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Original Article

The impact of physical therapy in patients with severe traumatic brain injury during acute and post-acute rehabilitation according to coma duration

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Abstract. [Purpose] The aim of study was to evaluate the impact of physical therapy on the recovery of motor and mental status in patients who sustained a severe traumatic brain injury, according to coma duration in acute and post-acute rehabilitation. [Subjects and Methods] The study population comprised patients with levels of consciousness ranging from 3 to 8 according to Glasgow Coma Scale score. The patients were divided into 2 groups based on coma duration as follows: group 1, those who were in a coma up to 1 week, and group 2, those who were in a coma for more than 2 weeks. The recovery of the patients' motor function was evaluated according to the Motor Assessment Scale and the recovery of mental status according to the Mini-Mental State Examination. [Results] The evaluation of motor and mental status recovery revealed that the patients who were in a coma up to 1 week recovered significantly better after physical therapy during the acute rehabilitation than those who were in a coma for longer than 2 weeks. [Conclusion] The recovery of motor and mental status of the patients in acute rehabilitation was significantly better for those in a coma for a shorter period.

Key words: Traumatic brain injury, Coma duration, Physical therapy

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INTRODUCTION

Traumatic brain injury (TBI) is one of the most common causes of mortality and disability worldwide, especially among children and young individuals. The annual number of TBI cases is considerably increasing, and TBI is the third leading cause of all injury-related deaths[1, 2].

The distribution of people who sustained a TBI according to gender is similar across the world. Men account for the greatest part of these patients. The male-to-female ratio is 3:1 in many countries worldwide, as well as in Lithuania[3–5]. Traffic accidents have been reported to be the most common cause of TBI. Among the elderly, TBI is most frequently caused by falls[6, 39].

Severe TBI is characterized by an extended period of unconsciousness, which can last for numerous days or even months, and coma, especially long-term, is an indicator of poor prognosis[7, 8]. TBI has been noted to cause movement, emotional, cognitive, and behavioral impairments[9–13, 38].

The relevance of treatment of patients who have sustained a TBI is increasing in all developed countries. However, to

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date, no effective and efficient treatment has been established that could prevent secondary brain damage caused by the inflammatory response at the site of injury[14].

Rehabilitation during the early period of the disease (acute rehabilitation) remains a main part of treatment for patients with TBIs. The application of physical therapy in these patients during the early inpatient period of rehabilitation (post-acute rehabilitation) is of paramount importance to ensure physical activity and the recovery of cognitive functions[15]. Physical therapy is a constituent of rehabilitation directed to the prevention of various complications (pneumonia, contractures, thromboembolism, etc.), improvement of motor function, training of balance and movement coordination, and improvement of cognition. Physical therapy covers patients' follow-up and assessment by using various standardized and nonstandardized tests and scales and the evaluation of the results obtained.

In the literature, emphasis is placed on coma duration in the recovery of motor and cognitive functions. Some authors have pointed out that the recovery of motor and mental status depends on the coma duration, while others have stated that prolonged coma only extends the period of rehabilitation, which is very practical regarding a financial aspect[16, 17].

The aim of this study was to evaluate the impact of physical therapy on the recovery of motor and mental status in patients who sustained severe traumatic brain injuries, according to coma duration in acute and post-acute rehabilitation.

SUBJECTS AND METHODS

This study was conducted in the brain injury and neurorehabilitation units of the Hospital of Lithuanian University of Health Sciences. Patients with severe TBI are typically treated first in acute medical settings, where the patient is medically stabilized and enrolled in acute rehabilitation, and then discharged to post-acute rehabilitation.

The study was approved by the Bioethics Center of Lithuanian University of Health Sciences (No. BC-SLF(M)-42). All of the participants provided their written informed consent prior to their participation in the study, in accordance with the ethical principles of the Declarations of Helsinki.

For the study, 52 patients (39 males and 13 females) were randomly enrolled during the acute rehabilitation, of whom 16 (11 males and 5 females) were referred to the neurorehabilitation unit during the post-acute rehabilitation.

