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ORIGINAL REPORT

TRAUMATIC BRAIN INJURY IS UNDER-DIAGNOSED IN PATIENTS WITH SPINAL CORD INJURY

Anu Tolonen, LicPsych[1], Jukka Turkka, MD, PhD[1], Oili Salonen, MD, PhD[2], Eija Ahoniemi, MD[1] and Hannu Alaranta, MD, PhD[1]

From the [1]Käpylä Rehabilitation Centre, Finnish Association of People with Mobility Disabilities, and [2]Department of Radiology, Helsinki University Hospital, Helsinki, Finland

Objective: **To investigate the occurrence and severity of traumatic brain injury in patients with traumatic spinal cord injury.**

Design: **Cross-sectional study with prospective neurological, neuropsychological and neuroradiological examinations and retrospective medical record review.**

Patients: **Thirty-one consecutive, traumatic spinal cord injury patients on their first post-acute rehabilitation period in a national rehabilitation centre.**

Methods: **The American Congress of Rehabilitation Medicine diagnostic criteria for mild traumatic brain injury were applied. Assessments were performed with neurological and neuropsychological examinations and magnetic resonance imaging 1.5T.**

Results: **Twenty-three of the 31 patients with spinal cord injury (74%) met the diagnostic criteria for traumatic brain injury. Nineteen patients had sustained a loss of consciousness or post-traumatic amnesia. Four patients had a focal neurological finding and 21 had neuropsychological findings apparently due to traumatic brain injury. Trauma-related magnetic resonance imaging abnormalities were detected in 10 patients. Traumatic brain injury was classified as moderate or severe in 17 patients and mild in 6 patients.**

Conclusion: **The results suggest a high frequency of traumatic brain injury in patients with traumatic spinal cord injury, and stress a special diagnostic issue to be considered in this patient group.**

Key words: traumatic brain injury, spinal cord injury, co-occurrence, rehabilitation.

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Correspondence address: Anu Tolonen, Käpylä Rehabilitation Centre, PO Box 103, FI-00251 Helsinki, Finland. E-mail: anu.tolonen@invalidiliitto.fi

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INTRODUCTION

Traumatic spinal cord injuries (SCI) typically result from high kinetic accidents such as falls or traffic accidents. As traumatic brain injury (TBI) occurs in similar circumstances, these neurotraumas can frequently be assumed to be present concomitantly. In fact, most cervical SCIs are secondary to indirect forces transmitted to the spine through the head (1). TBI has been suggested to be a major concern in the rehabilitation, vocational planning and psychosocial survival of patients with SCI (2–7). After SCI, paraplegia or tetraplegia alone represents the onset of a massive change in the life of any individual. In addition, most patients with SCI experience medical problems, including neurogenic bladder and bowel, loss of sensation, spasticity, pain, sexual dysfunction and skin problems. However, from the perspectives of vocational planning, supportive interventions and psychosocial outcome, concomitant TBI is a central factor to be considered.

TBI produces marked disturbances in cognitive and emotional functioning, e.g. fatigue, problems in attention, concentration, memory, and judgement, irritability, emotional lability, and acting in socially inappropriate ways. Patients with SCI with concomitant TBI are at risk for a complicated rehabilitation process and unfavourable outcome if TBI is not recognized and the rehabilitation approach modified.

In SCI, because the enormous physical injury is a focus of concern, the basic indicators of TBI, including loss of consciousness (LOC), post-traumatic amnesia (PTA), neurological symptoms and signs due to TBI, and neurobehavioural changes, may go undetected and undocumented. Furthermore, patients with a Glasgow Coma Score (GCS) (8) of 13–15 may also suffer from severe TBI (9), and often structural damage cannot be detected in conventional neuroradiological examinations, such as magnetic resonance imaging (MRI) despite brain injury (10, 11). Altered mental status, e.g. fatigue, information processing problems, and changes in behavioural and emotional regulation, can be misinterpreted as post-anaesthesial sequelae, effects of medication, or a psychological reaction to a massive life change.

In the systematic studies examining the co-occurrence of TBI in traumatic SCI, the prevalence was estimated to be 40–60% (2–7). However, only 1 or 2 indicators (LOC, PTA, neuropsychological deficits) have been used when diagnosing TBI. Previous studies have not combined neurological, neuropsychological and neuroradiological methods in evaluating the occurrence and severity of TBI within a SCI population.

