60	16 (80.0)	4 (20.0)	
	>60	13 (61.9)	8 (38.1)	
Trauma type	Two-car accident	11 (55.0)	9 (45.0)	0.063
	Accident with pedestrian	7 (77.8)	2 (22.2)	
	Car with motorcycle accident	7 (100.0)	0 (0.0)	
	Falling from a height	21 (75.0)	7 (25.0)	
	Car rollover	7 (77.8)	2 (22.2)	
	Motorcycle rollover	8 (100.0)	0 (0.0)	
	Motorcycle with pedestrian accident	2 (66.7)	1 (33.3)	
	Falling from a level height	15 (93.8)	1 (3.6)	
Outcome	Hospitalized	57 (85.1)	10 (14.9)	0.020
	Discharged	18 (60.0)	12 (40.0)	
	Deceased	3 (100.0)	0 (0.0)	

Table 3: Average age according to the variables of gender, type of trauma, and outcome in patients with TBI

Variable	Variable category	Frequency	Age average	Standard deviation	Min	Max	p value
Gender	Male	78	39.46	18.47	18	87	0.055[1]
	Female	22	48.09	18.28	18	87	
Trauma type	Two-car accident	20	38.25	16.29	18	72	0.022[2]
	Accidents with pedestrians	9	54.67	20.95	18	87	
	Car with motorcycle accident	7	29.71	9.43	18	44	
	Falling from a height	28	48.46	18.68	20	87	
	Car rollover	9	41.00	16.29	21	68	
	Motorcycle rollover	8	30.50	14.54	19	64	
	Motorcycle with pedestrian accident	3	34.33	24.91	18	63	
	Falling from a level height	16	37.38	19.50	18	73	
Outcome	Hospitalized	67	41.15	18.79	18	87	0.665[2]
	Discharged	30	40.87	17.52	18	87	
	Deceased	3	51.00	31.95	26	87	

1: Independent samples t-test, 2: One-way ANOVA

comparison test (LSD) revealed significant differences in mean NIS scores between "two-car accident" and "accident with pedestrian" traumas (p=0.001), "accident with pedestrian" and "falling from a height" traumas (p=0.003), "accident with pedestrian" and "car rollover" traumas (p=0.004), "accident with pedestrian" and "motorcycle

Table 4: Comparison of mean NIS and GCS scores according to the variables of gender, type of trauma, and outcome in patients with TBI (nine patients were excluded during NIS score evaluation because of toxicology suspicious finding) (one patient's GCS score was variable and altered and then excluded during evaluation in this table).

Variable	Variable category	Frequency	Initial GCS score Median	Min	Max	p value
Gender	Male	77	15	3	15	0.305[1]
	Female	22	15	10	15	
Trauma type	Two-car accident	20	15	3	15	0.129[2]
	Accidents with pedestrians	9	14	3	15	
	Car with motorcycle accident	7	14	11	15	
	Falling from a height	27	15	4	15	
	Car rollover	9	15	4	15	
	Motorcycle rollover	8	14	13	15	
	Motorcycle with pedestrian accident	3	14	14	15	
	Falling from a level height	16	15	14	15	
Outcome	Hospitalized	66	14	4	15	<0.001[2]
	Discharged	30	15	15	15	
	Deceased	3	3	3	4	

Variable	Variable category	Frequency	NIS mean	Standard deviation	Min	Max	p value
Gender	Male	72	6.17	5.38	0	30	0.035[1]
	Female	19	3.37	3.66	0	13	
Trauma type	Two-car accident	18	4.44	3.59	0	11	0.011[2]
	Accidents with pedestrians	7	11.86	10.54	0	21	
	Car with motorcycle accident	6	7.50	6.16	0	18	
	Falling from a height	25	5.56	4.00	0	15	
	Car rollover	8	4.38	5.34	0	12	
	Motorcycle rollover	8	6.88	3.72	2	12	
	Motorcycle with pedestrian accident	3	7.67	5.03	3	13	
	Falling from a level height	16	3.00	3.03	0	10	
Outcome	Hospitalized	59	6.61	4.77	0	21	<0.001[2]
	Discharged	30	2.53	1.98	0	8	
	Deceased	2	21.00	12.73	3	12	

[1]: Independent samples t-test, [2]: One-way ANOVA, GCS: Glasgow Coma Scale, NIS: Neuropsychological Impairment Scale

rollover" traumas (p=0.05), as well as between "accident with pedestrian" and "other" traumas (p>0.001).

