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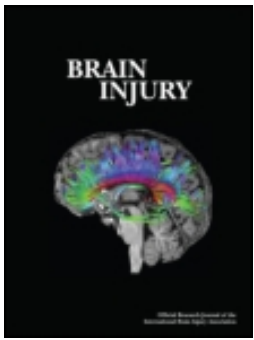
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Convergence insufficiency in brain-injured patients

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Disorders of eye movements are relatively common in brain-injured patients. Some of these disturbances are caused by direct trauma to the orbital content, cranial nerves and other brain areas. Convergence, which is a part of the near-vision complex and depends on the integrative function of the cortical and subcortical areas, is commonly affected by traumatic brain injury. Intact vergence needs the integrative function of brain structures associated with acquisition of information on one side and intact mesencephalic function, including function of a vergence integrator, and their interconnections.

Clinical investigation of vergence function in 26 traumatically brain-injured patients examined as early as possible after trauma revealed disturbances in over a third of the examinees. A follow-up of 72 patients some 3 years after injury revealed vergence insufficiency in 42%. Convergence insufficiency was associated with longer periods of coma ($p < 0.001$), presence of cognitive disturbances ($p < 0.005$) and patients' failing to find work in the open market ($p < 0.01$). It is suggested that the presence of disturbed vergence several years after trauma, and its close association with prolonged coma and cognitive disturbances, is an expression of permanent damage to mesencephalic and cortical brain structures and can serve as an important aid in evaluation of these patients. This paper describes the close relationship between vergence state and over-all rehabilitation outcome as evaluated by patients' occupational status.

Introduction

Clinicians recognized disturbances in eye movement following traumatic brain injury (TBI) many centuries ago [1], and Cross [2] and Jaensch [3] first described specific disturbances in convergence following TBI over 40 years ago. Walsh and Hoyt [4] have stated that this disturbance is of a supranuclear nature but gave no data on the incidence of the phenomenon. Interest in eye movements increased when the four subsystems governing eye movements were better recognized [5, 6].

Convergence is the simultaneous and synchronous adduction movement of the eyes resulting in an increasing angle between the visual axes. It is voluntary and is an essential part of the near-vision complex. Convergence is accomplished by an integrated action of visual information processing by mesencephalic structures, which have numerous cortical and subcortical connections, and the motor act of the oculomotor nerve. Convergence movements may be initiated by means of cortical occipital areas and by stimuli generated at other cortical areas [7]. It is therefore not surprising that such a complex integrated system is highly vulnerable to TBI. However, we could not find any reports of the incidence of convergence insufficiency in TBI.

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Clinical observations in TBI patients treated at the Loewenstein Rehabilitation Hospital (LRH) over the years have given the impression that visual disturbances are quite common, especially during the first few months after sustaining trauma, and tend to disappear as time passes. This study was conducted in order to determine the frequency of convergence insufficiency in TBI patients and to evaluate its association with various neurobehavioural deficits and rehabilitation outcome.

Patients and methods

The study was based on two different populations of TBI patients with regard to time elapsed after trauma. The larger group consisted of 72 consecutive TBI patients (aged 29 ± 9.9 years) who were rehabilitated at the LRH and were re-evaluated at the follow-up clinic about 3 years after trauma. The second group consisted of 26 TBI cooperative in-patients (aged 30 ± 18.1 years) who were able to perform the convergence near-point test. The mean time elapsed post-injury for the TBI in-patients was 3 months. The duration of coma for all patients is given in table 1. Convergence insufficiency was measured for each patient using the RAF Near Point Rule which is calibrated and adjusted for different ages.

The presence of dysphasic, cognitive and behavioural disturbances was carefully assessed for each patient. No patient had symptoms or signs of conversion neurosis or hysteria. The over-all rehabilitation outcome was recorded only for the group of the 72 patients seen at the follow-up clinic 3 years after injury. Actual work placement was used for measuring rehabilitation outcome as this criterion had been found previously to be an objective measure [8–10] with a good correlation with the subjective evaluations of TBI patients about their quality of survival [11].

Table 1. Coma duration (in days) of TBI patients with and without vergence insufficiency.

