Clinical Article

Memory Dysfunctions after Mild and Moderate Traumatic Brain Injury : Comparison between Patients with and without Frontal Lobe Injury

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Objective : The purpose of this study was to assess memory dysfunction in patients with mild and moderate traumatic brain injury (TBI) with and without frontal lobe injury (FLI).

Methods : The subjects were 110 TBI patients, who had recovered from the acute clinical phase, and comprised 20 (18.2%) mild TBI (MTBI) patients with FLI, 16 (14.5%) MTBI patients without FLI, 51 (46.4%) moderate TBI (MOTBI) patients with FLI and 23 (20.9%) MTBI patients without FLI. All patients were administrated the Korean version of the Memory Assessment Scale (K-MAS).

Results : Almost all the Summary Scale scores on the K-MAS failed to show any differences between TBI patients with and without FLI, but differences did emerge by types at severities. TBI patients with FLI showed higher Global Memory ability than TBI patients without FLI if their TBI was only mild, but when their TBI was more severe, this finding was reversed, and TBI patients with FLI showed lower Verbal and Global Memory abilities than TBI patients without FLI.

Conclusion : Different kinds of assessment tools are needed for the measurement of memory abilities in TBI patients with FLI, and that the selection of the appropriate tool depends on the severity of the TBI.

KEY WORDS : Frontal lobe injury · Memory · Severity.

INTRODUCTION

Memory impairment is a common complaint following traumatic brain injury (TBI)[2,25,37] and is frequently associated with medial temporal or diencephalic pathology. Damage to these structures usually leads to anterograde amnesia and characteristic impairments in recall and recognition[1].

In contrast, frontal lobe injury (FLI) is characterized by cognitive, behavioral, and emotional changes, and frontal lobe impaired patients exhibit disruptions in the memory process when recall depends on self-initiated cues, organization, search selection, and verification of the stored information[34,36]. Although it is widely believed that these memory problems result from several functional deficits caused by

lesions to the frontal cortex, the evidence for this is still rather weak. In addition, the nature of these functions is poorly understood, and little is known about the extent to which the memory deficits are specific to frontal lobe lesions[10]. Furthermore, although memory disorders have long been associated with prefrontal lesions, when these patients are carefully examined, they typically do not have a disorder of the memory system, but rather disorders of one or more of the functions, which facilitate memory[29].

While memory dysfunctions following moderate and severe TBI resemble those following frontal lobe injuries, this needs to be tested directly by comparing TBI patients with and without focal frontal lesions with non-TBI focal frontal lesion patients as controls. However, because of the diffuse nature of the injury, patients with TBI are not the ideal group for studying brain-behavior relations. In particular, the suggested similarity between patients with TBI and those suffering frontal lobe injuries should be viewed cautiously. Nevertheless, an improved understanding of the memory disturbance following TBI could contribute to the assessment and rehabilitation of this patient population[44].

The studies on memory deficit following TBI can be clinically driven using standard memory tests or theoretically driven using measures of specific aspects of memory within well-controlled experimental paradigms[44]. In clinical practice, the results of memory assessments are used to monitor progress during treatment with, for example, medication and cognitive remediation programs. They are also used to explore various clinical questions in working with forensic patients. With forensic patients, in particular, the use of formal, officially approved and published standard tests has been an essential requirement, and assessment using a theoretical experimental paradigm with this group of patients may lead to scientific argument and disagreement.

The lack of a more definitive understanding of memory functions in patients with FLI adds to the controversy on the diffuse nature of this injury. Although patients will often score within normal limits on standard memory tests (e.g., Wechsler Memory Scale-III), close relatives will report considerable everyday memory problems. This apparent failure to remember is a common feature of frontal lobe syndromes[38].

In this study, we investigated the memory characteristics of patients with TBIs of varying severity, with or without FLI, using the results of formally standardized, official and published memory test.

MATERIALS AND METHODS

Subject selection procedure

Approval for retrospective chart reviews was obtained from the Y University medical center where this study was conducted during the period July 1998 to October 2008.

Subject selection

All subjects were TBI patients who had recovered from the acute clinical phase and were between 18 and 60 years of age. Patients were excluded if they had a history of documented hypoxia, a prior or subsequent head trauma resulting in a neurological condition, a psychiatric illness, a history of alcohol or substance abuse, were suffering from mental retardation, or had experienced a chronic illness over the past six months. Also excluded were any patients with a severe TBI, because they would have been unable complete some of neurocognitive tests, and any patients who met the criteria for probable or definite malingering of a neurocognitive dysfunction.