The level of their consciousness ranged from 3 to 8 according to Glasgow Coma Scale scores. According to coma duration, the patients were divided into 2 groups as follows: the first group comprised patients who were in a coma up to 1 week (group 1), and the second group included patients who were in a coma for more than 2 weeks but not longer than 4 weeks (group 2). Each group consisted of 26 patients during the acute rehabilitation period. No significant gender- and age-related differences were observed between the two groups ($p>0.05$). In the neurorehabilitation unit (post-acute rehabilitation), 10 patients in group 1 and 6 patients in group 2 were admitted. No sex- and age-related significant differences were found between the two groups ($p>0.05$).

Rehabilitation covered two periods as follows: an acute period from injury to condition stabilization (in the brain injury unit; acute rehabilitation) and from condition stabilization to the recovery of functions (in the neurorehabilitation unit; post-acute rehabilitation). The patients in both groups underwent four assessments of functional and mental status. During the acute rehabilitation, the patients were assessed in the brain injury unit before the physical therapy procedures (assessment 1) and before discharge during the last physical therapy procedure (assessment 2). During the post-acute rehabilitation, the study took place in the neurorehabilitation unit. Assessments were performed before physical therapy procedures (assessment 3) and before discharge during the last physical therapy procedure (assessment 4). The patients underwent individual sessions of physical therapy every day. Each procedure performed twice a day usually took 30–60 minutes to complete. In the brain injury unit, during the acute rehabilitation, the patients underwent 14.6 ± 4.3 procedures. In the neurorehabilitation unit, during the post-acute rehabilitation, the patients underwent 78.7 ± 2.8 procedures. In post-acute rehabilitation, an individual rehabilitation plan is tailored to each patient. After a comprehensive patient examination, the physical therapist considered the impairment of the patient's motor (muscle tone, muscle strength, balance, movement coordination, and proprioception) and cognitive (memory, perception, and motivation) functions in creating an individual physical therapy plan.

The duration of the physical therapy procedures and complexity, repetition number, and intensity of exercises were tailored individually, considering the patient's state of consciousness, age, and physical status. The physical therapy program consisted of positioning, and passive and active physical therapies to strengthen the limb and trunk muscles, to increase the range of motion, to improve the coordination of movements and balance, and to train functional movements. Moreover, cognitive functions were trained. The patients were taught to concentrate their attention to a movement being performed, motivated to remember and perceive verbal information, and count the movements performed[17]. The patients received physical therapy and regular medicament treatment prescribed by their physicians.

Motor recovery was assessed according to the Motor Assessment Scale (MAS), and the recovery of mental status was evaluated according to the Mini-Mental State Examination (MMSE)[19, 20]. Activities according to the MAS were evaluated based on the patient's abilities to perform them. Each motor item was scored on a 0- to 6-point scale. The minimal score according to the MAS was 0, and the maximal score was 54. The following functions were assessed: supine to side lying, supine to sitting over side of bed, balanced sitting, sitting to standing, walking, upper arm function, hand movements, advanced hand activities, and general muscle tone.

Mental status was evaluated according to the MMSE, which tests orientation to time and place, recall, attention, short-term

memory, language, comprehension, writing, reading, and ability to copy a drawing. MMSE scores ranged from 0 to 30. A score of 0 to 10 indicates severe cognitive impairment; 11 to 20, moderate; 21 to 24, mild; and ≥25, no cognitive impairment.

Statistical data analysis was performed by using the SPSS 17.0 software. The Excel 2007 for Windows program was used to graphically depict the results of the study. Continuous data were expressed as mean and standard deviation. Differences between the means of the independent samples were evaluated with the Student t-test; those between the means of dependent samples, with the paired t-test. The dependence between variables was determined with the χ^2 criterion. The nonparametric criteria for two independent or dependent samples were determined by using the Mann-Whitney U test or Wilcoxon test, respectively. The *z* criterion was calculated. The Spearman correlation coefficient (*r*) was used to evaluate the strength of the relationship between variables. Differences were considered significant when p was ≤0.05.