Patients	n	Mean \pm S.D.	Range
<i>Follow-up TBI patients ($p < 0.001$)</i>			
Normal vergence	42	11.8 ± 11.3	0–45
Vergence insufficiency	30	31.8 ± 37.5	0–160
<i>Hospitalized TBI patients ($p = n.s.$)</i>			
Normal vergence	16	10.9 ± 11.4	0–45
Vergence insufficiency	10	12.7 ± 14.6	2–50
<i>Follow-up and hospitalized TBI patients ($p < 0.001$)</i>			
Follow-up patients	72	20.1 ± 27.3	0–160
Hospitalized patients	26	11.6 ± 12.5	0–65

Results

Convergence insufficiency was common in both groups; 42% of the follow-up patients and 38% of the in-patients showed convergence insufficiency. No differences in age distribution were found between the two groups of TBI patients and between patients who had convergence insufficiency and those who did not. However, the duration of coma was significantly longer in the patients seen at the follow-up clinic in comparison to the TBI in-patients ($p < 0.001$).

Table 2. Vergence insufficiency and its relationship to aphasia, cognition and behavioural disturbances in 72 TBI patients examined 3 years after sustaining trauma.

Disturbance	Total	Normal function		Disturbed function	
		<i>n</i>	%	<i>n</i>	%
<i>Aphasia (p < 0.03)</i>					
Normal vergence	41†	33	80.7	8	19.5
Vergence insufficiency	30	11	26.2	13	43.3
<i>Cognition (p < 0.001)</i>					
Normal vergence	42	11	26.2	31	73.8
Vergence insufficiency	—	—	—	30	100.0
<i>Behaviour (p = n.s.)</i>					
Normal vergence	42	20	47.6	22	52.4
Vergence insufficiency	30	13	43.3	17	56.7

† Data missing for one patient.

Table 3. Vergence insufficiency and employment status (open market employment versus sheltered conditions and unemployable patients) in 72 TBI patients examined 3 years after sustaining trauma. $p = 0.007$ in all instances.

Open market								
Previous level		Lower level		Sheltered work		Unemployable		Total
<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>
<i>Normal vergence</i>								
8	19	18	43	12	29	4	9	42
<i>Vergence insufficiency</i>								
1	3	8	27	16	53	5	17	30

Convergence insufficiency was significantly associated with dysphasic and cognitive disturbances ($p < 0.03$ and $p < 0.001$, respectively) but not with behavioural disturbances (table 2). Convergence insufficiency was most common ($p < 0.007$) in TBI patients failing to reach a working position in the open market (patients working in the open market versus patients working under sheltered conditions and patients who are unable to work), as shown in table 3.

Discussion

The function of the vergence system requires the acquisition and processing of visual information, intact mesencephalic optic supranuclear subsystems and the motor output conveyed by the oculomotor and abducens nerves. The neural control of vergence eye movements, which is neurologically independent of the conjugate system [12], is used to

move the eyes in opposite directions in the horizontal plane in order to maintain binocular alignment when gaze is shifted between targets at different distance. Mays and co-workers [13–15] have described the characteristics of mesencephalic convergence and divergence neurons. There are two subpopulations of cells which discharge in relation to vergence velocity or vergence angle. These cells are independent of accommodation [16]. The existence of a neural integrator [17, 18] or a parallel operator [19] for vergence function has been suggested by several workers. It is clear that the movement of the eyes towards a target in the visual field occurs after a target selection process, based on sensory information and after an element of prediction has taken place. It is therefore not surprising that such a complex system is easily affected by trauma and that TBI patients show multiple abnormalities in the visual system. Ron [20] studied the plastic changes of eye movements following CNS trauma and failed to improve vergence capacity as these patients were found to be less cooperative and training aimed at improving convergence was virtually impossible.

Our findings suggest that long-standing vergence insufficiency is fairly common (42%) following severe TBI. Its existence is significantly associated with coma lasting more than 30 days, indicating most probably midbrain and brain stem damage. In addition, convergence insufficiency is more common in the presence of dysphasic and cognitive disturbances, i.e. processes associated with cortical functions which are an integral part of the intact information processing system. It is of interest to note that behavioural disturbances, which are more anterior by nature and are usually associated with frontal lobe damage, were not associated with convergence insufficiency. Overall rehabilitation outcome as evaluated by actual work placement was highly associated with presence of vergence insufficiency.

According to our clinical experience, most of the visual disturbance tends to disappear during the first year following trauma. Convergence insufficiency, seen in TBI patients several years following trauma, may therefore present a sum of permanent brain damage in these patients. It is suggested that attention should be paid to the existence of disturbances of eye movements in TBI patients as these disturbances can serve as another prognostic measure for vocational rehabilitation outcome. Further studies can perhaps contribute to the relative part played by either cortical or subcortical subsystems to the evolution of vergence insufficiency in TBI patients.

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