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Neuropsychological Recovery Pattern in Traumatic Brain Injury: A Longitudinal Study

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Abstract: ***Head injury accounts for a quarter of trauma related deaths but for a much larger proportion of lifelong disability. With the rise in high speed traffic, the number of high velocity injuries, resulting in mainly diffuse head trauma has also increased drastically. The cognitive and behavioral sequelae of closed head injury may be extensive and diverse -ranging from cognitive deficits to psychiatric symptoms. Subtle neuropsychological deficits, mainly in the realm of attention, cognitive processing capacity and learning and memory may persist for a long time in patients who otherwise show a good physical/clinical recovery from the head injury and may affect their return to a normal life. Thus, it becomes important to evaluate the long term outcome of head injury in order to make suitable efforts for the rehabilitation of disabled persons. The aim of this study was to assess if a differential pattern of recovery existed in the head injured at the second evaluation. 45 Clinically recovered patients with closed head injury were assessed at 3 months and 6 months following the trauma, utilizing a battery of neuropsychological measures sensitive to the effects of head injury. The result on the Neuropsychological measures provided evidence of gross brain dysfunction at the first assessment –indicative of diffuse involvement and marked recovery in some functions at the second assessment. Deficits were found to be persistent on measures of sustained attention, speed of complex information processing tasks, visual learning and memory and visual scanning tasks, whereas, significant improvement was evident in certain verbal tasks and simple visual memory tasks. These results indicate poor recovery of right hemispheric functions, and a probable differential recovery pattern of brain functions. The implications of these results will be discussed.***

Keywords: Neuro psychological recovery, Longitudinal pattern, Traumatic brain injury

1. Introduction

Head injury accounts for a quarter of trauma related deaths but for a much larger proportion of lifelong disability. With the rise in high speed traffic, the number of high velocity injuries, resulting in mainly diffuse head trauma has also increased drastically. The importance of road traffic accidents leading to head injury also stems from the fact that most of the victims are young adults in the 16-25 years of age group, given to speeding and high risk behavior, and "throwing caution to the winds". This results in a substantial and steadily increasing population of disabled survivors making increasing and long lasting demands on their families and society, depriving them of their most productive years of life. Thus, it becomes important to evaluate the long term outcome of head injury in order to make appropriate arrangements for the rehabilitation of disabled persons.

Medical literature on head injury has shown an understandable preoccupation with outcome after head injury, yet such outcome studies have mainly focused on only the physical deficits and very simple indices of recovery, such as return to work, but the cognitive or higher mental functions have often been neglected. The involvement of higher mental (cognitive) functions can affect several domains in a person's life, such as psychosocial, behavioral, occupational and interpersonal functioning. As the time since injury increases, the outcome becomes increasingly dominated by neuropsychological factors rather than physical.

Cognitive disorders experienced by Traumatic Brain Injury patients can present immediately after the initial injury or evolve during the subsequent months to years. Many patients live with sustained alterations in cognition and behavior for the rest of their lives

The cognitive and behavioral sequelae of closed head injury may be extensive and diverse -ranging from cognitive deficits to psychiatric symptoms. The cognitive disturbances post head injury may range from intellectual impairment to language and memory disturbances (Levin, 1995).

Subtle neuropsychological deficits, mainly in the realm of attention, cognitive processing capacity and learning and memory may persist for a long time in patients who otherwise show a good physical/clinical recovery from the head injury. These deficits may be extremely disabling and affect a person's occupational and psychosocial functioning, and may not manifest on simple psychometric measures, but might require sensitive measures to detect these subtle but persisting and debilitating deficits (Stuss et al, 1985). The Closed Head Injured patients may show a slowness of information processing, which might reflect in their decision making, response selection & retrieval (Dikmen et al, 1987 & 1991)

It's important to evaluate and assess the long term outcome of these cognitive deficits, in order to ascertain the improvement in patient's functioning over a long time. In long term studies with CHI patients, it has been reported that the recovery pattern may follow a differential path with certain functions recovering at a faster rate, compared to others recovering at a retarded rate (Mukundan et al , 1987 and Dikmen et al 1991 & 2009)

2. Review of Relevant Literature

A host of studies are available in the literature concerning with the neuropsychological deficits after a head injury. However, most of the studies do not address the issue of neuropsychological or cognitive recovery process longitudinally. Usually the cognitive deficits are assessed at some point of time after injury. Very Few studies are reported using the same sample with repeated observations at different time frames after the injury. Considerable effort is required in such studies and many problems are encountered in conducting and interpreting them.