The aim of this study was to investigate the occurrence and severity of TBI by using neurological, neuropsychological and neuroradiological examinations in patients with traumatic SCI admitted to the rehabilitation centre.

METHODS

The study was carried out between April 2000 and September 2001 at the Käpylä Rehabilitation Centre, Helsinki, Finland, according to the

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principles of the Declaration of Helsinki and with the approval of the local ethics committees. Informed consent was obtained from all patients.

There are no data on the actual incidence of traumatic SCI in Finland. More than 90% of all patients with traumatic SCI with paraplegia or tetraplegia in Finland are referred to the Käpylä Rehabilitation Centre upon conclusion of the acute phase. The incidence of referred patients is 1.1/100,000 inhabitants per year.

Patients

Thirty-one (1 female and 30 males, mean age 36 years) of 80 consecutive patients with traumatic SCI on the first post-acute rehabilitation period fulfilled the following inclusion criteria: (*i*) age 16–54 years; (*ii*) no history of prolonged alcohol or substance abuse; and (*iii*) no history of psychiatric or cerebral disorder including TBI. Because the neuropsychological test battery is appropriate only for adults over 16 years of age, younger patients were not studied. Also, the patients over 54 years of age were excluded because age-related non-specific changes may confound the MRI interpretation. The exclusion criteria (*ii*) and (*iii*) were used to ensure that neuropsychological and neurological examinations did not reflect these possibly pre-existing conditions.

Forty-nine of the original 80 patients were excluded for the following reasons: age under 16 years or over 54 years ($n = 26$), prolonged alcohol or substance abuse ($n = 11$), psychiatric disorder ($n = 3$), previous cerebral disorder ($n = 1$), insufficient knowledge of Finnish or Swedish ($n = 4$), refusal ($n = 2$), rehabilitation period too short ($n = 1$) and Hallowest not suitable for MRI ($n = 1$).

The mean period of education of the patients was 12 (range 8–16) years. SCIs were caused by traffic accidents ($n = 14$; 46%), falls ($n = 13$; 42%), diving accidents ($n = 2$; 6%), and other causes ($n = 2$; 6%). Twelve patients had complete lesions of the spinal cord according to the impairment scale by American Spinal Injury Association (ASIA) (12, 13). Patients' spinal cord injuries are presented in Table I.

TBI diagnostic criteria

The diagnostic criteria for mild TBI diagnostics by the American Congress of Rehabilitation Medicine (14) were applied (Table II). The criteria include any of the following: (*i*) any period of LOC; (*ii*) any PTA; (*iii*) any alteration in mental state; and (*iv*) any focal neurological finding (transient or permanent) due to TBI. To ascertain that all the patients with TBI were detected, we added to the diagnostic criteria neuropsychological finding due to TBI in the study phase and neuroradiological finding due to TBI during either the acute phase or the study phase.

To investigate these criteria, patients underwent neurological, neuroradiological and neuropsychological examinations. The diagnostic finding was excluded from the analysis if there was any confounding factor, e.g. intoxication, hypoxia, medication or other medical condition affecting brain function and cognition.

Table I. *Classification of patients according to spinal cord injury and American Spinal Injury Association (ASIA) Impairment Scale (AIS)*

	AIS				
	A	B	C	D	Total
Tetraplegia	3	4	7	2	16
Paraplegia	9	2	3	1	15
Total	12	6	10	3	31

A: Complete: no motor or sensory function is preserved in the sacral segments S4–S5.
B: Incomplete: sensory but not motor function is preserved below the neurological level and includes the sacral segments S4–S5.
C: Incomplete: motor function is preserved below the neurological level, and more than half of key muscles below the neurological level have a muscle grade less than 3.
D: Incomplete: motor function is preserved below the neurological level, and at least half of key muscles below the neurological have a muscle grade of 3 or more.

