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ORIGINAL STUDIES
ORIGINALNI NAUČNI RADOVI

CORRELATION BETWEEN AGE, STATE OF CONSCIOUSNESS, AND FINDINGS ON COMPUTED TOMOGRAPHY OF THE BRAIN IN PATIENTS WITH MILD TRAUMATIC BRAIN INJURY

POVEZANOST STAROSNE DOBI, STANJA SVESTI I NALAZA NA KOMPJUTERIZOVANOJ TOMOGRAFIJI MOZGA KOD PACIJENATA SA BLAGIM TRAUMATSKIM MOŽDANIM OŠTEĆENJEM

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Abstract
Introduction. Traumatic brain injury affects over 50 million people worldwide annually, with mild traumatic brain injury accounting for approximately 80%. The number of elderly patients sustaining such injuries is increasing. This study aimed to compare differences in consciousness impairment and computed tomography findings among mild traumatic brain injury patients of different age groups upon hospital admission. **Material and Methods.** This retrospective study included 150 patients with mild traumatic brain injury hospitalized at the Neurosurgery Clinic of the Clinical Center of Vojvodina between January 1, 2020 and July 1, 2021. Patients were categorized into three age groups and compared based on the level of consciousness impairment, assessed using the Glasgow Coma Scale, and computed tomography findings evaluated using the Rotterdam score. **Results.** Statistical analysis revealed that the mean Rotterdam score was 1.6 in patients aged 18-30 years, 1.64 in those aged 31-65 years, and 2.36 in patients over 65 years. The difference between the mean Rotterdam scores between the oldest group and other two groups was highly statistically significant. **Conclusion.** The findings indicate a significant correlation between age and injury severity, with older patients exhibiting more severe computed tomography findings. However, impairment of consciousness at admission remained comparable across all age groups.
Key words: Brain Concussion; Consciousness; Tomography, X-Ray Computed; Age Factors; Glasgow Coma Scale

Sažetak
Uvod. U svetu više od 50 miliona ljudi godišnje pretrpi traumatsko moždano oštećenje što predstavlja rastući zdravstveno-socijalni problem. Najveći broj povređenih je u grupi sa blagim traumatskim moždanim oštećenjem, oko 80%. Takođe je rastući broj povređenih starije životne dobi. Ciljevi ovog istraživanja bili su: Poređenje razlika povređenih sa blagim traumatskim moždanim oštećenjem različitih životnih dobi u odnosu na poremećaj stanja svesti nalazom kompjuterizovane tomografije prilikom prijema u bolnicu. **Materijal i metode.** Retrospektivna studija obuhvatila je 150 povređenih sa blagim traumatskim moždanim oštećenjem koji su hospitalizovani na Klinici za neurohirurgiju Univerzitetskog kliničkog centra Vojvodine u periodu od 1. 1. 2020. do 1. 7. 2021. godine. Povređeni su prema starosti podeljeni u tri grupe. Grupe se poređene u odnosu na poremećaj stanja svesti povređenih (vrednovan *Glazgovskom koma skalom*) i nalaz pregleda kompjuterizovane tomografije (vrednovan *Roterdamskim skorom*). **Rezultati.** Statističkom obradom dobijeno je da je prosečna vrednost *Roterdamskog skora* u grupi povređenih od 18 do 30 godina iznosila 1,6; prosečna vrednost skora u grupi povređenih od 31 do 65 godina iznosila je 1,64, dok je u grupi povređenih starijih od 65 godina iznosila 2,36. Razlika između prosečnih vrednosti skorova između starijih od 65 i ostale dve grupe je visoko statistički značajna. **Zaključak.** Rezultati ove studije ukazuju na statistički značajnu razliku prosečne vrednosti *Roterdamskog skora* kod povređenih sa blagim traumatskim moždanim oštećenjem različitih životnih grupa u smislu da stariji povređeni imaju teže povrede, dok je poremećaj stanja svesti svih ispitanih grupa na prijemu bio isti.
Ključne reči: traumatsko moždano oštećenje; stanje svesti; kompjuterizovana tomografija; uzrast; Glazgov koma skor

Introduction

Traumatic brain injury (TBI) refers to structural brain damage and/or alternations in the physiological brain function resulting from an external mechanical force. It is classified as mild, moderate, or severe [1]. Each year, more than 50 million people worldwide experience TBI, making it a growing public health

