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Alterations in working memory due to mild traumatic brain injury: evidences from neuropsychiatric tests - A cross sectional study

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Abstract: *Background and Objective:* Mild Traumatic Brain Injury (mTBI) is a common condition seen in neurosurgery, representing 80% of all head trauma patients admitted to hospital. With this study an attempt was made to determine cognitive impairments (particularly working memory dysfunction) caused as a sequelae of mild traumatic brain injury because correlations have been drawn since long amongst them and no significant data regarding the same is available. To assess the cognitive deficits in the working memory of subjects who have suffered mTBI with a GCS of 15/15 admitted in neurosurgery ward of Prabhakar Kore Charitable hospital, Belgaum. *Methodology:* A cross sectional study from February to July 2019 was carried out on 30 patients in neurosurgery department of KLEH, JNMC, Statistical analysis was done using SSPS version 20 and Unpaired T test was performed. The following tests were performed-Rey-Osterrieth Complex Figure Test (working memory) and Symbol Digit Modality Test (working memory). *Results:* Scores for ROCF figure copy score 31.7 ± 3.21, ROCF figure recall 20.5 ± 6.7, and correct score in SDMT 45.7 ± 1.2 were characteristically lower as compared to normative data. *Conclusion:* The working memory showed impairments and deviation from normative findings. The functional alterations in the pathway of formation and retrieval of memory involving the decoupling of the dorso-lateral pre-frontal cortex (DLPFC) causes impaired divided attention and inability to shift flexibly between attentional sets andreduced executive functioning that integrates the processing and interaction of cognitive processes

Keywords: ROCF, SDMT, Working memory, Traumatic brain injury.

Introduction

Traumatic brain injury (TBI) is a multifaceted condition, not a singular event. Mild Traumatic Brain Injury (mTBI) is a very common condition seen in neurosurgery, and represents 80% of all head trauma patients admitted to hospital [1]. It is caused by direct head impact or by an encephalic deceleration effect that produces a period of temporal and spatial disorientation, admitted with a Glasgow Coma Scale score of 13-15[2].

Culotta et al in 1996 following a retrospective study found that patients with a GCS of 13–15 represented a heterogeneous group of patients with statistically significant different head tomography abnormality rates [3]. For the purpose of this study we have restricted our research pertaining to only those patients who present with mild traumatic brain injuries with a GCS score of 15/15. Previously, mTBI was considered a temporary disruption that was thought to have a self-limiting short course [4-5]. Now, however, it is understood that it may involve structural plastic changes in the brain parenchyma leading to long term effects [6]. Researchers have often attributed mTBI to cause early onset discrepancies in working memory [7-9].

Working memory is the ability to transiently store and manipulate information to be used for cognitive or behavioral guidance [10], often referred to as short term memory. A research by the Department of Psychiatry, Dartmouth reported that there was a marked difference in the brain activation patterns of MTBI patients when compared to controls in response to increasing Working Memory processing loads [11].

Studies have demonstrated that similar cerebral areas are involved in tasks requiring working memory, episodic memory processes as well as executive functions [12]. Thus a relation can be drawn between conditions affecting areas of the brain involving working memory and their long term effects on memory. Contrasting results of previously carried out research with a few researchers stating no effect of mTBI on cognitive abilities [13-14] while others claiming the opposite are available. Since no clear answer regarding these paradigms are present with us, this study was undertaken to help aid researchers form a directed opinion and avoid pending complications. Also, to form rehabilitation modules for patients afflicted with mTBI.

Aim: To assess the cognitive deficits in working memory of subjects who have suffered mild traumatic brain injury with a GCS of 15/15 admitted in neurosurgery ward of Prabhakar Kore Charitable hospital, Belgaum.

Material and Methods

Study population: Patients attending the neurosurgery OPD at KLEH's Prabhakar Core charitable hospital with a history of traumatic head injury and getting admitted to the IPD for further evaluation.