Clinical studies of neuropsychological outcome have shown residual neuropsychological deficits in the head injured even long after the clinical recovery from trauma (Conzen et al 1992 & Dikmen et al ,1990). Dikmen et al (2009) indicated that there was adequate suggestive evidence that moderate and severe brain injuries are associated with cognitive impairments, 6 months or longer post injury.

Kraus et al (2005) reported that 10–50% of individuals with a history of traumatic brain injury have persistent cognitive and behavioral complaints and less favorable outcomes, thus enduring long-term injury-related disabilities. Sterr et al (2006) and Bohnen (1992) reported neuro cognitive deficits even with mild head injury, especially on information processing tasks. Stuss et al (1985) reported evidence of "subtle" cognitive deficits in head injured even after 'good' recovery . Hellawell et al (1999) reported severe cognitive deficits and psychosocial problems up to 2 years post HI. Schretlen and Shapiro (2003) also found evidence of persistent cognitive deficits at 2 years. .

Dikmen et al (1990) found evidence of persistent cognitive deficits over a 2 year period and marked improvement during the first year. They also found a remarkably consistent improvement in verbal IQ compared to other measures. Levin et al (1990) in a long term study, found impairment in memory and slowed information processing at 1 year and also reported recovery of language and visuo spatial ability to near normal. Clifton et al (1993) reported the performance on the 'sensitive' tests (attention, memory and motor speed) to be affected maximally at 6 months post injury. Levin et al (1992) found pervasive deficits at the first assessment following the trauma, and a trend from pervasive to specific deficits at 3 months follow up testing.

As reported in some of the studies mentioned above, there is evidence of a probable differential recovery of neuropsychological functions after the closed head injury: i.e. some functions recovering earlier than others. Levin et al (1988) pointed to disproportionately severe memory deficit as compared to normal IQ. Memory deficits were more apparent on complex tasks like selective reminding and complex figure. In addition, Brooks (1975) reported that performance functions recovered at a slower rate compared to verbal functions. Mukundan et al (1987) found marked improvement in verbal functions at 3 months, but poor recovery in visual learning, mental mathematics, visual scanning, which continued to be impaired even at 1 year. These findings point to an impairment in simultaneous processing, a deficit in right hemisphere, in patients with diffuse brain injury. These findings are also corroborated by a slowing down of brain activity in visual tasks (Mukundan et al, 1990).

Most of the studies cited above point towards presence of subtle attention deficits and memory disturbances in the head injured. There is also an indication of residual disturbance of the right hemisphere functions, which may be due to a cortical slowing in the head injured. Hence, in the present study, measurement of errors was also included along with the time factor in completion of more 'sensitive 'tests of brain dysfunction.

3. The Present Study

The objective of this study was to understand the nature and magnitude of cognitive deficits in closed head injured patients and to determine the pattern of recovery of the neuropsychological functions of the left and the right cerebral hemispheres, using a battery of sensitive neuropsychological measures. The patients were assessed at 3 and 6 months post injury. This was done in order to ascertain if there were any differences between the recovery patterns of the two hemispheres, though there was radiological and clinical evidence of diffuse involvement of both hemispheres at the time of injury.

45 patients with a history of closed head injury with a definite loss of consciousness, who fulfilled the stringent inclusion and exclusion criteria, were selected for the study. Only patients who had clinically recovered from a single diffuse head injury were included in the study. The exclusion criteria being : a) h/o alcoholism or heavy social drinking b) surgery for any depressed skull fractures or clots, c) impairment of vision or hearing, d) post traumatic seizures, e) previous history of any psychiatric or neurological disorders and f) education below 10^{th} class.

These patients were referred from the neurosurgical units of 2 hospitals, within 3-4 weeks following the injury. After initial evaluation of the severity, they were taken up for the assessment after approximately 3 months following the injury. Regular follow ups were maintained and the second assessment was done 3 months later. However, repeat assessment was possible for only 34 patients. The mean age of the patient group was 30.61 years with an education of 14.11 years. The mean duration from injury to 1^{st} assessment was 97.88 days and duration of second assessment from that of the first was 118.80 days.

A Normal age and education matched control group was also assessed utilizing the same measures. For the assessment purpose, The Neuropsychological Battery For Brain Dysfunction (NIMHANS) was utilized along with certain other tests sensitive to the effects of head injury. These tests included measures of sustained and divided attention, Information processing speed, Visuo-spatial functions, Verbal and Visual learning and memory, Abstract reasoning and language functions. Most of the test data was scored qualitatively and quantitatively, wherever objective scores were available, in order to establish the nature of deficits. The performance of the patient group was compared with the normal control group as well as within the patient

group over the two assessments, so as to delineate the improvement or deterioration, if any.