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Abbreviations

TBI	– traumatic brain injury
MTBI	– mild traumatic brain injury
GCS	– Glasgow Coma Scale
CT	– computed tomography
OAC	– oral anticoagulant
AP	– antiplatelet
APT	– antiplatelet therapy

and societal concern. In Europe, the estimated annual hospitalization rate due to TBI is 262 per 100,000 individuals. The majority of cases - approximately 80% – fall into the category of mild TBI (MTBI) [2, 3]. TBI remains the leading cause of mortality and morbidity in individuals under 45 and is becoming increasingly prevalent among those over 65. Moreover, it is a major contributor to long-term disability, affecting not only survivors but also their families and society as a whole. The financial burden of TBI is substantial, encompassing both direct healthcare and rehabilitation costs as well as indirect costs related to loss of work ability [1, 4]. Additionally, approximately 10% of MTBI cases may lead to adjustment disorders [5].

The Glasgow Coma Scale (GCS) is a widely used tool for assessing consciousness levels and evaluating the severity of neurological impairment following head trauma [6–8]. It consists of three components: eye opening, best verbal response, and best motor response, with total scores ranging from 3 to 15. Patients with a GCS of 15 are fully conscious and responsive, while those with a score of 3 are in deep coma, showing no response to painful stimuli [9]. The severity of TBI is directly correlated with the degree of consciousness impairment and is classified as mild (GCS 13-15), moderate (GCS 9-12), or severe TBI (GCS ≤8) [8].

Computed tomography (CT) has become the gold standard for TBI evaluation due to its ability to detect cranial and intracranial injuries immediately. However, the clinical outcome of TBI remains unpredictable, leading to the development of various prognostic models [10, 11]. Among these, the Rotterdam CT score is widely used tool to predict injury severity. It evaluates initial CT findings based on the condition of the basal cisterns, midline shift, presence of epidural hematoma, and traumatic subarachnoid or intraventricular hemorrhage. The Rotterdam score has demonstrated strong prognostic accuracy and is predominantly applied in moderate and severe TBI cases [12, 13]. Its simplicity, reproducibility, and minimal inter-examiner variability make it a valuable tool for comparing research outcomes across studies and/or institutions [11, 14].

This study aims to:

- Identify differences in MTBI patients of different age groups regarding consciousness impairment and CT findings upon hospital admission.

- Compare gender differences, the impact of oral anticoagulant or antiplatelet therapy, and injury mechanisms in relation to consciousness impairment and CT findings at admission.

We hypothesize that older patients will present with similar levels of consciousness impairment at admission compared to younger patients, but their CT findings will indicate a higher Rotterdam CT score.

Given the potentially severe consequences, the unpredictable outcomes, and the risk of underestimating injury severity in TBI cases, it is essential to further investigate the significance of initial consciousness levels and CT findings at admission across different age groups.

Material and Methods

This retrospective study included 150 randomly selected patients with MTBI who were hospitalized at the Neurosurgery Clinic of the University Clinical Center of Vojvodina between January 2020 and July 2021. Ethical approval was obtained from the Ethics and Expert Committee of the University Clinical Center of Vojvodina (00-144).

Patients were included if they: had sustained a mild traumatic brain injury, defined by GCS score of 13-15 upon admission, were aged 18 years or older, underwent a cranial CT scan at admission, and had available medical documentation, including reports from a specialist or a resident in emergency medicine or neurosurgery at the time of admission.

Exclusion criteria included: absence of reports from a specialist or a resident in emergency medicine and neurosurgery at admission, lack of cranial CT scan at admission or inadequate imaging for evaluation, GCS scores indicating moderate or severe TBI, and admitted to another clinic within the University Clinical Center of Vojvodina due to more severe primary injury. Based on these criteria, 150 patients were classified into three age groups, with 50 patients in each: Group 1:18-30 years, Group 2:31-65 years, and Group 3:66 years and older.

The following clinical and radiological parameters were analyzed: age, sex, GCS score at admission, mechanisms of injury, use of oral anticoagulant (OAC) or antiplatelet therapy (APT), and CT findings.