Sample size estimation: Based on the pilot study conducted using State Trait Anxiety Inventory, effect size was 28

- Expected reduction-(mean)-d = 11.5
- SD = σ= 40
- Power = 80%
- α error= 0.05;
  One sided Zα=1.65
- β error=0.2;
  Zβ=0.84

$$n = [(Z\alpha+Z\beta)\ \sigma/d]^2 = 30.02 \cong 30$$

Study design: Cross sectional study

Period: Period from February 2019 to July 2019

Criteria for selection of the study group:

- *Inclusion criteria:* Both male and female patients with a mild head injury and a GCS score of 15/15 belonging to the age group from 30 to 55 years (middle aged)
- *Exclusion criteria:*
  1. Patients with H/O Dementia as per DSM 4 criteria.
  2. Any Psychiatric history
  3. With H/O visual, hearing disabilities or communication abnormalities.
  4. Patients who are on medication (sedatives, antipsychotics etc.) which affect memory.

The study was approved by IEC (ref: MDC/DOME/76) of the college and theparticipants voluntarily signed the written informed consent. A structured Performa was used to collect socio-demographic and nationality information from all participants

Study procedure: Rey- Osterrieth Complex Figure Test (ROCF) [15] was used for each patient to assess working memory by visual-spatial constitutional ability and visual memory. The test consisted of a copy trial followed by a recall trial 3 min later. The patient was asked to copy the given figure, with the subject's copy exposed for a maximum of 5.After a delay filled with other task (in our study, a concentration test was given namely SDMT), the patient was asked to draw the figure on a fresh sheet of paper by memory.

For scoring purpose, the figure is broken down into 18 elements and scored, depending on the accuracy, distortion, and location of its reproduction. Grading was done on the basis of;

- A copy score (which reflects the accuracy of the original)
- A recall score (accuracy of figure recalled to that of original)
- The time required for copy and recall

The task is essentially an incidental learning test: There is no warning of the memory component until the subject is asked to recall the figure from memory.

The Symbol Digit Modality Test [16] was given during the delay between the copy and recall test for ROCF and it assessed concentration ability by divided attention, visual scanning, tracking, and motor speed.

Each patient was given a test sheet which consisted of 8 lines with 15 symbols in each line and contained a box below each symbol to be filled in the corresponding number. A "coding key" was provided at the top of the page which consisted of "9 abstract symbols" each paired with a number from 1-9. The patient was asked to scan the key and write down the number corresponding to each symbol, as rapidly as possible. Once the test form was placed before the patient, 90 seconds were allowed to complete the trial.

Statistical Analysis: The analysis of the results was as Mean ± SD. Unpaired t-test was used to compare results from normative values and a "p' value of less than 0.05 was considered significant.

Results

The following results were obtained, with the demographic data of the patients recorded as follows;

Table-1: Demographic Data

Sex	**Male**		**Female**	
	100%		0.00%	
Age	**35-40**	**40-45**	**45-50**	**50-55**
	33% (10)	17% (5)	17% (5)	33% (10)
Level of education	**<12 YRS**	**=12 YRS**		**>12 YRS**
	33% (10)	10% (3)		56% (7)
Cause of injury	**Fall**	**Violence**	**Rta**	**Other**
	26% (8)	0%	30% (9)	43% (13)
Loss of consciousness	**YES**		**NO**	
	26% (8)		73% (22)	
Post traumatic amnesia	**YES**		**NO**	
	33% (10)		66% (20)	
Confusion	**YES**		**NO**	
	50% (15)		50% (15)	
Under alcohol influence	**YES**		**NO**	
	3% (1)		97% (29)	
Time between injury and initial assessment	**<24 HRS**	**24-48 HRS**		**>48 HRS**
	50% (15)	33% (10)		16% (5)

Icd 10 co-morbidities associated	**Htn**	**Dm**	**Alc/drug dependence**	**Tb**	**Thyroid disorder**
	43% (13)	17% (5)	50% (15)	0%	3% (1)