A Neurobehavioral Rating Scale (Levin et al, 1987) was also utilized for the patient population, in order to assess associated problems. This is a 27 item, 7 point rating scale, with symptoms ranging from "not present" to "extremely severe". Administration of the test requires a structured interview and a brief assessment for cognitive functions.
The analysis of data was based on the following aspects:

1) Nature of initial deficits evident on the first assessment
2) Nature of recovery of these deficits, if any, at the time of second assessment.
3) Lateralization effects

4. Analysis of Data

The first set of analysis was meant to determine a neuropsychological impairment profile at 3 and 6 months post injury. Group comparisons between the two head injury groups (I assessment and II assessment) and the normal group were made using Analysis of Variance (ANOVA). Subsequently, depending on the level of significance of f value, pair wise comparison of means was done using 'Tukey's test' for post-hoc comparisons. For all evaluations of statistical significance, the 5% probability value was accepted as the indicator of head injury related deficits.

A multivariate discriminate function analysis was computed for a selected no. of variables, in order to determine whether patients with CHI could be differentiated significantly from the normal group, using tests considered sensitive to the effects of head injury.

For all the timed tests, the time taken to complete the task as well as an error score was included for the analysis. However, certain test results were analyzed only qualitatively. Thus an idiometric approach was utilized and the percentage of patients showing impairment on these tasks was computed.

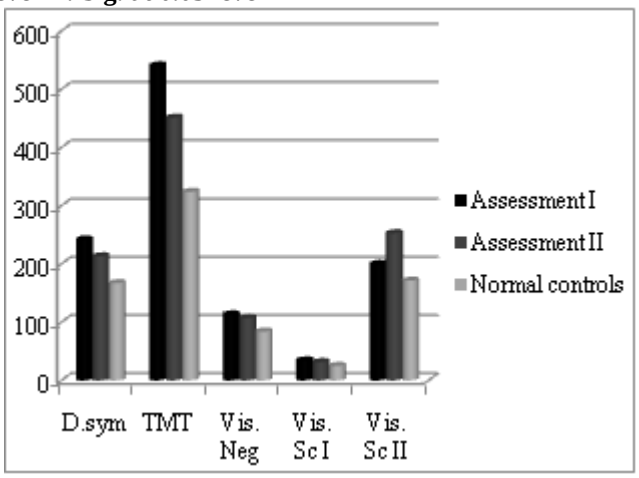
5. Results

There was no significant difference between the head injured group and the normal control group in terms of mean age and education (no. of years). Significant neuropsychological deficits were seen in the patient group at the 1st assessment, 3 months post injury. Deficits were evident on the tests of attention, verbal and visual learning and memory, immediate verbal and visual memory and tests of Visuo-spatial perception and organization. There were omissions and poorly organized recall in both verbal and visual domains.

Table 1: Showing Neuropsychological test scores and significance of difference between the patient group and the control group for Assessment I & II (time in sec.)

Test (s)	Assessment I		Assessment		Normal		F	P
	Mea	SD	Mea	SD	Mea	SD		
D.sym	242.	73.7	213.	50.3	167.	24.	18.	*
TMT	540.	185.	451.	169.	323.	77.	17.	*
Vis.	113.	34.5	107.	25.9	83.9	16.	11.	*
Vis.	34.5	10.8	31.8	7.83	25.0	5.4	7.1	*
Vis.	200.	74.5	252.	87.3	171.	43.	10.	*

Higher score means poorer performance ** : Sig. at 0.01 level * : Sig. at 0.05 level