Axial cranial CT scans were evaluated by a neuroradiologist and a neurosurgeon using the Vue PACS Carestream program to identify signs of traumatic brain injury. For patients with abnormal CT findings, the Rotterdam CT score was calculated based on the following criteria:

– Basal cisterns morphology: Normal (0 points), compressed (1 point), or absent (2 points).

– Midline shift, defined as the deviation of the *septum pellucidum* from the line passing along the *falx cerebri*: ≥5 mm (1 point) or <5 mm (0 points).

– Epidural hematoma: Present (1 point) or absent (0 points).

– Traumatic subarachnoid hemorrhage (tSAH) or intraventricular hemorrhage (IVH): Present (1 point) or absent (0 points).

The final Rotterdam CT score was obtained by summing the assigned points and adding 1. The lowest possible score (1) indicated a normal CT scan, while the highest (6) represented the most severe findings. In this study, the Rotterdam CT score was used solely for the numerical assessment of morphological changes on CT scans and not for outcome prediction.

Statistical analysis was conducted using SPSS Statistics 25.0. Data were presented as absolute numbers, percentages, or mean values ± standard deviation in tables or graphs. Normality of distribution was assessed using the Kolmogorov-Smirnov test. The Mann-Whitney U test and the Kruskal-Wallis test were applied for non-parametric comparisons. A p-value <0.05 was considered statistically significant.

Results

In the 18-30 age group, 37 participants (74%) were male and 13 (26%) were female **(Figure 1)**, with a mean age of 24.68 ± 3.61 years. The average GCS score was 14.86, with 44 patients (88%) presenting with a GCS of 15, five (10%) with a GCS of 14, and one (2%) with a GCS of 13 **(Figure 2)**. Regarding injury mechanisms, traffic accidents accounted for 48%, followed by assaults (30%), falls from height (10%), and sports injuries, same-level falls, and unspecified mechanisms (4% each) **(Figure 3)**. None of patients in this group were receiving OAC or APT therapy.

In the 31-65 age group, 33 participants (66%) were male and 17 (34%) were female **(Figure 1)**, with a mean age of 47.60 ± 9.56 years. The average GCS score was 14.76, with 38 patients (76%) scoring 15 and 12 (24%) scoring 14 **(Figure 2)**. Same-level falls and traffic accidents were the most frequent causes (32% each), followed by unspecified mechanisms (16%), falls from height (10%), assaults (8%), and other mechanisms (2%) **(Figure 3)**. Only one patient in this group was on OAC or APT therapy.

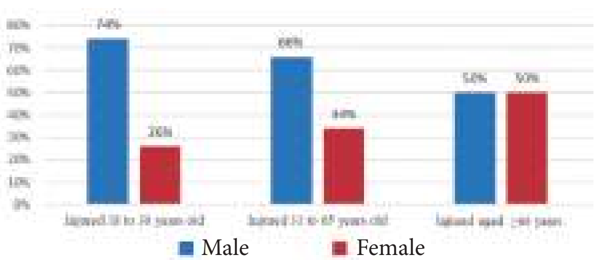

Figure 1. Gender distribution in the examined groups

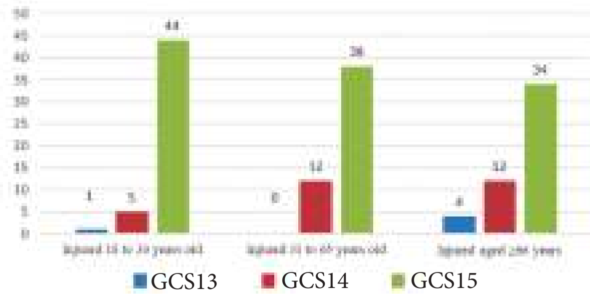

Figure 2. Average GCS value among the groups

In the ≥66 age group, there was an equal distribution of males and females (25 each) **(Figure 1)**, with a mean age of 77.24 ± 7.23 years. The average GCS score was 14.6, with 34 patients (68%) scoring 15, 12 (24%) scoring 14, and four (8%) scoring 13 **(Figure 2)**. Same-level falls were the most common cause (64%), followed by traffic accidents (18%), falls from height (10%), unspecified mechanisms (6%), and assaults (2%) **(Figure 3)**. In this group, 26% of patients were on OAC or APT therapy.