Furthermore, a significant difference was observed in mean NIS scores among the outcomes of hospitalization, discharge, and death (p<0.001). The mean NIS scores for hospitalization, discharge, and death outcomes were 6.61, 2.53, and 21.00, respectively. Further analysis using the LSD test indicated significant differences in mean NIS scores between hospitalization and discharge (p<0.001) and hospitalization and death (p<0.001), as well as between discharge and death (p>0.001) (Table 4).

The independent samples t-test revealed no statistically significant differences in the median initial Glasgow Coma Scale (GCS) scores between male and female patients (p=0.305), with the median initial GCS score for both groups being 15.

The one-way ANOVA also revealed no significant differences in the median initial GCS scores across various types of trauma (p=0.129).

However, the mean GCS scores exhibited a significant difference among the outcomes of hospitalization, discharge, and death (p<0.001), with the scores being 14, 15, and 3, respectively. Further analysis using the two-by-two mean comparison test (Tukey's post hoc test) revealed significant differences in mean GCS scores between hospitalization and discharge (p=0.004) and hospitalization and death (p<0.001), as well as between discharge and death (p>0.001) (Table 4).

Moreover, the Pearson correlation coefficient test revealed a significant negative correlation between the NIS and initial GCS scores (r=−0.534; p<0.001).

DISCUSSION

Mild TBI, characterized by a GCS score of ≥13, constitutes the majority of traumatic injuries, especially in the domain of sports (3). In a comprehensive study involving 17,470 patients with TBI, 57% initially experienced a loss of consciousness, which decreased to 12% after the implementation of initial treatment interventions. By the end of the treatment period, 98% of these patients had fully regained consciousness, indicating significant improvement (11).

After prolonged hospitalization, most people with TBI require a prolonged period of rehabilitation and may face problems such as physical, cognitive, psychological, and behavioral difficulties (12).

Research suggests that various factors, including age and initial GCS score, play a significant role in predicting the outcome of individuals with TBI (13).

Various criteria, such as the initial GCS score, disability criteria, and length of hospital stay, are used to predict the prognosis of individuals with TBI.

The NIS is a standard assessment tool for screening adults' neuropsychological symptoms. It comprises various sections addressing general and specific disorders, encompassing symptoms that might go unnoticed during diagnostic and treatment processes or may not be explicitly communicated by the patient. The NIS serves as a valuable instrument for a detailed evaluation of neuropsychiatric complications. It helps in identifying the affected areas and determining whether the patient benefits from treatment by aligning with treatment goals.

The NIS questionnaire includes 95 items and covers aspects related to motor function, tone and joint movement limitations, sensory perception, perceptual function, speech abilities, cognitive function, behavior, mood, vision and hearing, pain sensation, and fatigue perception (14).

Although movement issues resulting from brain trauma tend to improve in the majority of patients, neuropsychological and behavioral challenges persist for months and even years. Therefore, these issues are labeled as invisible disabilities, affecting various facets of an individual's life, including personal, social, familial, and professional dimensions, ultimately impacting both career and overall quality of life (15, 16).

In our study, the mean age of the patients was 41.36 years, and there was a remarkable gender disparity, with the majority (78%) being men in terms of relative frequency.

Skaansar et al. conducted a study in 2020 to investigate TBI across various age categories, including 1571 patients aged ≥15 years, and showed that the average age was 58 years, with a remarkable predominance of men, constituting 70% of the participants. Furthermore, 39% of the examined population was aged ≥65 years (17).