RESULTS

During the acute rehabilitation, the motor function of the patients in group 1 before physical therapy was severely impaired. The application of various physical therapy methods and special means resulted in an improvement in the motor function at the beginning of the acute period (3.3 ± 1.7 vs. 4.0 ± 1.8, $p<0.05$). In group 2, the motor function was rated with a score of 1.6 ± 1.3 before physical therapy and 2.7 ± 1.7 after physical therapy procedures ($p<0.05$) according to the MAS. The evaluation of motor recovery during the acute rehabilitation according to coma duration revealed that the patients in group 1 showed significantly better motor recovery after the physical therapy sessions than their counterparts in group 2 ($p<0.05$; Table 1). Moreover, a trend toward a positive impact of faster improvement of motor functions on the faster motor recovery was observed during the post-acute rehabilitation.

The abilities that showed significant differences between the groups during the acute rehabilitation according to coma duration were analyzed more thoughtfully. The evaluation and comparison of walking ability according to the MAS at the end of the acute rehabilitation revealed significant differences between the groups ($p<0.05$). The recovery of functions in the patients in group 1 was better (i.e., they were able to perform more complex tasks) than that in the patients in group 2.

The application of special physical therapy measures resulted in a significant improvement in the upper arm function in both groups after physical therapy at the end of acute rehabilitation ($p<0.05$). Comparison of the results between the groups showed a better recovery of upper arm function in the patients of group 1 ($p<0.05$). This shows that coma duration influenced the recovery of movements.

At the end of the acute rehabilitation, most of the patients in group 1 could perform independently tasks such as moving items from one side of the body to another, whereas the patients in group 2 could only perform wrist movements such as supination and pronation. After physical therapy during acute rehabilitation, the patients in group 1 could perform more-complex tasks than their counterparts in group 2 ($p<0.05$).

At the beginning of the post-acute rehabilitation, the patients in groups 1 and 2 scored 3.4 ± 1.2 and 2.9 ± 1.2 on the MAS, respectively. After physical therapy, a significant improvement in motor function was observed (MAS scores, 4.1 ± 1.4 and 3.7 ± 1.4, respectively; both $p<0.05$).

The evaluation and comparison of general muscle tone according to the MAS at the beginning of the post-acute rehabilitation revealed that the patients who were in a coma for a shorter period had significantly better general muscle tone than those who were in a coma for more than 2 weeks ($p<0.05$). However, at the end of the post-acute rehabilitation, no significant difference between the groups was observed ($p>0.05$).

In summary, the results of this study indicate no significant differences in motor recovery between assessments 2 and 4 ($p>0.05$; Table 2), and only a trend toward improved motor function was observed.

In the acute rehabilitation, mental status as assessed by using the MMSE before physical therapy was severely impaired in both groups (MMSE scores, 1.4 ± 0.8 and 0.8 ± 0.8, respectively). At the end of the acute rehabilitation after physical therapy, a significant improvement in mental status was observed in both groups as follows: the patients in the groups 1 and 2 scored 2.2 ± 0.6 and 1.7 ± 0.8 on the MMSE, respectively, with the differences between the periods being significant ($p<0.05$).

After the physical therapy procedures, the orientation to time improved significantly in all the evaluated patients ($p<0.05$). The comparison of the results between the groups revealed that the patients in group 1 had significantly better orientation to time than those in group 2 ($p<0.05$). The evaluation of orientation to time after physical therapy revealed significantly better results in group 1 than in group 2 ($p<0.05$). Moreover, a significant difference between the groups was observed in the evaluation of attention according to the MMSE ($p<0.05$).

After physical therapy, during which the patients were asked to recognize the means of physical therapy, they were named significantly better by the patients of the group 1 ($p<0.05$). At the beginning of acute rehabilitation, of the 20 patients who sustained severe TBIs in group 1, 3 could repeat the words *no*, *ifs*, *ands*, and *buts*. None of the patients in group 2 could repeat these words. A comparison of the ability to repeat these words after physical therapy at the end of the acute rehabilitation revealed that the patients in group 1 performed this task significantly better that the patients in group 2 ($p<0.05$).

