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Clinical Article

Neuropsychological Assessment of Adult Patients with Shunted Hydrocephalus

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Objective : This study is planned to determine the neurocognitive difficulties of hydrocephalic adults.
Methods : The research group contained healthy adults (control group, n : 15), and hydrocephalic adults (n : 15). Hydrocephalic group consisted of patients with idiopathic aquaduct stenosis and post-meningitis hydrocephalus. All patients were followed with shunted hydrocephalus and not gone to shunt revision during last two years. They were chosen from either asymptomatic or had only minor symptoms without motor and sensorineural deficit. A neuropsychological test battery (Raven Standart Progressive Matrices, Bender-Gestalt Test, Cancellation Test, Clock Drawing Test, Facial Recognition Test, Line Orientation Test, Serial Digit Learning Test, Stroop Color Word Interference Test-TBAG Form, Verbal Fluency Test, Verbal Fluency Test, Visual-Aural Digit Span Test-B) was applied to all groups.
Results : Neuropsychological assessment of hydrocephalic patients demonstrated that they had poor performance on visual, semantic and working memory, visuoconstructive and frontal functions, reading, attention, motor coordination and executive function of parietal lobe which related with complex and perseverative behaviour. Eventually, these patients had significant impairment on the neurocognitive functions of their frontal, parietal and temporal lobes. On the other hand, the statistical analyses performed on demographic data showed that the aetiology of the hydrocephalus, age, sex and localization of the shunt (frontal or posterior parietal) did not affect the test results.
Conclusion : This prospective study showed that adult patients with hydrocephalus have serious neuropsychological problems which might be directly caused by the hydrocephalus; and these problems may cause serious adaptive difficulties in their social, cultural, behavioral and academic life.

KEY WORDS : Adult · Hydrocephalus · Neuropsychological assessment.

INTRODUCTION

The term of hydrocephalus means that an abnormal accumulation of cerebrospinal fluid (CSF) in the cerebral ventricular system which increases the intracranial pressure (ICP)[22]. Increased ICP can cause some neuropsychological problems[8]. In literature, some authors suggested that although the hydrocephalus is apparently arrested, the disorder may progress and produce neuropsychological disturbances in certain patients. Recent study results have support this thesis that these patients have persistent neuropsychological difficulties affecting visuospatial, language skills and motor functions; and difficulties in other nonverbal domains such as attention, memory, maths, numeracy, and problem solving[3,12,14,22]. Because these problems with memory and concentration reduce intellectual ability and decrease performance in school, these patients have serious adaptive problems in their social, cultural, behavioral and academic life[11,12,14].

In literature, aim of most studies were constructed to describe the neuropsychological difficulties of the spina bifida with hydrocephalus. Neurodevelopmental disorders affecting physical, cognitive, and adaptive function throughout the childhood years has been well demonstrated in those studies. However, little knowledge about the adult outcomes of the neuropsychological difficulties. Some of the cognitive disfunction in hydrocephalic young adult with spina bifida are now being identified; but their adaptive difficulties are poorly explained[11,12,14,22]. In these studies, there are some questions between the aetiological factors

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and development of the neuropsychological difficulties. The purpose of this prospective study was to describe neuropsychological problems, and other intellectual skill difficulties of adult patients with hydrocephalus without spina bifida.

Table 1. Descriptive table of the demographic data of the all group

Group	Sex	N	Min	Max	Mean	SD
Hydrocephalus	Famale	6	26.09	40	33.88	5.84
	Male	9	22.11	60	36.85	13.36
Control	Famale	6	28.08	42.1	35.07	6.36
	Male	9	24.09	53.8	36.61	9.63

N : number of the patients, Min : minimum age, Max : maximum age, Mean : mean of age, SD : standart deviation

MATERIALS AND METHODS

Subjects

The research group contained healthy adults (control group) and hydrocephlic adults (hydrocephalus group). Non of the patients had overt clinical signs or symptoms of increased intracerebral pressure.