Neurological examinations

The neurological examination was performed by the neurologist (JT), who was unaware of the results of neuroradiological and neuropsychological examinations. This examination included an evaluation of any neurological symptoms and signs due to TBI, such as cranial nerve dysfunction, pyramidal and extrapyramidal signs, sensory hemisyndrome, and cerebellar signs based on medical records, patients' history and clinical examination. The routine pattern of examination comprised sensory evaluation, muscle tone and power measurements in the upper extremities of patients with paraplegia, and deep tendon reflex and finger-to-nose testing. GCS at the time of injury or at admission and any alteration of consciousness after the injury were evaluated retrospectively from the medical documents by the neurologist. Also, secondary brain injuries and other complications affecting brain function, such as hypoxia, massive bleeding and medications, were evaluated by the same neurologist. The neurological examinations were performed 17.8 weeks (mean; standard deviation (SD) 11.5) after the injury. The ASIA impairment scale (12, 13) was performed by the physiatrist (EA) at the beginning of the rehabilitation period.

Neuroradiological examination

MRI was performed 20.6 weeks (mean; SD 10.8) after the injury and evaluated by the neuroradiologist (OS), who was unaware of the results of neurological and neuropsychological examinations. The examinations were performed with a Siemens Vision imager (Erlangen, Germany) operating at 1.5 T. Axial scans with T2 TSE, FLAIR, and T2* gradient echo sequences were obtained. Also obtained were T2 TSE coronal and

Table II. *Diagnostic criteria for classification of traumatic brain injury (TBI) severity*

Diagnostic criteria	Mild	Moderate	Severe
Altered level or loss of consciousness	GCS 13–15 and/or any LOC < 30 min	GCS 9–12 and/or LOC > 30 min – 6 h	GCS 3–8 and/or LOC > 6 h
PTA	Any PTA < 24 h	24 h – 7 days	> 7 days
Neurological finding due to TBI	No findings	Transient neurological finding (symptom)	Permanent neurological finding (sign)
Neuroradiological finding due to TBI	No findings	Neuroradiological TBI finding	Neuroradiological TBI finding and neurosurgical operation
Neuropsychological finding due to TBI	No neuropsychological findings in tests but subjective symptoms with predictable normal work and ADL performance	1–2 SD* in tests or limited capability in work but normal ADL	> 2 SD* in tests or unable to work and permanent difficulties in ADL

*Worse than the normal mean in one or more neuropsychological tests.
LOC: loss of consciousness; GCS: Glasgow Coma Score; PTA: post-traumatic amnesia; ADL: activities of daily living; SD: standard deviation.

T1 3D MPRAGE sagittal slices. Non-specific high signal foci were excluded from the analysis, only contusions and post-hemorrhagic lesions with typical location to diffuse axonal injury were included.

Neuropsychological examination

The neuropsychological examination was carried out by the clinical neuropsychologist (AT), who was unaware of the results of neurological and neuroradiological examinations. Three sub-tests (Arithmetic, Digit Span and Similarities) of the Wechsler Adult Intelligence Scale Revised (WAIS-R) (15) were used. A computerized version of the Paced Auditory Serial Addition Test (PASAT) (16) was applied for testing attention. Memory functions were evaluated by using the Visual Pairs subtest from the Wechsler Memory Scale Revised (WMS-R) (17), the Buschke-Fuld Selective Reminding test (18) and Kalska's Memory for Person Data, which is a modification of Cronholm's and Molander's KS-memory test. For studying behavioural, emotional and personality changes, the Depression Scale (19, 20) and the Neurobehavioural