HTN- hypertension, DM- diabetes mellitus, ALC DEPENDENCE- alcohol dependence, TB – tuberculosis

Table-2: Data for SDMT test in head injury patients

	SCORE (mean ± S.D)	**P value**	**Normative value**
CORRRECT score	45.7 ± 1.2	**0.03**	**54.4 ± 7.6**
ERROR score	1.35 ± 1.87	0.302 (non-significant)	--
Statistically significant p-value (<0.05)			

The Symbol Digit Modality Test scores- to assess concentration ability by divided attention, visual scanning, tracking, and motor speed.

Table 2 Gives data for SDMT, showing a poor performance in SDMT with a mean correct score of 45.7, *SD*= 1.2 and the mean error score of 1.35, SD=1.87 with the p value for

error score = 0.302 (significant p value < 0.05). Rey- Osterrieth Complex Figure Test (ROCF) score- to assess working memory by visual-spatial constitutional ability and visual memory.

Table 3- ROCF scores,

	Score (mean ± SD)	P value	Normative value
Figure copy	31.7 ± 3.21	0.04	33.9±2.36
Figure recall	20.5 ± 5.31	0.032	22.8±4.01
Significant p values <0.05			

Table 3 gives data for ROCF copying and recall tests, with a mean score of 31.7 ± 3.21 for copy figure test and a p value of 0.04 and the mean score for recall figure test = 20.5 ± 6.7 with a significant p value

Discussion

The findings from this study suggest that traumatic brain injury, even of a mild degree has long term effects on different aspects of memory. There is a significant slowing in processing speed while performing cognitively demanding tasks in these patients. Since TBI can result in diverse mental and physical sequelae that often are as unique to individual casualties as personality, a need to study every aspect and presentation resulting from a mTBI is necessary [17].

Specific areas within the brain are responsible for different kinds of memory functions, involving complex interaction between the biochemistry of neurons and their electrical activity in specific anatomical structures. One such area in the brain is the left Dorsolateral Prefrontal Cortex (DLPFC), which has been associated to control manipulations related to working memory [18].

1. Concentration ability measured by the SDMT, showed a poor performance in SDMT, where normative data for written SDMT test for the age groups of 30 to 55 was taken to be mean= 54.4 ± 7.6 [19] for the correct score and in this study, the observed score was 45.7 ± 1.2

Ideally, an individual is able to develop multiple attentional processing streams simultaneously (divided attention or "multitasking") and shift flexibly between attentional sets. These attentional processes are sub served by a large, selective, distributed neural network, comprised of multiple central nervous system structures including the reticular formation, thalamus, hippocampal and entorhinal areas, the frontal and right parietal lobes, and the axonal connections between these areas. Marked disruptions in the structure or functioning of this network may produce these symptoms [20]. About 40%–60% of individuals with mTBI are reported to have attention deficits in the first 3 months postinjury [21] some of these patients often progress to have chronic cognitive disability which is often overlooked because on presentation the patient seems to have sustained only a minor injury. It is thus important to recognize these deficits as early as possible.

2. Visual-spatial constitutional ability and visual memory were assessed with the help of the ROCF test, which showed poor performance for both the figure copying and figure recall as compared to the normative data, taken to be 33.9 ± 2.36 (copy) and 22.8 ± 4.01(recall) [22] when compared to the scores obtained in this study which were 31.7 ± 3.21 (observed copy score)and 20.5 ± 6.7 (observed recall score)

Researchers have previously proven that participants with mTBI often struggle to maintain their attentional resources while performing one or more concurrent tasks [23]. Since the ROCF test measures the working memory which is under the control of the executive functions referring to a collection of abilities including categorization and abstraction, systematic memory searching and information retrieval, problem solving. Executive function is most often ascribed to the function of dorsolateral prefrontal-subcortical circuit [24], and in particular its ability to integrate the processing and interaction of more "basic" cognitive processes carried on elsewhere in the brain [20]. Executive dysfunction is a relatively common consequence of TBI, and may arise as a direct effect of injury to the frontal lobes or instead as a consequence of disturbances in the more basic aspects of cognition [25].