Controlling contaminating variables

To increase homogeneity among the groups of patients whose data were used in this study, the groups were matched for age, sex, education and premorbid intelligence. In a recent study to explore the relationships between various demographic characteristics and cognitive functioning in TBI patients[23], memory was related to age and gender, especially in the mild or moderate TBI patients, but was unrelated to either educational or occupational level irrespective of TBI severity.

Group classification and preliminary statistical analysis

Patients selected by the first inclusion criteria were separated into four groups: TBI patients with left frontal injury, with right frontal injury, with both right and left frontal injury, and TBI patients without FLI. The classification of inpatients was based on information in the final and confirmed discharge summary, including radiological CT/MRI scan results at the initial, follow-up or/and final state stage of TBI. In the case of out-patients, it was based on information which sought from referral sources, final and confirmed diagnosis, the medical records from other hospitals, and any other official medical records.

The four groups were then further divided into two groups based on the GCS score either at the accident scene or upon initial examination following their arrival at the hospital. These subgroups were defined as mild TBI (MTBI; GCS score 13-15) and moderate TBI (MOTBI; GCS score 9-12).

For verification of unbiased subject-sampling, preliminary statistical analyses were done using frequency analysis and a two-way ANOVA. We found no statistically significant differences between any of main comparison groups on any of the potential biasing variables. The region of the FLI made no significant difference statistically, but there were some interaction effects between severity of TBI and some of the variables, and these caused some confusion in interpretation of the results. Nevertheless, we concluded that classifying patients based on TBI severities and presence or absence of FLI was the preferred method.

Final groups of selected patients

A total of 110 TBI patients were selected from both hospitalized and outpatient referrals and classified as follows; mild TBI patients with FLI (MTBI FLI; n = 20, 18.2%) and without FLI (MTBI NFLI; n = 16, 14.5%), and moderate TBI patients with FLI (MOTBI NFI; n = 51, 46.4%) and without FLI (MOTBI NFI; n = 23, 20.9%). The demographic characteristics of the TBI subjects are presented in Table 1. The TBI subjects were predominantly male (n = 90, 81.8%) with a mean age of 42.41 ± 13.37 years and an average length of formal education of 9.86 ± 4.17 years. The

majority were married (70.9%, n = 78) and resided in an urban area (78.2%, n = 86). Occupational status at the time of injury was as follows: unskilled laborer/ farmer (52.7%, n = 58); clerical worker (28.2%, n = 31); none (15.5%, n = 17); and merchant (3.6%, n = 4). There were no statistically significant differences between the groups in the distributions of these demographic characteri-stics and estimates of premorbid intelligence. The clinical character-istics of the four TBI groups are presented in Table 2. The causes of TBI were traffic accident as a pedestrian (27.3%, n = 30), traffic accident in a car (56.4%, n = 62), industry injury (13.6%, n = 15), violence (1.8%, n = 2), and others (0.9%, n = 1). The types of head trauma were brain hemo-rrhage (70.0%, n = 77), brain contusion (38.2%, n = 42), and others (12.7%, n = 14). Loss of consciousness due the

accident occurred in78.2% (n = 86) of the patients, and 95.5% (n = 105) were hospitalized.

Materials

Korean Memory Assessment Scale (K-MAS)[24,50]

MAS is comprehensive, standardized memory assessment battery, which is designed to fulfill ordinary clinical assessment needs in a manner suitable for various kinds of clinical situations and demands[29]. The original version of the MAS was developed by Williams[50], and a validation study of a Korean version of the MAS (K-MAS) was reported by Lee, Park, Ahn, Kim & Jeung[24].

The K-MAS assesses three kinds of memory functions : attentional functions and short-term memory; learning and