Statistical analysis showed that the mean Rotterdam CT scores were 1.6 in the 18-30 age group, 1.64

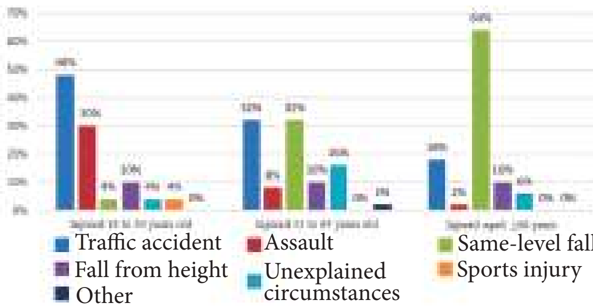

Figure 3. Distribution of injury mechanisms in the examined groups

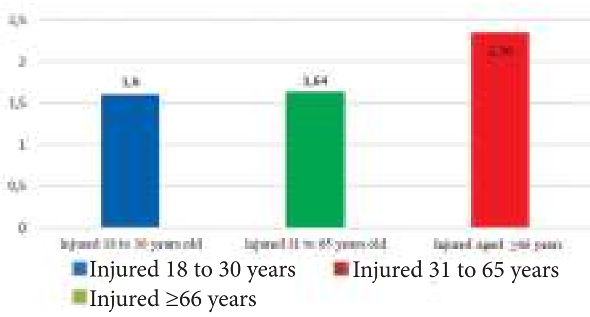

Figure 4. Average value of the Rotterdam CT score of all subjects

Table 1. Results on the Rotterdam CT score affected by age

Compared groups	Rotterdam CT score	Mann Whitney U test	p value
Injured aged 18-30	1.6	615.00	p<0.001
Injured aged 66 or older	2.36		
Injured aged 18-30	1.6	1230.00	p=0.734
Injured aged 31-65	1.64		
Injured aged 31-65	1.64	654.00	p<0.001
Injured aged 66 or older	2.36		

in the 31-65 age group, and 2.36 in the ≥66 group **(Figure 4).** A Kruskal-Wallis test showed a statistically significant difference among the three age groups (χ^2=29.29; p<0.001).

The analysis of Rotterdam CT score averages across age groups revealed the following findings: no significant difference was observed between individuals aged 18-30 years and 31-65 years (U = 1230.00, p = 0.734); significant differences were found when comparing individuals aged 18-30 years with those aged 66 or over (U = 615.00, p < 0.001) and between individuals aged 31-65 years and those aged 66 or over (U = 654.00, p < 0.001). In both comparisons involving the ≥66 age group, Rotterdam CT scores were significantly higher **(Table 1).**

Statistically significant differences in mean Rotterdam CT scores were observed across groups based on GCS. No significant difference was found between injured individuals with GCS 13 and GCS 14 (p = 0.393). Significant differences were observed between injured individuals with GCS 13 and GCS 15 (p = 0.05) and between GCS 14 and GCS 15 (p = 0.047). In both cases, Rotterdam CT scores were significantly higher in the lower GCS groups (GCS 13 and 14) compared to GCS 15.

No statistically significant differences in Rotterdam CT score averages were found based on: OAC and/or APT therapy (Mann-Whitney U = 762.00; p = 0.17); Gender (Mann-Whitney U = 2049.00; p = 1.77); Mechanism of injury (Kruskal-Wallis test = 11.32; p = 0.09).

Discussion

This study revealed difference in gender distribution and injury mechanisms within and between age groups. Among individuals aged 18-30, males accounted for 74% of cases, while females represented 26%. This discrepancy can be attributed to injury mechanism, as 48% of cases were due to traffic trauma, and studies suggest that men are more prone to aggressive and high-risk driving behaviors, increasing the likelihood of accidents [15, 16]. Additionally, 30% of injuries in this group resulted from assaults, where men are also more commonly involved [17, 18]. In the 31-65 age group, 66% of cases involved males and 34% females. The most common injury mechanisms were traffic trauma (32%) and same-level falls (32%). A gradual shift in gender distribution and injury mechanisms were observed with aging. In the ≥66 age group, male and female representation was equal (50% each). This can be explained by the high prevalence (64%) of same-level falls as the leading injury mechanism [19]. The relationship between gender and injury mechanisms observed in this study aligns with previous findings [19–21].