Subsequently, in a systematic study, Mollayeva et al. examined 58 registered articles on TBIs, which included 1,265,955 patients, to determine the frequency of age and gender in these patients. They reported that 67% of the study patients were men (18). This gender predominance is consistent with the findings of the two abovementioned studies.

Zia et al. evaluated 3749 patients with TBI whose average age was 28 years. The highest occurrence was observed in the age group of 19–45 years, and men were predominant. They found that the primary cause of TBI in the examined population was road accidents (42.1% involving pedestrians and 28.1% involving motorcyclists), followed by falls from heights (11.1%) (19).

Although the average age and proportion of occurrence in various age groups documented in comparable studies

vary from those observed in our study, this disparity is affected by the demographic characteristics specific to distinct geographic regions of the analyzed samples (17, 19).

The predominant cause of TBI in our investigation, with the highest incidence, was associated with falls from elevated surfaces (28%), followed by involvement in two-vehicle accidents (20%).

Lee et al. evaluated the prognostic factors in individuals with TBIs. Over three months, they examined 42 patients with TBIs whose average age was 44.5 years (range: 8–73 years). The primary cause of injury in 45.2% of the patients was falling from a height, followed by motorcycle, pedestrian, bicycle, and car accidents (20). This finding was in contrast to those reported by Zia et al., where falling from a height was the third most prevalent mechanism, following a car accident involving a pedestrian and an accident when riding as a motorcycle passenger (19).

Ponsford et al. conducted a study in 2008 involving 60 patients with mild-to-severe TBIs, wherein they reported a correlation between suboptimal The Extended Glasgow Outcome Scale (GOS-E) criteria and impaired performance in processing speed, attention, memory, and executive function (21).

The mean initial GCS score in our study patients was 14.3 for men and 13.74 for women. Although there was no significant difference across various trauma mechanisms, there was a clear correlation with the outcome. Specifically, the mean GCS scores for discharged, hospitalized, and deceased patients were 15, 13.85, and 3.33, respectively. When comparing this outcome with the findings of Lee et al. and Ponsford et al, it appears that a low GCS score is related to a poorer short-term outcome and an inferior long-term prognosis (20, 21).

Our study also indicated a negative correlation between GCS and NIS scores, consistent with the findings of Ponsford et al who showed a correlation between low GCS scores and suboptimal neuropsychological performance (21).

Comparable studies have yielded multiple results on the relevance of neuropsychological factors in predicting the outcomes of patients with TBIs. For instance, Sigurdardottir et al. reported that improved neuropsychological functioning, including higher verbal, reasoning, visual, spatial, and perceptual skills, and reduced short-term memory impairment are associated with a more favorable prognosis (22).

Although our study contributes valuable insights for understanding TBIs, it is essential to acknowledge certain limitations inherent in the research design. First, our sample size may limit generalizability, and caution should be exercised when extrapolating these findings to broader populations. Furthermore, the retrospective study design introduces the potential for recall bias, as reliance on medical records may capture only some relevant details.

Moreover, our study's focus on specific demographic and neuropsychological factors necessarily excludes consideration of other potentially influential variables. Future studies could benefit from a more expansive approach to include a broader array of factors that contribute to a more comprehensive understanding of TBIs.

CONCLUSION

TBI is more prevalent among men and women aged 21–40 years. Falls from a height constitute the primary cause. Most patients exhibit a GCS score of >13, signifying mild traumatic injuries. An inverse relationship between NIS and initial GCS scores suggests that lower NIS scores are associated with better outcomes, indicating its utility as a predictive factor.