Table 1. Demographic characteristics of 110 traumatic brain injury patients

	MTBI (n = 36)		MOTBI (n = 74)		Total (%)
	FLI (n = 20) (%)	NFLI (n = 16) (%)	FLI (n = 51) (%)	NFLI (n = 23) (%)	
Gender					
Male	15 (75.0)	14 (87.5)	43 (84.3)	18 (78.3)	90 (81.8)
Female	5 (25.0)	2 (12.5)	8 (15.7)	5 (21.7)	20 (18.2)
Age					
Below 29 years	5 (25.0)	3 (18.8)	10 (19.6)	4 (17.4)	22 (20.0)
30-39 years	2 (10.0)	3 (18.8)	10 (19.6)	6 (26.1)	21 (19.1)
40-49 years	3 (15.0)	4 (25.0)	17 (33.3)	7 (30.4)	31 (28.2)
50-59 years	6 (30.0)	4 (25.0)	9 (17.6)	4 (17.4)	23 (20.9)
Above 60 years	4 (20.0)	2 (12.5)	5 (9.8)	2 (8.7)	13 (11.8)
Mean ± SD (years)	45.38 ± 15.38	43.86 ± 13.06	41.43 ± 12.62	40.97 ± 13.75	42.41 ± 13.37
Marriage					
Married	13 (65.0)	12 (75.0)	37 (72.5)	16 (69.6)	78 (70.9)
Unmarried	5 (25.0)	4 (25.0)	12 (23.5)	6 (26.1)	27 (24.6)
Bereavement			1 (2.0)		1 (0.9)
Divorce	2 (10.0)		1 (2.0)	1 (4.3)	4 (3.5)
Educational periods					
None	9 (45.0)	4 (25.0)	16 (31.4)	8 (34.8)	37 (33.6)
1-6 years (elementary school)	2 (10.0)	5 (31.3)	5 (9.8)	3 (13.0)	15 (13.6)
7-9 years (middle school)	6 (30.0)	3 (18.8)	19 (37.3)	9 (39.1)	37 (33.6)
Above 10 years (above high school)	3 (15.0)	4 (25.0)	11 (21.6)	3 (13.0)	21 (19.1)
Mean ± SD (years)	9.03 ± 3.91	10.19 ± 4.29	10.26 ± 4.22	9.46 ± 4.34	9.86 ± 4.17
Occupation					
None	5 (25.0)	2 (12.5)	4 (7.8)	6 (26.1)	17 (15.5)
Unskilled laborer/Farmer	11 (55.0)	9 (56.3)	27 (52.9)	11 (47.8)	58 (52.7)
Merchant	1 (5.0)	1 (6.3)	2 (3.9)		4 (3.6)
Clerical worker	3 (15.0)	4 (25.0)	18 (35.3)	6 (26.1)	31 (28.2)
Place of residence					
Urban	14 (70.0)	14 (87.5)	39 (76.5)	19 (82.6)	86 (78.2)
Rural	6 (30.0)	2 (12.5)	12 (23.5)	4 (17.4)	24 (21.8)
Premorbid Intelligence Estimates (mean ± SD)					
Verbal Intelligence	97.85 ± 9.14	100.63 ± 11.79	100.78 ± 10.46	98.22 ± 11.62	99.69 ± 10.63
Performance Intelligence	98.25 ± 10.31	99.88 ± 10.51	99.84 ± 9.34	98.26 ± 11.10	99.23 ± 9.96
Full Scale Intelligence	97.90 ± 9.98	100.38 ± 11.84	100.59 ± 10.64	98.17 ± 12.20	99.56 ± 10.96

FLI : frontal lobe injury, FNFLI : none frontal lobe injury, MOTBI : moderate traumatic brain injury, MTBI : mild traumatic brain injury, SD : standard deviation

immediate (as distinguished from short-term) memory; and memory following a delay. These functions are examined in both verbal and (purportedly) nonverbal modalities, and one test involves the integration of verbal (names) and nonverbal (faces) material. The result sheet provides a test profile for all immediate and delayed test scores and two other sets of scores : Verbal Memory Process scores, which are the scores on Intrusions, Clustering, Cued List Recall, and List Recognition, and Summary Scale Scores, which are the three summary scores for the different aspects of memory and a Global Memory Scale score. The Global Memory Scale score is the sum of the Verbal and Visual Memory summary scores. In the validation study of K-MAS, reliability (generalizability) coefficients for subtests, summary scales, and global memory scales averaged from 0.55 to 0.90, from 0.74 to 0.87 and 0.87 respectively, based on a sample of 57 subjects (mean age = 45 ± 17.03 years). The K-MAS scores have high internal consistency, and a factor analysis of the K-MAS in a normal population has revealed a two-factor structure : a 'Verbal Attention and General Memory' factor and a 'Visual Memory and Short-Term Memory' factor. The reliability and validity of the K-MAS has been confirmed as satisfactory, and the battery is widely accepted in Korea and other countries for evaluating the memory functions of patients with traumatic brain injury.

