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NEUROREHABILITATION IN PATIENTS WITH TRAUMATIC BRAIN INJURY

Dragan Rapaić[1], Vuk Aleksić[2], Dragan Pavlović[1], Dragan Marinković[1], Branko Đurović[3], Rosanda Ilić[3], Marko Đurović[3], Irena Cvrkota[3], & Marko Rapaić[1]

[1] University of Belgrade, Faculty of Special Education and Rehabilitation, Belgrade, Serbia
[2] Department of Neurosurgery, Clinical - Hospital Centre Zemun, Belgrade, Serbia
[3] Neurosurgery clinic, Clinical Centre of Serbia, Belgrade, Serbia

SUMMARY

Patients with traumatic brain injury (TBI) may have significant cognitive deficit and rehabilitation is based on the improvement of remaining abilities aiming to bring the person closer to premorbid profile. The aim of this study was to compare attention, memory and constructive-praxis state between healthy individuals and TBI patients before and after 4-weeks of special neurorehabilitation therapy. The experimental group (E) consisted of 15 patients with brain injury, while the control group (C) consisted of 15 healthy subjects. The assessment instruments were the subtests of "Attention" and "Memory" tests, and performed before and after the 4-weeks-therapy (focus, attention transfer, memory, and constructive practice therapy). Descriptive statistical methods and two-factor-analysis of variance was used as analytical statistical methods, where one factor represented group affiliation and the other was measurement (before and after therapy). The difference significance was determined at the level of error probability of type Iα = 0.05 (statistically significant difference p < 0.05, highly statistically significant difference p < 0.01). Results showed that all groups had 15 respondent (10 men, 5 women), ages between 15 and 18 years. In all tests high statistically significant difference between E and C group was found on the first measurement. Statistically significant difference between subjects of both groups on the second measurement was also found. High statistically significant difference of the E group on the first and second measurement was found. It can be said that applied therapies were effective. However, patients demonstrated lower score on tests after therapy than their healthy matches, indicating that four-week-therapy is not sufficient and should be continued.

Key words: neurorehabilitation, brain injury, cognitive deficit

INTRODUCTION

Rehabilitation of patients with brain injuries in special education and rehabilitation (defectology) is oriented towards the problems of persons with disabilities, not methods of rehabilitation. Rehabilitation of these patients is based on residual abilities, cognitive and motor learning, adaptive, compensatory and substitution potentials, with the aim of limiting or completely eliminating deficits. So, therapy of brain injured patients in special education and rehabilitation is oriented towards raising those cognitive and motor functions that will enable patients to integrate into the family, educational, professional and social environment. The main goal of therapy for patients with brain injury is to bring them closer as much as possible to their premorbid personality profile.

The specific goals of therapy are: (a) motor deficit therapy (initiation, navigation, capture and constructive praxis); (b) cognitive deficit therapy (attention, learning, thinking and memory); (c) establishing a dynamic relationship and transferring the effect of motor function therapy on cognitive functions and vice versa; (d) therapeutic programs for each cognitive dysfunction include a link to motor dysfunctions; (e) motor dysfunction therapy programs are related to cognitive dysfunctions.

Brain injuries

Traumatic Brain Injury (TBI) is the most common cause of death and impairment of quality of life in young people. In the United States, over 1.5 million people suffer a brain injury every year, from which about 300,000 require hospital treatment. Therefore, the treatment of brain injuries requires considerable financial support and represents a significant burden on the financial budget of each state. Traffic accidents are the most common cause of head and brain injuries in young people, while falls from a height are the most common in people over 65 years of age (Thurman, Alverson, Dunn, Guerrero, & Sniezek, 1999).

This severe pathology is increasingly catching the attention of physicians, which can easily be seen when the term *brain injury* is typed into the medical database *PubMed*®. It can be seen that in 2017 there were over 4000 papers on this subject, while in 2018 there were about 3500 papers with a title containing this key term. TBI is defined as brain damage caused by an external force, which can be due to sudden accelerations or decelerations of the head and neck, direct blows to the head, blast injuries or penetrating injuries of a foreign body. An important feature of brain injury is temporary or permanent loss of brain function (loss of consciousness, amnesia, neurological deficit), while structural damage may or may not be seen by modern technologies (Ghajar, 2000).