Table III. *Traumatic brain injury (TBI) diagnostic findings*

Patients No./Age (years)	GCS	Length of PTA	Neurological finding	Radiological finding	Neuropsychological finding	TBI diagnosis
1/36	15	16 h	–	–	Severe	Severe
2/19	CF 14[2]	8 days	CF non-specific finding	Contusions at both sides of cerebellum	Moderate	Severe
3/32	CF 14[2]	CF 2.5 days[2, 5]	–	–	Mild	Mild
4/27	CF 14[2]	CF 14 days[2, 5, 6]	–	Haemorrhage, DAI	Mild	Moderate
5/46	15	2–3 min	–	CF non-specific high signal foci of white matter	Mild	Mild
6/54	15	–	CF non-specific finding	CF non-specific high signal foci of white matter	–	No
7/24	15	5 min	–	–	Severe	Severe
8/48	15	CF 6 days[5]	–	–	–	No
9/33	14	3 h CF 3–4 weeks[5, 6]	CF non-specific finding	Right temporal contusion, DAI	Severe	Severe
10/37	14	12 h	–	–	Mild	Moderate
11/23	14	3 h, CF 3 weeks[5]	CF non-specific finding	–	Mild	Mild
12/50	15	30 min	–	CF non-specific high signal foci of white matter	–	Mild
13/45	15	CF 12 hours[2, 5]	–	–	–	No
14/37	15	60 min	–	–	Moderate	Moderate
15/35	CF 13[2]	CF 7 days[2, 5]	–	Traumatic subarachnoidal haemorrhage	Mild	Moderate
16/52[1]	15	3 h	–	CF non-specific high signal foci of white matter	–	Mild
17/48	CF 6[2]	CF 20 h[2, 5]	CF non-specific finding	–	Moderate	Moderate
18/34	3	4 weeks	Transient left hand weakness	Left temporal contusion, DAI	Severe	Severe
19/46	15	CF 3 days[5]	CF non-specific finding	CF non-specific high signal foci of white matter	–	No
20/53	15	–	–	CF non-specific high signal foci of white matter	–	No
21/41	15	6 days	–	–	Moderate	Moderate
22/51	5	3 weeks	Transient double vision	DAI, cortical atrophy	Severe	Severe
23/24	15	CF 2 weeks[2, 5]	–	–	–	No
24/29	15	6 days	–	DAI	Mild	Moderate
25/28	15	6 weeks	Transient anosmia and visual disturbances	CF non-specific high signal foci of white matter	Moderate	Severe
26/16	3	3 weeks	Transient double vision, weakness of left hand, increased left arm reflexes	DAI, contusion	Mild	Severe
27/26	13	5 min, CF 2 weeks[5, 7]	–	Contusion in right cerebellum, DAI	Severe	Severe
28/54	CF 3[3]	CF 2 weeks[3, 5]	CF transient aphasia symptoms[3]	–	–	No
29/22	15	20 min, CF 6 days[5, 6, 8]	–	DAI	Moderate	Moderate
30/34	15	1 h, CF 1 week[5, 6, 9]	–	–	Mild	Mild
31/19	CF 9[4]	CF 3 weeks[4, 5]	CF non-specific finding	–	–	No

[1]Female, [2]alcohol, [3]respiratory failure, [4]electric shock, [5]anaesthesia, sedation, medication, [6]hypoxia, [7]metabolic disturbance, [8]asystole, [9]pulmonary thromboembolism with a seizure.

GCS: Glasgow Coma Score; PTA: post-traumatic amnesia; DAI: diffuse axonal injury; CF: confounding factors, the variable/finding excluded from the analysis.

Rating Scale (21) were used. Any symptoms of post-traumatic stress disorder (PTSD) (22) and the length of PTA (23) were evaluated retrospectively during the clinical interview by the neuropsychologist. The neuropsychological examinations were performed 19.6 weeks (mean; SD 11.6) after the injury. Neuropsychological findings with confounding factors were excluded from the analysis.

Severity of TBI

The diagnostic criteria for classification of TBI severity are outlined in Table II. The highest rating of severity received was used to define the severity of TBI of each patient.

Statistical analysis

Descriptive statistics were computed for all relevant variables. A dependence test was used to examine the dependence between the neurological level of spinal cord injury and the severity of TBI.

RESULTS

Twenty-three of the 31 patients with SCI (74.2%) met one or more of the diagnostic criteria of TBI (Table III). For 4 of these patients, GCS and PTA could not be reliably defined due to confounding factors (use of alcohol at the time of the accident, medication, hypoxia). Two of these 4 patients, however, showed MRI abnormalities related to TBI, and all 4 patients had neuropsychological symptoms or signs due to TBI. Based on these findings, they were diagnosed with TBI.

Seven (22.6%) patients had a GCS of less than 15, and 19 (61.3%) had PTA (Table III). Neurological signs or symptoms due to TBI were found in 4 (12.9%) patients and neuropsychological signs or symptoms in 21 (67.7%). MRI revealed abnormalities specific to TBI in 10 (32.3%) patients. All non-specific findings or any findings with confounding factors were excluded from the analysis (Table III). None of the patients diagnosed for TBI fulfilled the diagnostic criteria for posttraumatic stress disorder or depression.