Test administration

Comprehensive neuropsychological tests including the K-

MAS were administered in a standardized manner as part of a neurocognitive evaluation by licensed clinical psychologists. Testing was performed only when participants were medically stable and could recall meaningful information and was done on an average of 23.48 ± 30.87 months after injury. There was a statistically significant difference at (p = 0.041) in the lapse of time between injury and test administration for the TBI patients with FLI compared with those without FLI, but this had no meaningful effect on the main dependent variables. In addition to the cognitive testing, each assessment involved a review of documentation and a clinical interview. All patients were given a routine warning that tests of cognitive impairment would be administered, that the tests were designed to ascertain whether they were faking or exaggerating, and that evidence of inadequate effort would be recorded.

Statistical analysis

Descriptive statistics, frequency analysis (X^2 and Fisher Exact tests) and a between groups two-way analysis of variance (injury severity vs. injury type) based on the General Linear Model (GLM) were used to determine the existence of any sampling biases in terms of the demographic and clinical variables. K-MAS scores between injury severity and type were also compared using a between groups two-way analysis of variance based on the GLM, and when these results showed interaction effects between injury severity and type, a simple main effect analysis was

Table 2. Clinical characteristics of 110 traumatic brain injury patients

	MTBI (n = 36)		MOTBI (n = 74)		Total (%)
	FLI (n = 20) (%)	NFLI (n = 16) (%)	FLI (n = 51) (%)	NFLI (n = 23) (%)	
Causes of head trauma					
Traffic accident in car	6 (30.0)	3 (18.7)	15 (29.4)	6 (30.0)	30 (27.3)
Traffic accident on pedestrian	11 (55.0)	11 (68.7)	27 (52.9)	13 (65.0)	62 (56.4)
Industry injury	2 (10.0)	1 (6.3)	8 (15.7)	4 (5.0)	15 (13.6)
Violence	1 (5.0)		1 (2.0)		2 (1.8)
Others		1 (6.3)			1 (0.9)
Main types of head trauma					
Brain contusion	4 (20.0)	7 (43.8)	23 (45.1)	8 (34.8)	42 (38.2)
Brain hemorrhage	15 (75.0)	11 (68.8)	37 (72.5)	14 (60.9)	77 (70.0)
Others	2 (10.0)	2 (12.5)	7 (13.7)	3 (13.0)	14 (12.7)
Loss of conscious					
Absent	7 (35.0)	5 (31.3)	51 (100.0)	23 (100.0)	86 (78.2)
Present	13 (65.0)	11 (68.7)			24 (22.8)
Hospitalization					
Yes	20 (100.0)	14 (87.5)	50 (23.5)	21 (91.3)	105 (95.5)
No		2 (12.5)	1 (76.5)	2 (8.7)	5 (4.5)
Time of assessment following head trauma*					
Mean ± SD (months)	10.21 ± 8.28	30.08 ± 56.89	23.60 ± 22.38	30.18 ± 32.86	23.48 ± 30.87

*Significant difference at p = 0.041 between FLI and NFLI groups. FLI : frontal lobe injury, MOTBI : moderate traumatic brain injury, MTBI : mild traumatic brain injury, n : numbers of patients, N : numbers of patients, SD : standard deviation

performed for type at severity (i.e., differences in the discrepancies between scores of TBI patients with and without frontal lobe damage at the two levels of TBI severity). The results were considered significant at the $p < 0.05$ level, and all data analyses were performed using SPSS Version 14.0.

RESULTS

Summaries of the analyses of all K-MAS scores for the four comparison groups are presented in Table 3 and in Fig. 1 and 2.

Subscale scores

There were no significant differences between the groups on the Verbal Span, Visual Span, List-Learning, Names-Faces and Delayed Names-Faces subscales. Similarly, there were no significant differences between groups on the List Recall, Delayed List Recall, Prose Memory, Delayed Prose Memory, Visual Reproduction and Visual Recognition

subscales, but there were significant interaction effects. For the Delayed Visual Recognition subscale, there was significant difference between the two levels of severity ($p = 0.035$) and also a significant interaction effect ($p = 0.004$). Simple main effects analyses for type at severity were done for the subscales showing interaction effects. List Recall, Visual Reproduction and Visual Recognition showed no significant differences for type at severity. Delayed List Recall (FLI; 3.65 ± 3.25, NFLI; 5.52 ± 3.87, $p = 0.034$), Prose Memory (FLI; 5.37 ± 3.43, NFLI; 7.43 ± 4.08, $p = 0.027$), and Delayed Prose Memory (FLI; 5.41 ± 3.61, NFLI; 7.61 ± 3.99, $p = 0.022$) showed significant differences for type at MOTBI. Delayed Visual Recognition (FLI; 8.05 ± 3.19, NFLI; 4.56 ± 3.18, $p = 0.031$) showed a significant difference for type at MTBI.