The severity of TBI can be evaluated with different scales, and the most commonly used in clinical practice is the Glasgow Coma Scale (GCS), which classifies TBI into 3 main groups: mild, moderate, and severe brain injury. The Glasgow Coma Scale (GCS) is a scoring system for evaluating the state of consciousness in people who have suffered brain injury. It ranges from 3 (deepest coma) to 15 (normal state of consciousness). About 80% of TBI are minor injuries with a GCS between 13 and 15, and in the majority of cases doesn't leave any neurological consequence. However, between 15% and 30% of the TBI patients develop some neurocognitive and behavioral changes (Deneshvar et al., 2011; Ghajar, 2000). Moderate TBI involve a GCS between 9 and 13, and the patient is lethargic or stuporous. In severe TBI (GCS 3-8), the patient is comatose, does not open his eyes or perform orders. Patients with severe TBI are at high risk for secondary brain injury, resulting from hypotension, hypoxia and/or brain swelling. If the GCS is lower than 9, there is a direct linear association with poor patients outcome that includes severe neurological deficit, vegetative status, and even death (Mckee & Daneshvar, 2015).

TBI are divided into two groups with respect to the time of onset: primary and secondary. Primary TBI occur at the time of injury when the tissue and blood vessels are stretched, pressed, or ruptured, e.g. they are caused by a direct or indirect effect of mechanical force (due to linear acceleration/deceleration forces, rotational forces, blast injuries, blunt object strikes, or penetrating injuries such as a projectile, and often by a combination of these mechanisms). Secondary TBI occur at a delayed time, e.g. minutes, hours, or days after injury, and represent a complication of primary injury, resulting from complex pathological biochemical and cellular cascades activated by injury (mitochondrial dysfunction, increased glutamate secretion, increased free radical production, calcium and sodium influx in the neurons, brain tissue ischemia, hypoxia, brain swelling, and consequent increased intracranial pressure) (Park, Bell, & Baker, 2008). Primary TBI are generally definitive. Secondary injuries are often reversible and that is why they represent a potential target for therapeutic procedures in the treatment of TBI.

The morphology TBI classification is very complex and is often identified with craniocerebral injuries classifications, which in addition to brain injuries include injuries to the skull and soft tissues of the head (injuries such as fracture of the skull and acute subdural hematoma are often associated). TBI are divided into: open and closed TBI depending on skin integrity in terms of morphological characteristics (although some authors presume only brain tissue exposure as a criterion). Open injuries can be penetrating and perforating. Closed injuries are further divided into focal and diffuse. Focal injuries can be extra-axial and intra-axial, depending on whether the pathological substrate is in the brain tissue itself (intra-axial, e.g. contusion) or around the brain tissue and by its compressive effect causes damage (extra-axial, e.g. epidural hematoma). Focal brain injuries include brain contusions and intracranial hematomas (epidural, subdural, and intracerebral). Diffuse brain injury refers to widespread brain dysfunction, most often without visible macroscopic structural damage, although in some cases macroscopic substrate may be evident, such as in diffuse brain tissue edema after injury. Often these injuries occur at the same time, and classification is more the result of a systematic approach for the purpose of treatment according to good medical practice protocols (Đurović, 2013).

Traumatic brain injury consequences

TBI in survivors leaves significant consequences, even in patients with mild traumatic brain injury (mTBI) (Pavlović, 1999). Severe disability after TBI is found in 15-20 per 100000 people per year (Fleminger & Ponsford, 2005). Most of these patients will have a combined mental and physical disability after the injury. When it comes to moderate and severe TBI, personality changes, amnesic disorders, reasoning, apathy, motor, speech and epilepsy disorders are very common (Lindsay, Bone, Fuller, & Callander, 2010). About 90% of patients recover at least partially within the first 6 months, but some continue to recover for many years. Permanent disability is present in 10% of mTBI, 66% in moderate TPM, and 100% when it comes to severe TBI (Frey, 2003).