After physical therapy, the recovery of mental status significantly differed between the groups ($p<0.05$). The patients in group 1 performed significantly better than those in group 2 on the tasks associated with orientation to time and place, attention, naming a pencil and a watch, and repetition of some words (Table 3). At the post-acute rehabilitation, the mental status of the patients in the group 1 was 1.4 ± 0.6 according to the MMSE before physical therapy. The application of special

Table 1. Motor recovery evaluated by using the Motor Assessment Scale in patients who sustained severe traumatic brain injuries, according to coma duration during the acute rehabilitation

	Group 1		Group 2	
	Assessment 1	Assessment 2	Assessment 1	Assessment 2
Supine to side lying	3.5	4.6	1.9	3.2
Supine to sitting over side of bed	3.4	4.5	1.6	3.1
Balanced sitting	3.25	4.05	1.4	2.8
Sitting to standing	2.5	3.6	0.8	2.2
Walking	2.15	3.3	0.45	1.45*
Upper arm function	2.5	4.2	1.55	2.85*
Hand movements	3.45	4.05	1.3	2.5*
Advanced hand movements	3.0	3.45	1.0	2.0*
General muscle tone	4.6	4.5	4.0	4.25*

*p<0.05, comparison of the groups before (assessment 1) and after physical therapy (assessment 2)

Table 2. Changes in motor function evaluated by using the Motor Assessment Scale during acute and post-acute rehabilitation in patients who sustained severe traumatic brain injuries

	Assessment 1	Assessment 2	Assessment 3	Assessment 4
Supine to side lying	2.7	3.9	3.9	5.0
Supine to sitting over side of bed	2.5	3.8	3.7*	4.7
Balanced sitting	2.2	3.5	3.2*	4.3
Sitting to standing	1.7	2.8	2.5	3.6
Walking	1.2	2.5	1.9*	2.9
Upper arm function	2.5	3.4	3.2	3.9
Hand movements	2.3	3.1	3	3.5
Advanced hand movements	2.0	2.8	2.1	2.9
General muscle tone	4.2	4.1	4.0	4.0

*p<0.05, comparison between assessments 1 and 3

Table 3. Recovery of mental status in patients who sustained severe traumatic brain injuries, according to coma duration during the acute rehabilitation

	Group 1		Group 2	
	Assessment 1	Assessment 2	Assessment 1	Assessment 2
Orientation to time	2.6	4.2	0.9***	2.75
Orientation to place	2.3	4.2	0.8***	2.7
Recall	2.2	2.9	1.9	2.6*
Attention	2.15	3.2	1.1	2.3**
Short-term memory	1.0	2.2	0.6	1.7
Subject naming	1.65	2.0	1.4	1.8**
Word repetition	0.2	0.8	0	0.4**
Folding a sheet of paper	0.8	2.5	0.6	2.0
Accomplishment of written command	0.75	1.0	0.6	0.9
Sentence writing	0.7	1.0	0.6	0.85
Copying a drawing	0.5	0.9	0.4	

*p<0.05, comparison between the groups during assessment 1 (before physical therapy)
**p<0.05, comparison between the groups during assessment 2 (after physical therapy)
***p<0.05, comparison between the groups during assessment 1 (before physical therapy) and assessment 2 (after physical therapy)

physical therapy methods resulted in a significant improvement in mental status that was rated with a score of 2.1 ± 0.6 at the end of post-acute rehabilitation ($p<0.05$). In group 2, the mental status before and after physical therapy were rated with scores of 1.9 ± 0.8 and 2.4 ± 0.6, respectively ($p<0.05$), according to the MMSE.