Verbal Memory Process Scores

There were no significant differences between the groups for any of the Verbal Memory Process Scale scores, but

Table 3. Comparisons of Korean Memory Assessment Scale scores between injury severity and type in 110 traumatic brain injury patients

	MTBI (n = 36)		MOTBI (n = 74)		p^*	$p^†$	$p^‡$
	FLI (n = 20) (mean ± SD)	NFLI (n = 16) (mean ± SD)	FLI (n = 51) (mean ± SD)	NFLI (n = 23) (mean ± SD)			
Subscale scores							
Verbal span	7.25 ± 3.86	5.75 ± 3.38	5.71 ± 3.81	6.09 ± 4.03	0.485	0.451	0.241
Visual span	9.50 ± 2.63	7.75 ± 3.68	7.31 ± 3.46	8.13 ± 3.78	0.517	0.211	0.077
List learning	5.00 ± 3.39	4.38 ± 3.12	4.24 ± 2.83	5.48 ± 3.37	0.635	0.794	0.153
List recall	5.70 ± 4.38	3.56 ± 3.41	3.96 ± 3.57	5.61 ± 3.80	0.756	0.846	0.018
Delayed list recall	5.15 ± 4.27	3.31 ± 3.26	3.65 ± 3.25	5.52 ± 3.87	0.980	0.640	0.015
Prose memory	7.60 ± 4.16	5.69 ± 4.30	5.37 ± 3.43	7.43 ± 4.08	0.926	0.766	0.015
Delayed prose memory	7.65 ± 3.83	5.88 ± 4.80	5.41 ± 3.61	7.61 ± 3.99	0.797	0.759	0.017
Names-faces	5.70 ± 3.47	4.56 ± 3.05	4.22 ± 3.02	4.70 ± 3.59	0.028	0.320	0.235
Delayed names-faces	6.35 ± 2.91	5.38 ± 3.28	4.41 ± 2.94	4.87 ± 3.22	0.686	0.058	0.264
Visual reproduction	7.80 ± 3.38	5.25 ± 4.19	6.37 ± 3.74	7.30 ± 4.16	0.317	0.697	0.033
Visual recognition	7.25 ± 3.82	4.56 ± 3.22	5.29 ± 3.48	6.87 ± 3.55	0.453	0.813	0.005
Delayed visual recognition	8.05 ± 3.19	4.56 ± 3.18	4.94 ± 3.16	5.48 ± 3.74	0.035	0.115	0.004
Verbal memory process scores							
Intrusions	1.70 ± 2.60	3.25 ± 4.89	2.80 ± 4.58	1.52 ± 2.11	0.871	0.705	0.088
Clustering : list learning	0.14 ± 0.10	0.15 ± 0.09	0.24 ± 0.65	0.15 ± 0.12	0.666	0.584	0.632
Clustering : list recall	0.26 ± 0.32	0.18 ± 0.21	0.17 ± 0.19	0.22 ± 0.17	0.780	0.569	0.133
Clustering : delayed list recall	0.19 ± 0.21	0.25 ± 0.24	0.18 ± 0.20	0.25 ± 0.19	0.153	0.943	0.933
Cued recall : list recall	7.05 ± 4.19	5.38 ± 3.83	6.12 ± 3.59	7.65 ± 3.02	0.927	0.379	0.037
Cued recall : delayed list recall	7.10 ± 4.28	5.88 ± 3.65	6.14 ± 3.84	7.52 ± 3.04	0.919	0.664	0.099
List recognition	9.65 ± 3.48	8.63 ± 3.86	8.90 ± 3.29	9.26 ± 3.08	0.638	0.937	0.330
Summary scale scores							
Immediate memory scale	92.30 ± 15.31	82.13 ± 20.03	80.33 ± 17.72	84.70 ± 20.29	0.448	0.221	0.060
Verbal memory scale	84.15 ± 21.85	73.00 ± 18.24	72.43 ± 16.22	82.30 ± 19.21	0.868	0.753	0.007
Visual memory scale	87.85 ± 18.52	74.75 ± 20.50	77.55 ± 21.07	84.70 ± 19.42	0.484	0.967	0.019
Global memory scale	83.45 ± 20.18	70.06 ± 18.08	71.94 ± 17.02	81.26 ± 19.12	0.595	0.968	0.004