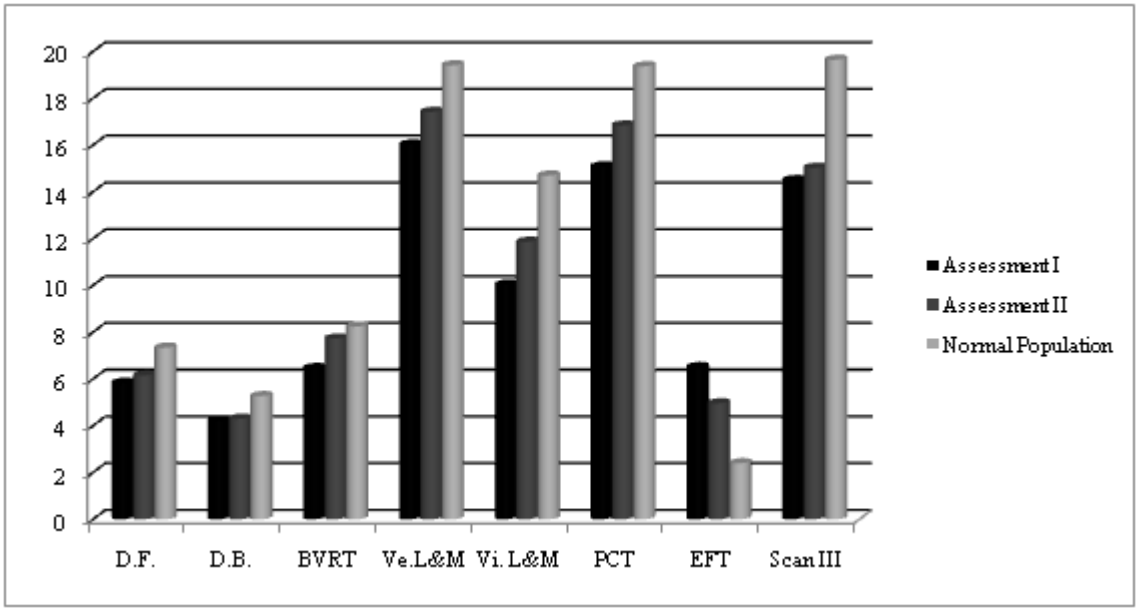
Graphical representation of the performance of the head injured in both assessments and the normal group on the attention tasks

D. Sym- Digit Symbol TMT- Trail Making Vis. Neg- Visual Neglect
Vis. Sc I & II- Visual Scanning I & II.

Table 2: showing Neuropsychological test scores and significance of difference between the patient group and the control group for Assessment I & II (time in sec.)

Test (s)	Assessment		Assessment		Normal		F	P
	Mea	SD	Mean	SD	Mea	SD		
D.F.	5.84	0.9	6.15	0.7	7.34	0.7	27.4	*
D.B.	4.23	0.7	4.30	0.6	5.27	0.7	20.1	*
BVRT	6.47	1.0	7.73	1.0	8.24	1.0	22.2	*
Ve.L&	16.0	2.0	17.42	2.1	19.4	1.1	19.7	*
Vi.	10.0	1.9	11.87	2.6	14.7	1.9	24.5	*
PCT	15.0	2.0	16..8	1.7	19.3	1.7	19.3	*
EFT	6.51	2.5	4.96	3.1	2.40	1.8	22.8	*
Scan III	14.5	4.2	15.03	3.4	19.6	3.9	16.1	*

Higher score means better performance ** : Sig. at 0.01 level * : Sig. at 0.05 level



Graphical representation of the performance of the head injured in both assessments and the normal group on some of the tasks

D. F.- Digit Forward D. B. Digit Backward BVRT- Benton Visual Retention Test Ve. L & M- Verbal learning & Memory Vi. L & M- Visual Learning & Memory PCT- Picture Completion Test EFT- Embedded Figures Test Scan III- Scanning

At the second assessment, 3 months later, the mean scores of the patient group on various tests indicated improvement in neuropsychological functioning in general. Minimal to moderate improvement was visible on all the tests, though the deficit did not normalize on all the tests. (Parallel forms were used on certain tasks to avoid practice effects). Significant improvement was seen on tests of visual memory and verbal learning and memory; however the scores did not normalize completely. Improvement was also evident on tasks requiring general ability and flexibility of control and reasoning (left hemispheric). There was no significant change between the two assessments on tests measuring attention, information processing speed, visuo-perceptual processing and visual learning and memory, indicating persistent deficits in these areas. Delayed recall was impaired in both the verbal and visual domain.

In the qualitative analysis, on tests of visuo-spatial integration and organization, and on tests of concept formation, the initial deficits at the first assessment were at a mild to moderate level, which improved considerably on the second assessment and were minimal.

Discriminant function analysis, using tests sensitive to CHI, significantly discriminated the HI group at the first assessment from the normal group. The coefficient indicated that digit symbol, trail making and visual numerical scanning tasks were most important in discriminating the two groups. The correct classification of subjects into their respective groups was 91.78% for each group.