Mild TBI was diagnosed in 6 (19.4%) of the 31 patients. Moderate TBI was found in 8 (25.8%) and severe in 9 (29.0%) patients (Tables III and IV). The neurological level of spinal cord injury did not correlate with the presence or severity of TBI (Table IV).

DISCUSSION

Twenty-three (74.2%) of the 31 patients with SCI were diagnosed with TBI. The co-occurrence of TBI with SCI has been estimated to be 40–60% in earlier studies using 1 or 2 TBI indicators (2–7). The higher occurrence of TBI in this study is explained by our combining several sensitive evaluation methods. In addition, centre as the only national unit for SCI rehabilitation represents the majority of severe, meaning paraplegic and tetraplegic, traumatic SCI patients in Finland.

Moderate or severe TBI was found in 54.8% of all SCI patients. Of patients diagnosed with TBI, 73.9% had moderate or severe TBI, which is much higher than the 8–10% typically seen in TBI epidemiological studies (24). The reason for the high prevalence of moderate and severe TBI in these SCI patients is probably the biomechanical effect of high force accidents. A marked disability as a consequence of moderate or severe TBI is likely, and even after apparently mild TBI more than 30% of patients have been reported to have major problems one year after the injury (24).

Only 9 patients had received a TBI diagnosis in the acute phase before arrival at the Käpylä Rehabilitation Centre. In patients with SCI, indicators of TBI, such as LOC and PTA, often go unrecognized in acute care and physiatric settings (3). The results of neurological and neuroradiological evaluations may be normal despite brain injury (10, 11). Patients with a GCS of 13–15 may also suffer from severe TBI (8, 24). In this study, PTA and neuropsychological findings were often found in patients with absent neurological and neuroradiological findings. Only those neuropsychological findings that were clinically evaluated to probably be TBI-related were reported in the results. Our results suggest that TBI is highly underdiagnosed in patients with traumatic SCI.

When all the 5 diagnostic criteria were pooled, TBI was diagnosed in 74.2% of the patients. Neuropsychological finding classified the same subgroup of TBI patients respectively (67.7%). Only 2 patients had PTA but no neuropsychological finding. Two patients showed neuropsychological finding due to TBI without any other clear diagnostic criteria findings. In earlier studies, 40–50% of traumatic SCI patients have had cognitive impairments (2, 4, 7).

Practical problem in diagnosing TBI after SCI, or other severe multi-trauma, is a variety of confounding factors, such as intoxication during the injury, hypoxia, medication, and complications of physical injuries. The same problem was evident also in this study. In order to avoid false diagnoses, we excluded all the TBI findings with any confounding factors from the analysis (Table III). Consequently, the actual occurrence of TBI in patients with traumatic SCI might be even higher than now reported.

Diagnosis of TBI in patients with concurrent traumatic SCI influences physiatric care, rehabilitation, and vocational planning. To avoid secondary complications, treatment and rehabilitation guidelines must be based on knowledge of these patients' specific cognitive and emotional limitations and needs.

The full effect of a TBI is often not immediately apparent; the extent of a mild TBI may go unnoticed for months or even years (25). To assess the significance and long-term consequences of a TBI in patients with SCI, a careful follow-up is crucial.

Table IV. *Severity of traumatic brain injury (TBI) according to neurological level of spinal cord injury*

	C2-C8		T1–T6		T7–		Total	
	n	%	*n*	%	*n*	%	*n*	%
No TBI	5	33.3	1	12.5	2	25.0	8	25.8
Mild TBI	2	13.3	2	25.0	2	25.0	6	19.4
Moderate TBI	4	26.7	2	25.0	2	25.0	8	25.8
Severe TBI	4	26.7	3	37.5	2	25.0	9	29.0
Total *n*, %	15	100.0	8	100.0	8	100.0	31	100.0

No significant difference was found between groups.

In conclusion, these results support our presumption that TBI is more frequent in patients with traumatic SCI than is reflected by clinical diagnoses at hospital admission. Therefore, to preserve a high standard of rehabilitation in patients with SCI, the possibility of concurrent TBI must be considered in order to avoid any secondary complications stemming from untreated TBI.

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