*p value of difference between mild and moderate TBI, †p value of difference between FLI and NFLI, ‡p value of interaction between injury severity and type. FLI : frontal lobe injury, FNFLI : none frontal lobe injury, MOTBI : moderate traumatic brain injury, MTBI : mild traumatic brain injury, SD : standard deviation
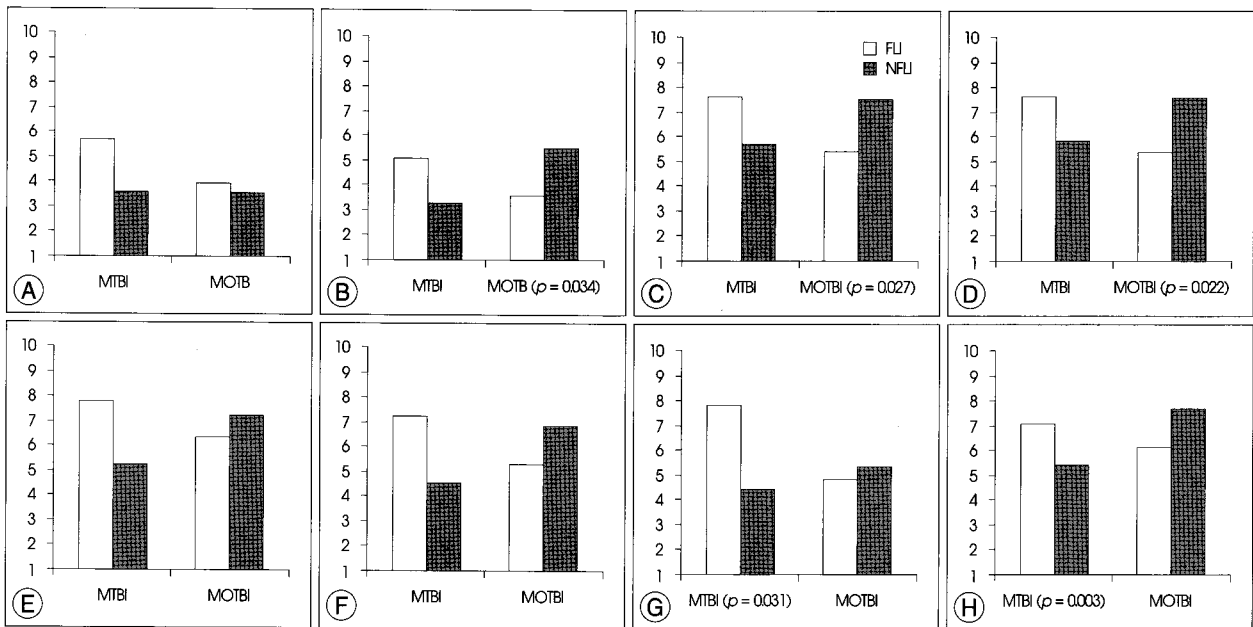
Fig. 1. The subscale and verbal memory process scores of Korean version of the Memory Assessment Scale. List recall (A), delayed list recall (B), prose memory (C), delayed prose memory (D), visual reproduction (E), visual recognition (F), delayed visual recognition (G), cued recall: list recall (H).
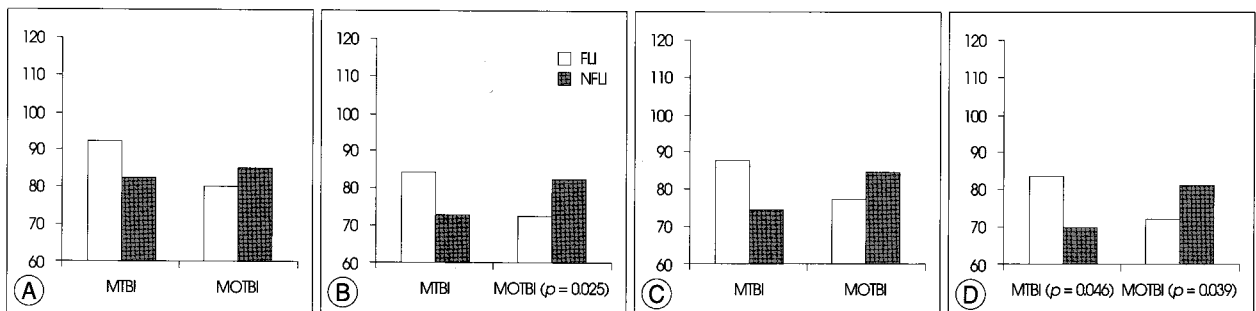

Fig. 2. Summary scores of Korean version of the Memory Assessment Scale (K-MAS). Immediate memory scale (A), verbal memory scale (B), visual memory scale (C), global memory scale (D).

significant interaction effects ($p < 0.037$) was found for Cued recall: list recall. A simple main effects analysis of this interaction showed a significant difference for type at MTBI (FLI; 7.05 ± 4.19, NFLI; 5.38 ± 3.83, $p = 0.003$).