Table 3: Showing discriminant function analysis

Actual Group	No. of cases	Predicted	Group membership
Group I (normal)	29	27 (93.1%)	2 (6.9%)
Group II (HI I asst.)	44	4 (9.1%)	40 (90.3%)
Percentage of "grouped cases " correctly classified: 91.78%			

6. Discussion

The head injured sample selected for the study was a fairly close representative of the closed head injured population in general. The average age of the patient group and the male-female ratio was similar to that reported in many incidence studies. The major cause of the head injury was also motor vehicle accidents, a fact similar to most studies. These patients were taken up for assessment, only after they were clinically recovered and free from any focal neurological deficits (examined by a neurosurgeon), which would have hampered their test performance.

The neurobehavioral profile emerging from the neurobehavioral rating scale is that of disturbances in attention, memory, somatic complaints, slowness and reduced efficiency. Most of these symptoms were of mild to moderate degree and there was evidence of improvement longitudinally. However, a persistent symptom reported by many patients was that of slowness and reduced efficiency in work and minimal attention and memory disturbances.

The present study provided convincing evidence of persistent cognitive deficits in patients with Head injury over a 6 month period. Though marked cognitive recovery was manifest over the 2 assessments, an evidence of better recovery in certain functions compared to others was also evident.

The 1st assessment revealed evidence of gross brain dysfunction in our sample, a finding corroborated by many other studies in the past (Levin et al, 1987, 1992 and 2010),. Cognitive deficits are common in head injured (Dikmen et

al 1990 & Dacey etal 1991), especially immediately after the trauma. Disturbances in learning and memory (Levin et al 2009), rate of information processing(Shum et al 1990) and adaptive functioning are often seen in closed head injury (Tate et al , 1991). A slowness in information uptake has also been implicated in head injured (Capruso & Levin, 1991), a finding seen in the present study too. In addition, the qualitative analysis revealed that these patients had problems in alternating, a deficit in sequential analysis, poor mental flexibility and an inability to benefit from cues. These patients also had a tendency to give up easily if the complexity of the task increased: an evidence of poor planning, deficit in executive functioning and motivation.

At the second assessment, the deficits persisted in some of the neuropsychological tests, with significant improvement evident on some others. These tests measured sustained attention, visual scanning, immediate visual memory, ability to sustain a flexible and complex mental set and ability to maintain rapid Visuo-motor activity. Patients' Performance on these tests was also highly correlated with each other in assessing the effects of head injury.

Many studies (Paniak et al, 1989 and Kreutzer et al, 1991) have reported some of the tests (digit symbol and trail making) to be extremely sensitive to brain damage (Levin et al , 1990 and others) and an extremely slow recovery rate of the functions sub-served by these tests. (Mandleberg and Brooks, 1976). Similar findings were reported in the present study. The Trail making test has also shown poor recovery at the second assessment. Extreme slowness and poor visuo-motor tracking and a disturbance in sequential analysis in the patient group was also noted in our study at both the assessments. Similar findings have been reported in the literature as well (Clifton, et al 1993).

Deficits in visual search and visual neglect were also noted to be persistent in the second assessment, also an indicator of impairment in sustained directed attention, mental tracking and parallel processing. All these deficits point towards evidence of slowed information processing, i.e. poor recovery of right hemispheric functions, especially the right fronto-parietal cortex.

Similarly, continued deficits in visual learning and memory tasks and improved performance in verbal learning and memory functions at the second assessment, indicates better recovery of left hemispheric functions(verbal) and persistently poor visual learning capacity, essentially demanding right hemispheric resources of simultaneous processing. Similar findings have been reported by Mukundan et al (1987).

7. Summary & Conclusions

1. Closed Head Injury resulted in significant neuropsychological deficits at 3 months post trauma. Performance on tasks of attention and memory was relatively poorer.
2. Significant improvement on certain tasks (especially verbal) was evident at the second assessment, whereas, insignificant improvement was seen in other tasks : viz: visual learning & memory, attentional tasks and complex information processing tasks. Some of these deficits are subtle in nature and can be detected only by very sensitive complex tasks, though with far reaching implications.
3. Improvement in certain functions and no change in other functions across the two assessments is indicative of a predominant left hemisphere functional recovery (verbal functions) and a retarded and slow rate of recovery in the right hemispheric functions(sustained attention and speed of information processing and mental tracking).
4. The above mentioned subtle deficits may lead to poor social, psychological and recreational adjustment, leading to problem at work and at home. These patients can be helped by cognitive retraining and specific counseling to handle the emotional and behavioral changes, thus aiding in their adjustment with family and at work.

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