The results and evidence of our study support previous research done which suggests that TBI predominately affects the frontal lobes, regardless of the mechanism of injury and subsequent pathophysiology [26] resulting in deficits in a range of cognitively demanding tasks like concentration ability and problem solving [27].

Conclusion

From the results obtained in the above study, we conclude that the effects of mild traumatic brain injury on memory are significant, as working memory showed impairment. These inferences were drawn on the basis of the following results obtained; Cognitive functions like concentration ability, divided attention, categorization and abstraction, systematic memory searching and information retrieval and problem solving, showed mild to moderate impairments. Such cognitive abilities are controlled by higher centers in the brain and a functional discontinuity or aberration in the distributed neural network, comprising of multiple central nervous system structures like the dorsolateral prefrontal-subcortical circuit may be the cause for these discrepancies after injury.

This study also aims to provide basis for the emergent need of early detection of such injuries in order to prevent permeant deficits and also to correct the damage caused by prompt rehabilitative techniques, like Cognitive Rehabilitation Therapy (CRT) [28], computer-assisted cognitive rehabilitation (CACR) [29], physical exercise [30].

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References

1. Andrade AF, Paiva W, Soares MS, De Amorim RL, Tavares WM, Teixeira MJ. Classification and management of mild head trauma. *Int J Gen Med.* 2011; 4:175-179.
2. Narayan RK, Wilberger JE, Povlishock JT, Levin HS. Outcomes from mild head injury. *Neurotrauma. New York, NY: McGraw-Hill* 1996;31-41
3. Culotta VP, Sementilli ME Gerold K et al Clinicopathological hetrogenicity in the classification of mild head injury. *Neurosurgery* 1996; 38: 245-250.
4. Denny-Brown DE, Russell WR. Experimental Concussion: (Section of Neurology). *Proc R Soc Med* 1941; 34(11):691-692.
5. Parkinson D. Concussion is completely reversible; an hypothesis. *Medical Hypotheses* 1992; 37(1): 37-39.
6. Bashir S, Vernet M, Yoo WK, Mizrahi I, Theoret H, Pascual-Leone A. Changes in cortical plasticity after mild traumatic brain injury. *Restor Neurol Neurosci* 2012; 30(4):277-282.
7. Sandry J, Chiou KS, DeLuca J et al. Individual differences in working memory capacity predicts responsiveness to memory rehabilitation after traumatic brain injury. *Arch Phys Med Rehabil* 2016; 97:1026-1029.
8. Van der Horn HJ, Liemburg EJ, Scheenen ME et al. Post-concussive complaints after mild traumatic brain injury associated with altered brain networks during working memory performance. *Brain Imaging Behav* 2016; 10:1243-1253.
9. Roe C, Sveen U, Alvsaker K et al. Post-concussion symptoms after mild traumatic brain injury: influence of demographic factors and injury severity in a 1-year cohort study. *Disabil Rehabil* 2009; 31:1235-1243.
10. Baddeley AD. Working memory. *Oxford: Oxford UniversityPress* 1986; 289
11. McAllister TW, Sparling MB, Flashman LA, Guerin SJ, Mamourian AC, Saykin AJ. Differential working memory load effects after mild traumatic brain injury. *Neuroimage* 2001; 14(5):1004-1012.
12. Van der Linden, Martial & Meulemans, Thierry & Marczewski, Philippe & Collette, Fabienne. The relationship between episodic memory, working memory, and executive functions: The contribution of the prefrontal cortex. *Psychologica Belgica* 2000; 40(4): 275-297.
13. Bruce JM, Echemendia RJ. History of multiple self-reported concussions is not associated with reduced cognitive abilities. *Neurosurgery* 2009; 64(1):100-106.
14. Belanger HG, Spiegel E, Vanderploeg RD. Neuropsychological performance following a history of multiple self-reported concussions: a meta-analysis. *J Int Neuropsychol Soc* 2010; 16(2):262-267.
15. Strauss E, Sherman EMS and Spreen O. A Compendium of Neuropsychological Tests: Administration, Norms and Commentary. 3rd ed. Chapter 10. Memory. Rey-Osterrieth Complex Figure Test (ROCF). *Oxford University Press.* 2006; 811-841.
16. Strauss E, Sherman EMS and Spreen O. A Compendium of Neuropsychological tests: Administration, Norms and Commentary. 3rd ed. Chapter 9. Attention. Symbol Digit Modalities Test (SDMT). *Oxford University Press.* 2006; 617-627.
17. Evans CT, St Andre JR, Pape TL-B, Steiner ML, Stroupe KT, Hogan TP and Smith BM. An