Mild traumatic brain injury

Mild traumatic brain injury has many different definitions, but most commonly is defined with the GCS score between 13 and 15 according to state of consciousness (Prince & Bruhns, 2017). Sometimes the term brain concussion is also used. By definition, there are no neurological consequences. Mild TBI results in cognitive, vestibular and psychiatric disorders. The most general disorder is slowing the speed and capacity of information processing (Ojile et al., 2006). In these patients, divided attention is problematic (performing multiple tasks at the same time), distractibility is enhanced, and patient may be confused in the acute phase. Usually, patients recover in the manner of few weeks, but in about 15% of patients the consequences are permanent (Røe, Sveen, Alvsåker, & Bautz-Holter, 2009). Neuropsychological examination shows disorders of attention, memory, speech, visuospatial gnosis, and abstract thinking (Pavlović, 1999). Patients are easily fatigued and dysphoric. Automated actions require a conscious effort. Post-concussion syndrome occurs in about 10-20% of patients with mild TBI, and it is characterized by chronic disorders such as headaches, neck pain, instability, dizziness, impaired attention and memory, dyspepsia syndrome, and depression (Alexander, 1995; Ruff, 2005).

Neuropsychological consequences

The neuropsychological consequences of TBI can be focal or diffuse and include deteriorated cognition, memory, personality, and social functioning (Pavlović, Ocić, Stefanova, & Filipović, 1994). Anterograde and retrograde amnesia can been maintained for some time (Wang & Li, 2016). Also, verbal functions recover faster while non-verbal functions recover for a longer period of time (Strub, Black, & Strub, 1988).

Prefrontal injuries are associated with dysexecutive syndrome, complex attention disorders, impaired instrumental activities of daily living, impaired social cognition, and impaired motor activity (Williamson, Scott, & Adams, 1996). Different speech disorders can occur in TBI: all types of aphasia, but also more subtle language disorders such as processing of complex verbal information, learning new information's and social functions (Gkoltsiou et al., 2008; Vas, Chapman, & Cook, 2015). In TBI visuo-spatial and visuo-structural disturbances are common (Ilie, Cusimano, & Li, 2017). Behavioral failures are mainly related to orbitofrontal lesions in the form of disinhibition, euphoria and loss of social norms and this lesion disrupt everyday life in great manner (Pavlović, Milović, Ocić, & Tomić, 2000).

Post-traumatic amnesia

Post-traumatic amnesia refers to declarative memory, namely the inability to remember new information (anterograde amnesia) and the difficulty of recalling already remembered information (retrograde amnesia) (Pavlović, 1999). The length of amnesia duration varies from case to case. In terms of retrograde amnesia, the amnesia period usually shortens and finally the patient can't remember only last 30 seconds before injury, when information was not transmitted into long-term memory. The period of anterograde amnesia varies, and this type of disorder is also characterized by poor strategies for remembering and recalling. Verbal memory is impaired in left-sided and spatial memory in right-sided lesions (HS, 1997).

Long-term consequences

Some disorders of memory may be permanent after TBI, especially since in the closed TBI, which is the most common, the temporal and frontal lobes, as well as the hippocampus are typically affected. Also the retrieval memory processes can be disturbed and working memory can be damaged. There are also frontal memory disorders that include disabled formulating strategies (Bigler et al., 1996).

Rehabilitation of cognitive and praxis dysfunctions in TBI patients - a theoretical approach

Anohin believes that no organization, no matter how extensive it may be in the number of constituent elements that make it up, can be called a self-regulatory system, if its functioning, that is, the interplay between the parts of that organization does not end with a useful result for the system and if there is no feedback to the managing center about the degree of usefulness of the results. He believes that within each functional system there is a possibility of extraordinary interchangeability, and mutual compensation of their effectors mechanisms. As a result, dropping out of one or more executable components from the machine, such a functional system can achieve a final adaptation result by introducing other components (Anohin, 1979). Luria believes that, in persons with brain injury, the intact parts of the brain are dynamically reorganized in the direction of performing functions in another way. He points out that the recovery of function in people with TBI occurs in the presence of "active exercises incorporated into the reeducation program". The basic principles of retraining (reeducation) are: (1) Formulation of a "restorative training" plan; (2) training the patient in the implementation of compensatory strategies (using the same functions in a different way); (3) the scope and content of restorative training must be elaborated (training tasks must be broken down into series of highly articulated skills and aptitude) (Luria, 1983).

The aim of this study was to compare attention, memory and constructive praxis state between healthy individuals and patients with TBI before and after 4-weeks of focus therapy, attention transfer therapy, memory therapy, and constructive praxis therapy.

METHOD

The experimental group (E) consisted of 15 patients with radiology confirmed brain contusion, while the control group (C) consisted of 15 healthy subjects. There were 10 men and 5 women in each group.