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. [CrossRef]
2. Dash HH, Chavali S. Management of traumatic brain injury patients. Korean J Anesthesiol 2018;71(1):12-21. [CrossRef]
3. Capizzi A, Woo J, Verduzco-Gutierrez M. Traumatic brain injury: an overview of epidemiology, pathophysiology, and medical management. Medical Clinics 2020;104(2):213-38. [CrossRef]
4. Capizzi A, Woo J, Verduzco-Gutierrez M. Traumatic Brain Injury: An Overview of Epidemiology, Pathophysiology, and Medical Management. Med Clin North Am 2020;104(2):213-38. [CrossRef]

5. 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. [CrossRef]

6. Masel BE, DeWitt DS. Traumatic brain injury: a disease process, not an event. J Neurotrauma 2010;27(8):1529-40. [CrossRef]

7. Pavlovic D, Pekic S, Stojanovic M, Popovic V. Traumatic brain injury: neuropathological, neurocognitive and neurobehavioral sequelae. Pituitary 2019;22(3):270-82. [CrossRef]

8. Cernak I. Animal models of head trauma. NeuroRx 2005;2(3):410-22. [CrossRef]

9. Gaetz M. The neurophysiology of brain injury. Clin Neurophysiol 2004;115(1):4-18. [CrossRef]

10. Bramlett HM, Dietrich WD. Long-term consequences of traumatic brain injury: Current status of potential mechanisms of injury and neurological outcomes. J Neurotrauma 2015;32(23):1834-48. [CrossRef]

11. Kowalski RG, Hammond FM, Weintraub AH, Nakase-Richardson R, Zafonte RD, Whyte J, et al. Recovery of Consciousness and Functional Outcome in Moderate and Severe Traumatic Brain Injury. JAMA Neurol 2021;78(5):548-57. [CrossRef]

12. Rosenfeld JV, Maas AI, Bragge P, Morganti-Kossmann MC, Manley GT, Gruen RL. Early management of severe traumatic brain injury. Lancet 2012;380(9847):1088-98. [CrossRef]

13. Godbolt AK, DeBoussard CN, Stenberg M, Lindgren M, Ulfarsson T, Borg J. Disorders of consciousness after severe traumatic brain injury: a Swedish-Icelandic study of incidence, outcomes and implications for optimizing care pathways. J Rehabil Med 2013;45(8):741-8. [CrossRef]

14. Hooper SR. Book Review: The Neuropsychological Impairment Scale. J Psychoeducational Assessment 1999;17(2):171-4. [CrossRef]

15. Chevignard M, Taillefer C, Picq C, Pradat-Diehl P. Ecological assessment of executive functions in a patient with acquired brain injury. Ann Readapt Med Phys 2008;51(2):74-83. [CrossRef]

16. Mazaux JM, Masson F, Levin HS, Alaoui P, Maurette P, Barat M. Long-term neuropsychological outcome and loss of social autonomy after traumatic brain injury. Arch Phys Med Rehabil 1997;78(12):1316-20. [CrossRef]

17. Skaansar O, Tverdal C, Rønning PA, Skogen K, Brommeland T, Røise O, et al. Traumatic brain injury-the effects of patient age on treatment intensity and mortality. BMC Neurol 2020;20(1):376. [CrossRef]

18. Mollayeva T, Mollayeva S, Pacheco N, Colantonio A. Systematic review of sex and gender effects in traumatic brain injury: equity in clinical and functional outcomes. Frontiers Neurol 2021;12:678971. [CrossRef]

19. Zia N, Mehmood A, Namaganda RH, Ssenyonjo H, Kobusingye O, Hyder AA. Causes and outcomes of traumatic brain injuries in Uganda: analysis from a pilot hospital registry. Trauma Surg Acute Care Open 2019;4(1):e000259. [CrossRef]

20. Lee SY, Kim SS, Kim CH, Park SW, Park JH, Yeo M. Prediction of outcome after traumatic brain injury using clinical and neuroimaging variables. J Clin Neurol 2012;8(3):224-9. [CrossRef]

21. Ponsford J, Draper K, Schönberger M. Functional outcome 10 years after traumatic brain injury: its relationship with demographic, injury severity, and cognitive and emotional status. J Int Neuropsychol Soc 2008;14(2):233-42. [CrossRef]

22. Sigurdardottir S, Andelic N, Roe C, Schanke AK. Cognitive recovery and predictors of functional outcome 1 year after traumatic brain injury. J Int Neuropsychol Soc 2009;15(5):740-50. [CrossRef]