At the post-acute rehabilitation, the evaluation of mental status and the comparison of the results between the groups revealed no significant differences in the evaluation of the following tasks: to read and do what was written ("Close your eyes"), to write a sentence, and to copy a drawing. While performing other tasks, significantly better results according to the MMSE were achieved by the group of patients who were in a coma for a shorter period ($p<0.05$). According to the results of this study, no significant differences in the evaluation of mental status after physical therapy were documented in the comparison between the groups ($p>0.05$).

During the study, the recovery of motor and mental status and whether these variables were interrelated were analyzed. A correlation analysis revealed a direct linear relationship between almost all the parameters of motor evaluation. Significant positive correlations between walking and sitting to standing ($r=0.835$, $p<0.05$), between walking and balanced sitting ($r=0.878$, $p<0.05$), and between orientation to time and place ($r=0.669$, $p<0.05$) were observed.

By analyzing the recovery of cognitive functions, whether a relationship exists between short-term memory and attention in patients who sustained severe TBIs was determined. The analysis revealed a significant linear relationship between short-term memory and attention ($r=0.675$, $p<0.05$).

The evaluation of motor parameters and mental status revealed that a significant moderate, positive relationship prevailed ($p<0.05$). A linear relationship was observed between motor parameters and orientation to time and place, attention, recall, and the tasks such as folding a sheet of paper in half and putting it down on the knees, sentence writing, and copying a drawing. A linear relationship was observed between attention and walking ($r=0.451$, $p<0.05$) and between orientation to time and sitting to standing ($r=0.569$, $p<0.05$).

While analyzing the recovery of motor and mental status separately during the acute rehabilitation before and after physical therapy, a weak significant correlation between these parameters was found both in group 1 ($r=0.245$, $p<0.05$) and group 2 ($r=0.265$, $p<0.05$). During the post-acute rehabilitation, a significant weak correlation was observed in group 1 ($r=0.262$, $p<0.05$). Meanwhile, in group 2, the correlation between mental status and motor recovery was moderate ($r=0.488$, $p<0.05$).

Evaluation and comparison of motor recovery at the end of the post-acute rehabilitation and mental status recovery at the end of the acute rehabilitation revealed a moderate significant correlation both in the patients who were in a coma up to 1 week ($r=0.378$, $p<0.05$) and those who were in a coma for more than 2 weeks ($r=0.488$, $p<0.05$).

DISCUSSION

TBI is one of the most common causes of death and disability, especially among children and young persons, worldwide, which can cause movement, cognitive, and behavioral impairments[9–13, 38]. Early rehabilitation interventions seem to be essential for successful patient recovery after a severe brain injury. It might even increase the chances for long-term survival[35, 36].

Physical therapy plays an important role in the recovery of impaired functions, during which the patient's functional status is assessed and appropriate methods and measures are tailored to individual patients[21]. In this study, the MAS was used to evaluate patient functional status as patients with TBI develop paralysis, muscle spasticity, and balance, coordination, and sensory impairments. All these factors limit mobility[8].

The results of this study showed that among all 8 motor abilities, the worst improvement was observed in walking ability. Walker and Pickett reported that gait impairment is a common problem in patients who sustained TBIs[22]. Therefore, other authors suggested paying special attention to walking, balancing, and stair climbing in the improvement of mobility of patients with TBI during physical therapy[23].

Sancisi et al. presented the case of a patient who sustained TBI and regained the abilities to walk, speak, perform daily activities, and undertake outdoor leisure activities independently after a 7 year rehabilitation[24]. This shows that motor functions can recover even after a long period and that every period is important for recovery. Williams and Goldie conducted a study that compared 40 subjects (20 runners and 20 nonrunners) who sustained TBIs. They had to perform 4 specific motor tasks, including to bound onto a leg, walk on toes, step backward up a step, and balance on one leg. The results showed that all these 4 tasks were the factors that influenced the ability to run, but coma duration did not have any impact in either the runners or the nonrunners[16]. Based on the present data, coma duration was associated with recovery of walking ability.

Tamashiro et al. investigated head control and turning, visual fixation and pursuit, and trunk movement and control in patients with TBIs and reported that significantly better results were achieved by the patients who were in a coma for a shorter period[25].