The inclusion criteria for the E group were: subjects had brain injury (as determined by the neurosurgeon); that there are no multiple skeletal bone fractures (as determined by the orthopedic surgeon); that there are indications for further neurological observation (as identified by the neurologist); that the patients are between 15 and 20 years of age of both sexes; that there were no developmental disorders in the subjects (as determined by taking a history from their parents). All patients had no neurological deficit in terms of extremity paresis or paralysis. C group consisted of healthy volunteers who were equal to members of the experimental group by gender, years of age, education level, school performance and occupation.

All E group subjects had brain contusion. According to the findings of the neurosurgeon 7 patients were operated, 9 patients had skull fracture, 7 subjects had brain edema, and 8 subjects had intracranial hemorrhage. All subjects sustained a brain injury in a car accident. All but one of the respondents were aware on the admission.

Each group had 15 respondents: 10 men and 5 women; 3 respondents were 15 years of age; 1 respondent was 16 years; 1 respondent of 17 years; 4 respondents aged 18; 1 respondent of 19 years and 3 respondents of 20 years.

The assessment instruments were the subtests of "Attention" and "Memory" tests (number memory test, orientation test, remembering time-distant events test, learning capabilities test, and the story recall test – all tests were from the "Mental Status Examination"). The results of each group respondents were calculated in relation to the maximum possible score of each individual subtest and the average achievement was calculated.

Constructive praxis was tested with subtests from the Mental Status Examination: "Picture copying" test and "Drawing on a command" test.

The measurement results in the surveys in all subtests are dichotomously categorized as "satisfactory" or "unsatisfactory".

Testing was performed before and after the therapy that consisted of focus therapy, attention transfer therapy, memory therapy, and constructive praxis therapy. Initial testing and therapy in E group started 7-10 day after injury. Therapy was conducted every day for four weeks.

Therapeutic tasks that related to focusing attention (focus therapy) consisted of requiring the patient to signalize: even numbers, odd numbers, and selected words that occur 6-7 times in literary content.

Therapeutic tasks related to attention transfer therapy required of patients the simultaneous enumeration of male and female names, followed by fruits and vegetables and finally domestic and wild animals.

In memory therapy tasks, we asked patients to remember the contents to which they were previously exposed and which are parts of their experiences. Memory tasks included remembering: a series of numbers, brief literary and simple visuals (photographs of things, animals and landscapes). Another element of this therapy was the time interval at which patients needed to memorize and repeat certain contents (short-term and long-term memory).

Constructive praxis therapy consisted of several tasks. In the first task, we asked patients to reconstruct photographs that were cut into 4 and then into 5, 6, and 7 sections. In the second task, it was necessary to imitate the construction made of cubes in the same way. We designed this task with 5 cubes at the beginning, and then we increased number of cubes and complexity of the task. The third task consisted of imitating models of triangles (12 triangles) in two sizes and two colors. Finally, patients were tasked with sketching simple three-dimensional drawings.

Frequencies and percentages were used as descriptive statistical methods. Two-factor analysis of variance was used as analytical statistical methods, where one factor represented group affiliation (E or C) and the other factor was measurement (before and after therapy. e.g. I and II measurement). The significance of the difference was determined at the level of error probability of type Ia = 0.05 (statistically significant difference $p < 0.05$, highly statistically significant difference $p < 0.01$). The results are presented in tables. Data were processed using the easy-R software system (EZR, version 1.41. 64-bit)®.

RESULTS

Table 1. *Respondents' achievements at Number memory test*

Group	Number memory test							
	Measurement							
	I				II			
	N	n	m	%	N	n	m	%
E	15	135	55	40.74	15	135	84	62.22
C	15	135	99	73.33	15	135	101	74.81

Tested differences on the subtest show high statistical significance between subjects of E and C group on the first measurement ($p < 0.01$); statistical significance between respondents of both groups on the second measurement ($p < 0.05$) and high statistical significance of the E group respondents on the first and second measurements ($p < 0.01$).

Table 2. *Respondents' achievements at Orientation test*

Group	Orientation test							
	Measurement							
	I				II			
	N	n	m	%	N	n	m	%
E	15	165	107	64.84	15	165	149	90.30
C	15	165	165	100	15	165	165	100

The intergroup differences on the first and second measurements are highly statistically significant ($p < 0.01$). There is a highly statistically significant difference in the E group subjects on the first and second measurements ($p < 0.01$).