Summary Scale Scores

The Verbal Memory Scale, Visual Memory Scale and Global Memory Scale scores showed no significant differences between groups, but all, except the Immediate Memory Scale, showed significant interaction effects. A simple main effects analysis revealed that the Verbal Memory Scale showed a significant differences for type at MOTBI (FLI; 72.43 ± 16.22, NFLI; 82.30 ± 19.21, $p = 0.025$), and the Global Memory Scale showed a significant differences for type at MTBI (FLI; 83.45 ± 20.18, NFLI; 70.06 ± 18.08, $p = 0.046$) and at MOTBI (FLI; 71.94 ± 7.02, NFLI; 81.26 ± 19.12, $p = 0.039$). The Visual Memory Scale showed no significant differences for type at severity.

DISCUSSION

The degree of neurocognitive or memory dysfunction after a TBI is affected by the nature, cause, severity and age at onset of the injury, and by premorbid intelligence and participation in a rehabilitation program, and studies of memory dysfunction after a TBI should exclude patients who are in a distressed emotional state or have a psychiatric disorder, have a pre-existing developmental/cognitive or neurological disorder, suffer from alcohol or drug abuse, or are involved in a litigation process[44]. In the present study, all of these exclusion criteria were used, and the factors considered to affect levels of memory impairment were controlled by matching and balancing patients between the comparison groups and then statistically verifying the results of this in a preliminary statistical analysis. The only variable, which was not successfully controlled in this way, was the time between the TBI and assessment, which was

found to be shorter for the TBI patients with FLI than for the TBI patient without FLI. One possible explanation for this may be that TBI patients with FLI show more severe, multiple or more important symptoms than those without FLI and, because of the additional complex problems associated with frontal lobe lesions, it is good clinical practice for clinicians to assess patients earlier than might be the case if no frontal damage is present. TBI patients with FLI generally show not only simple or complicated deficits of cognitive functions, but also experience varying deficits of the neuro-behavioral spectrum even when the TBI is classified as mild using common medical criteria. Impairment in the executive functions of the frontal lobe can have wide-ranging effects on an individual's ability to function effectively in his or her daily life, and can impair job performance, activities of daily living, and interpersonal relationships[33].

Comparisons of memory abilities in TBI patients with and without FLI in terms of injury severity were performed using a standardized memory assessment battery, which is widely used for routine clinical purposes. Summary Scale scores on the Immediate, Verbal, Visual and Global Memory scales showed no differences between TBI patients with and without FLI, but did show different by type at severity. MTBI patients with FLI showed higher Global Memory ability than MOTBI patients without FLI, MOTBI patients with FLI showed lower Verbal and Global memory abilities than MTBI patients without FLI.

Ignoring the severity of TBI, we could conclude that FLI does not affect memory function. Other studies including patients with mild traumatic brain injuries[5,9,12,13] showed mixed results, but most studies including those on patients with moderate to severe traumatic brain injuries[4,7,8,11,19,21,35,41,45-49] showed impaired memory functions. These results show that the relationship between the severity of the injury and memory performance of patients with TBI is moderate[25,26].

The Global, Verbal and Visual Memory scores indicate that MTBI patients with FLI were either not, or only minimally, affected by FLI, whereas MOTBI patients were more affected. These results suggest that, when a standardized clinical test of memory is used, the memory facilitating functions of the frontal lobes in patients with a MTBI are relatively preserved when their frontal lobes are damaged : this is not, however, the case in patients with a more severe TBI who show clear evidence of memory impairments if there is frontal lobe damage. Some subscale scores and Cued recall : list recall scores showed the same results as above.