evaluation of the Veterans Affairs traumatic brain injury screening process among Operation Enduring Freedom and/or Operation Iraqi Freedom veterans. *PMR* 2013; 5:210-220
18. Barbey AK, Koenigs M, Grafman J. Dorsolateral prefrontal contributions to human working memory. *Cortex* 2013; 49(5):1195-1205.
19. Lorne T. Yeudall Delee Fromm John R. Reddon William O. Stefanyk. Normative data stratified by age and sex for 12 neuropsychological tests. *Journal of clinical psychology* 1986; 42(6): 918-946.
20. Arciniegas DB, Held K, Wagner P. Cognitive impairment following traumatic brain injury. *Curr Treat Options Neurol.* 2002; 4(1):43-57.
21. Warden DL, Gordon B. Neurobehavioural Guidelines Working Group. Neurobehavioral guidelines Working Group. guidelines for the pharmacologic treatment of neurobehavioral sequelae of traumatic brain injury. *J Neurotrauma* 2006; 23:1468–1501.
22. Herlekar SS. Effect of instrumental music on anxiety, concentration, working memory and autonomic parameters in Indian and Malaysian students, a randomized controlled trial. 1st ed. *KLE University Belgaum* 2014; 58
23. Ponsford J, Kinsella G. Attentional deficits following closed-head injury. *J Clin Exp Neuropsychol* 1992; 14: 822-838.
24. Mega MS, Cummings JL. Frontal-subcortical circuits and neuropsychiatric disorders. *J Neuropsychiatry Clin Neurosci* 1994; 6(4):358-370.
25. Spikman JM, Deelman BG, van Zomeren AH. Executive functioning, attention and frontal lesions in patients with chronic CHI. *J Clin Exp Neuropsychol* 2000; 22(3): 325-338.
26. Stuss DT. Traumatic brain injury: relation to executive dysfunction and the frontal lobes. *Curr Opin Neurol* 2011; 24(6):584-589.
27. Daffner KR, Mesulam MM, Scinto LF, Acar D, Faust R, Chabrerie A, et al. The central role of the prefrontal cortex in directing attention to novel events. *Brain* 2000; 123: 927-939.
28. Amanda R. Rabinowitz, Harvey S. Levin Cognitive Sequelae of Traumatic Brain Injury. *Psychiatr Clin North Am* 2014; 37(1): 1-11.
29. Chen SH, Thomas JD, Glueckauf RL, Bracy OL. The effectiveness of computer-assisted cognitive rehabilitation for persons with traumatic brain injury. *Brain Inj* 1997; 11(3):197-209.
30. Morris T, Gomes Osman J, Tormos Muñoz JM, Costa Miserachs D, Pascual Leone A. The role of physical exercise in cognitive recovery after traumatic brain injury: A systematic review. *Restor Neurol Neurosci* 2016; 34(6):977-988.

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