Table 3. *Respondents' achievements at Remembering time-distant events*

Group	Remembering time-distant events							
	Measurement							
	I				II			
	N	n	m	%	N	n	m	%
E	15	90	46	51.11	15	90	76	84.44
C	15	90	90	100	15	90	90	100

The intergroup differences tested on the first and second measurements are highly statistically significant ($p < 0.01$). The differences between the first and second measurements in the E group respondents are highly statistically significant ($p < 0.01$).

Table 4. *Respondents' achievements at Learning capabilities test*

Group	Learning capabilities test							
	Measurement							
	I				II			
	N	n	m	%	N	n	m	%
E	15	180	41	22.77	15	180	93	51.66
C	15	180	172	95.55	15	180	175	97.22

Intergroup differences of E and C group on the first and second measurements are highly statistically significant ($p < 0.01$). There is a highly statistically significant difference in the E group respondents on the first and second measurements ($p < 0.01$).

Table 5. *Respondents' achievements at Story recall test*

Group	Story recall test							
	Measurement							
	I				II			
	N	n	m	%	N	n	m	%
E	15	330	47	14.24	15	330	95	28.78
C	15	330	164	49.69	15	330	169	51.21

There is a highly statistically significant difference between the subjects of both groups on the first and second measurements ($p < 0.01$). There is also a highly statistically significant difference in the E group subjects on the first and second measurements ($p < 0.01$).

Table 6. *Respondents' achievements at Picture copying test*

Group	Picture copying test							
	Measurement							
	I				II			
	N	n	m	%	N	n	m	%
E	15	225	127	56.44	15	225	178	79.11
C	15	225	223	99.11	15	225	224	99.55

The intergroup differences in the study groups on the first and second measurements are highly statistically significant ($p < 0.01$). There are highly statistically significant differences in the first and second measurements in the E group patients ($p < 0.01$).

Table 7. *Respondents' achievements at Drawing on a command test*

Group	Drawing on a command test							
	Measurement							
	I				II			
	N	n	m	%	N	n	m	%
E	15	135	65	48.14	15	135	104	77.03
C	15	135	132	97.77	15	135	134	99.25

The intergroup differences in the study groups on the first and second measurements are highly statistically significant ($p < 0.01$), also there are highly statistically significant differences in the first and second measurements in the E group patients ($p < 0.01$).

DISCUSION AND CONCLUSION

Based on the results obtained regarding attention and memory, we can conclude that the therapy we used was effective and that patients achieved significant recovery. An integral part of this finding is that their lagging behind their healthy peers is also significant and that four weeks of therapy is not enough. We can very likely conclude that the recovery of attention led to the recovery of memory, most notably memory for orientation and memory of distant events, and significantly less memory - new learning abilities and memory - a story to repeat. Patient achievement in the domain of cognitive function can be interpreted by complexity of these functions. These findings are in accordance with other studies. Lesniak et al., (2019) showed that a comprehensive program of cognitive rehabilitation may improve memory and attention, as well as cognitive functioning on daily basis in patients with severe or moderate TBI (Leśniak, Iwański, Szutkowska-Hoser, & Seniów, 2019).

Results related to therapy of constructive praxis indicate significant patient recovery and effectiveness of therapy. It is noticeable that patients performances are still significantly behind their healthy peers and that therapy should be continued. Patient outcomes are significantly more consistent after treatment compared to pre-treatment results. This information can be interpreted by the relative closeness of the ability of constructive praxis - drawing on a command and constructive praxis - picture copying.

Even though the apraxia incidence after TBI is considerable, the evidence on treatment and recovery is very obscure. There are several reasons for this: (1) apraxia patients often seem to be unaware of deficit and hardly ever complain; (2) recovery from apraxia is sometimes considered to be spontaneous and treatment is not necessary; (3) some studies showed that apraxia occurs when performance is requested of patients in testing situations and that correct performance is displayed in non-testing situations (Leśniak et al., 2019). These points of view probably threw apraxia problems into the scientific shadow which is why the number of studies on this topic is very small. However, available studies were analized by EFNS members of the task force on cognitive rehabilitation, and their results clearly suggest that treatment of apraxia should be part of the rehabilitation program after TBI. Our findings also suggest that therapy of constructive praxis leads to significant patient recovery (Cappa et al., 2005).

There is a clearly need for adequately designed, large, randomized studies in this area of rehabilitation after TBI, which should take into account specific problems such as patient heterogeneity and treatment standardization, after which better guidelines would be used in every day clinical practice.

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