As the global population ages, older individuals are more susceptible to cardiovascular diseases requiring OAC or APT therapy, which increased the risk of severe clinical outcomes following TBI [22]. In this study, 26% of individuals aged ≥66 and one person aged 31-65 were on OAC/APT therapy. Statistical analysis showed no significant difference in Rotterdam CT scores between those using and not using these therapies. However, the average Rotterdam CT score was higher in the older age group, likely due to a greater incidence of hemorrhagic lesions.

Although the Rotterdam CT score is a reliable predictor of TBI outcomes, it has certain limitations. It does not account for lesion size or localization, both of which significantly influence prognosis. It does not include all intracranial abnormalities on CT scans, such as acute subdural hematomas, intracerebral hematomas, brain contusions, or diffuse axonal injury. Subdural hematoma is the most common pathology in elderly patients with same-level falls, which constituted 64% of injury mechanisms in individuals aged ≥66 in this study. If an updated scoring system accounted for subdural hematoma presence, older patients would likely have even higher scores, increasing the difference between age groups [23].

The intracranial space has a fixed volume composed of brain tissue, cerebrospinal fluid, blood vessels, and pathological process. Any increase in volume – as seen in TBI – raises intracranial pressure, leading to symptoms such as altered consciousness, which is assessed using the GCS.

With aging, brain atrophy leads to decrease in brain volume, enhancing the intracranial compensatory capacities. As a result, intracranial hemorrhage can expand significantly before causing neurological deterioration. This explains why older patients with extensive intracranial pathology may present with relatively mild clinical symptoms at admission, creating a misleading impression of less severe injury. This study included only mild TBI cases (GCS 13-15), meaning all patients had similar clinical presentation at admission. However, according to **Table 1,** older patients (≥66 years) had similar GCS scores to younger patients, despite having more extensive intracranial pathology.

A study at the University of California demonstrated that age affects GCS and Rotterdam CT scores, with older patients exhibiting higher GCS scores at admission despite similar Rotterdam CT scores [24]. Our findings are consistent with this. Additionally, another study found a correlation between older age and better clinical presentation at admission. When injuries were assessed using the Abbreviated Injury Scale (AIS), it was observed that among patients with severe injuries (AIS 5), older individuals typically had mild neurological deficits (GCS 13-15). In contrast, younger individuals had severe neurological deficits (GCS 3-8). However, mortality was higher in the elderly group. In the above study, the patients were divided into two groups: older patients (≥65 years) and younger patients (<65 years). Differences in patient stratification between studies should be considered, as they may influence certain results [8]. A study from Great Britain also found that patients aged ≥65 years had higher GCS scores at admission than patients under 65 years of age for the same injury severity as assessed by AIS [25].

One of the limitations of this study is that the Rotterdam CT score is primarily used for outcome prediction, rather than for evaluating intracranial pathology extent, which was its application here. Additionally, Rotterdam CT scores are mainly used for moderate and severe TBI, whereas this study focused only on mild TBI. As a result, only five patients had a Rotterdam CT score of 4, and no patients had scores of 5 or 6. Future studies should include patients with moderate and severe TBI, allowing for more comprehensive analysis of age-related effects on consciousness impairment and CT findings at admission.

Conclusion

The study demonstrates a statistically significant difference in Rotterdam computed tomography scores among patients with mild traumatic brain injury aged ≥66 compared to those aged 18-30 and 31-65, indicating that older patients sustain more severe intracranial injuries (higher Rotterdam computed tomography scores).

However, no statistically significant difference was observed in Rotterdam computed tomography scores between the 18-30 and 31-65 age groups.

Additionally, there was no statistically significant difference in Rotterdam computed tomography scores based on gender, mechanism of injury, or the use of oral anticoagulant or antiplatelet therapy. Nevertheless, differences were noted in the distribution of gender, injury mechanisms, and oral anticoagulant/antiplatelet therapy therapy use within and between age groups.

Despite older patients having more extensive intracranial injuries, their level of consciousness at admission Glasgow Coma Scale was comparable to that of younger patients. As a result, older patients may appear less severely injured than they actually are, potentially leading to an underestimation of injury severity.

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