The evaluation of hand movements according to the MAS revealed that the smallest improvement in recovery was documented while performing advanced hand movements both in the patients who were in a coma up to 1 week and in those who were in a coma for more than 2 weeks. Only at the end of the acute rehabilitation did the patients who were in a coma for the shorter period showed significantly better recovery results for hand movements. Based on the present data, in the patients with TBIs, advanced hand movements were the most impaired, and upper hand function was the least impaired. Cho et al. emphasized that the individual training of hand movements is an effective physical therapy method to recover the movements

of the affected hand of patients with TBIs[26].

The findings of this study indicated that in the recovery of mental status, coma duration was associated with orientation to time and place, attention, naming a pencil and a watch, and word repetition. Meanwhile, Lammi et al. do not recommend making prognostic statements on the recovery of mental status based on coma duration[18]. These results suggest that more-extensive studies involving later rehabilitation stages should be conducted.

Literature sources report that with an improvement in the balance of patients with neurological impairments, gait improves as well. This study shows a significant positive correlation between walking and sitting to standing, as well as between walking and balanced sitting. Some studies suggest that gait should be trained in patients who sustained a TBI, and various gait training methods such as treadmill walking with self-support using the upper limbs improve the effectiveness of rehabilitation[27].

Tappan conducted a study that was aimed at determining if attention and cognitive function training had an impact on balance training in patients who had sustained head injuries. A 16-year-old patient who sustained a head injury underwent physical therapy, which aimed to improve patient's balance in a quiet, nondistracting environment and then in a distracting environment. Losses of balance became more frequent in distracting environments when the patient diverted his attention to a distraction. His physical therapy plan of care included balance training and improvement of cognitive functions. After 11 weeks of outpatient therapy, no losses of balance occurred, and the patient returned to school activities. The author reported that besides balance training, perception and cognitive function training in patients with head injuries is needed as well[28]. Based on the data from the study of McNett et al., the effectiveness of training of these functions can be limited by agitation behavior and decreased concentration span[29]. Moreover, other authors reported that the effectiveness of physical therapy was reduced not only by complications such as contractures, spasticity, and impaired balance, but also by attention and behavior disorders, lack of motivation, and depression[30].

The data from the study by Kollen et al. showed that improvement in standing balance was more important than improvement in leg strength in order to achieve improvement in walking ability, and attention and spatial perception were directly related to gait[31]. The results of this study are in line with those of the abovementioned study; a moderate correlation was found between attention and walking both in the patients who were in a coma up to 1 week and in those who were in a coma for more than 2 weeks.

Based on the results of the study by Franckevičiūtė and Kriščiūnas, cognitive functions in patients who had sustained TBIs recovered slower than motor functions while applying physical therapy[32]. Meanwhile, Schiff reported that cognitive recovery could be strongly dissociated from motor recovery[33]. However, more comprehensive studies with a larger number of patients conducted at the late rehabilitation stage are needed to evaluate associations between the lack of motivation and recovery of motor and cognitive functions.

No doubt, the recovery period can be influenced by certain factors related to postoperative complications, patient's motivation, emotional state, and so on. However, this study did not investigate the impact of these factors on recovery, and additional studies should be conducted. The number of patients with coma who are undergoing post-acute rehabilitation is low, and this limitation did not allow the formation of sufficiently homogeneous groups and perform a comprehensive statistical analysis. Experts in the field believe that comprehensive multidisciplinary post-acute rehabilitation is the best approach for addressing impairments from severe TBI, although access to these services can be problematic. Health insurance reimbursement policies may limit the degree to which patients can participate in rehabilitation programs[34]. Patients who were in a coma for a long time could be clinically healthy and could have recovered motor functions, but severely impaired cognitive functions limit the application of physical therapy[16, 21, 37].

In summary, the recovery of motor and mental status of the patients in the acute rehabilitation was significantly better for those who were in a coma for a shorter period, although this study did not reveal associations between coma duration and recovery during post-acute rehabilitation.

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