One shortcoming of our neuropsychological assessment is that we used the K-MAS, which is a standardized test with highly structured tasks. Use of this particular assessment tool makes it difficult to adequately investigate the integrity

of the executive control system because the examiner gives the patient instructions on what to do and when to begin and then keeps the patient on task until the task is completed[3]. Most cognitive tests allow the subjects little room for discretionary behaviors, including many behaviors thought to be sensitive to executive functions or frontal lobe disorder[15,28,39]. The very long process of assessing frontal lobe functions with a comprehensive and clinically driven standardized memory test may mask evidence of an existing impairment. As a result, patients having the same level of severity (MTBI only), but no FLI, could have showed lower memory abilities due to of the nature of the memory test administered.

MOTBI patients were different from MTBI patients. MOTBI patients with or without FLI showed no difference in Verbal and Visual Span, List-Learning, Names-Faces, Delayed Names-Faces, and almost all the Verbal Memory Process abilities. However, when FLI was present, MOTBI patients performed at a lower level than those without FLI on the Verbal and Global Memory scales, Delayed List Recall, Prose Memory, and Delayed Prose Memory scales. On the other hand, performances according to type and severity level varied in List Recall, Visual Reproduction, and Visual Recognition abilities. The memory facilitating functions of the frontal lobe or executive functions seem to have contributed to the implementation of a strategic approach and conceptual elaboration of information at the retrieval stages of the memory process, but Vakil[44] suggests that the most vulnerable memory processes following TBI very much resemble the memory deficits reported in patients following frontal lobe damage, i.e., difficulties in applying an active or effortful strategy in the learning or retrieval process.

The frontal lobes facilitate memory in a variety of ways[29] and FLI causes deficits in providing structure to stimulus encoding[14], a diminished capacity to integrate temporally separated events[16,17], and poor recall of contextual information (impaired source memory)[22]. These more common patterns of memory deficits are secondary to the disruption of executive or planning abilities, and both encoding and retrieval can present relatively novel problems which require strategic organization to arrive at an optimal solution. If planning ability is impaired, then encoding will be inefficient and memory will be poor. Similarly, if retrieval is rendered inefficient by poor planning so that search and monitoring operations are sub-optimal, then memory will be poor[10,30-32,40,42,43].

In conclusion, TBI patients with FLI did not show any deficits or superior performance in clinically driven, structured, and comprehensive memory tests when they are

compared with TBI patients without frontal lobe injury and MTBI. Gershberg and Shimamura[20] found that strategy instruction at either study (encoding) or test (retrieval) improved recall in patients with frontal lesions, and patients with frontal lobe damage may score at the average or even well above average level on measures of intellectual functioning in tests such as the WAIS-R[6]. These findings suggest that memory tests, which are theoretically driven, more sensitive and specific to frontal lobe functions, and have been used in well-controlled experimental paradigms, are more appropriate for the assessment of memory abilities in MTBI patients with FLI. MOTBI patients with FLI have shown more severe memory deficits than those without FLI on tests of Global Memory abilities as well as on tests of some specific memory processes such as list recall and prose memory abilities. That is, different kinds of assessment tools are needed for the measurement of memory abilities in TBI patients with FLI, and that the selection of the appropriate tool depends on the severity of the TBI. If mild TBI patients with FLI are known to be in the average range of intelligence using standard and formal intelligence tests such as Korean Wechsler Adult Intelligence Scale, then comprehensive, standardized, formal memory tests will be useless in the detection of memory deficits. Conversely, theoretically driven memory tests with well-controlled experimental paradigms may overestimate memory deficits in MOTBI patients with FLI because of the diffuse nature of the brain injury.

The main limitations of this study were that we did not fully consider specific locations or the volume of frontal lobe injury. In the preliminary statistical analysis, side of FLI appeared to make no difference. Some studies have shown that focalized lesion and volume or size did not affect frontal lobe functions or executive functions evaluation. Levin et al.[27] suggested that focal lesions do not necessarily correlate with neuropsychological impairment following TBI. However, global indicators of diffuse axonal injury or white matter atrophy do appear to show significant correlations with cognitive functioning[18]. This means that some level of disruption of functioning in frontal-subcortical systems or in the connections between these systems and other parts of the brain can result in impaired executive capacities in the frontal lobe[33].

CONCLUSION

TBI patients with frontal lone injury did not show any deficits or superior performance in clinically driven, structured, and comprehensive memory tests when they are compared with TBI patients without FLI and MTBI.

MOTBI patients with FLI have shown more severe memory deficits than those without FLI on tests of Global Memory abilities as well as on tests of some specific memory processes such as list recall and prose memory abilities. Different kinds of assessment tools are needed for the measurement of memory abilities in TBI patients with frontal lobe injury, and that the selection of the appropriate tool depends on the severity of the TBI.

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