The hydrocephalus group (n : 15) consisted of 9 male (mean age, 36.85 ± 13.36 years) and 6 female (mean age, 33.88 ± 5.84 years) who followed with shunted hydrocephalus and not gone to shunt revision last two years at the Hacettepe University Faculty of Medicine, Department of Neurosurgery. The hydrocephalus group subjects were chosen from adults who were either asymptomatic or had only minor symptoms (such as sporadic headache, attention and memory difficulties, psychomotor slowness, etc.) without motor and sensorineural deficit. All subjects with other neurological abnormalities such as tumour, intraventricular haemorrhage, epilepsy or stroke were excluded. This group could be divided into two subgroups aetiologically as follows : idiopathic aquaductal stenosis (n : 7), and post-meningitis hydrocephalus (n : 8). Post-meningitis hydrocephalus patients who were treated absolutely had not any infection parameter in CSF sample. Three of them had tuberculous meningitis, 2 had mumps, 3 had *Haemophilus influenzae.* All subjects were statistically analysed to determine the effect of the aetiological factors described above on the all neuropsychological tests points used by "Indipendent Sample t-test"; and there was no statistically significant difference between them; and this group was therefore not divided into its subgroups.

The control group (n : 15) consisted of 9 male (mean age, 36.61 ± 9.63 years) and 6 female (mean age, 35.07 ± 6.36 years) were chosen from healthy adults. The all groups' sex and age discrimination are shown at the Table 1.

Neuropsychological assessment

Patients underwent neuropsychological examinations which were administered in the same order by the same examiner. They were evaluated by an experienced neuropsychologist (EEB) blinded to the groups. The examiner performed ten different neuropsychological tests battery to all groups with its routin procedures. These tests are described below respectively.

Raven Standart Progressive Matrices (RSPM)

It was originally developed by Raven et al.[24] The test is accepted as a culture-fair test of general intelligence (g factor) and also of visuospatial cognition (*K* factor)[24]. Raven Standart Progressive Matrices (RSPM) performance requires working memory, category shift, mental flexibility, problem solving, abstraction and reasoning; these functions are combined under the umbrella term, "executive functions"[16,19,23].

Bender-Gestalt Test (BGT)

It is first developed by Bender[1]. This test is used to evaluate "visual-motor maturity", to screen for developmental disorders, or to assess neurological function or brain damage. It measures perceptual motor skills, perceptual motor development, and gives an indication of neurological intactness of *parietal lobes*[19].

Cancellation Test (CT)

It was originally developed by Weintraub and Mesulam[28] to measure a sensory component of the *parietal lobes* that is related to perceptual errors, a motor component that is related to visual search and scan and a motivational component that is related to expectation and affect. Cancellation Test (CT) is used in the literature as a measure of visuomotor performance and of vigilance and sustained attention[15,18,19].

Clock Drawing Test (CDT)

The Clock Drawing Test (CDT) draws on several skills, including auditory comprehension, visuospatial ability, and constructional praxis which are mainly functions of the parietal lobes. Additionally, the CDT may detect deficits in executive functioning that are overlooked by other routine cognitive tests. Since executive function relates to a person's ability to plan, initiate, sequence, monitor and stop complex behavior, it may be particularly useful when assessing patients' functional status[26].

Facial Recognition Test (FRT)

This instrument consists of 13 pairs of stimulus plates, which require the patient to perform 27 visuoperceptive discriminations of unfamiliar Caucasoid faces. The task has neither memory nor speed components. It measures visuospatial recognition function of the posterior association cortex and *temporal lobe*[19].

Line Orientation Test (LOT)

It was originally developed by Benton et al.[2] to measure visuospatial perception and orientation. This test measures visual-perceptual/visual-spatial discrimination, and the patient's ability to analyze and synthesize visual form and spatial relations. It is more specific for the right hemispheric cognitive functions and sensitive especially in the injuries involving the right cerebral hemisphere and *parietal lobe*[16,19].

Serial Digit Learning Test (SDLT)

Tasks that involve digit series are among the primary tools of neuropsychology for measuring attention, learning, and memory, since the contaminating effect of associative influences is lower on digits than on words or pictures. This test has demonstrated validity and provides additional substantive data in the evaluation of brain-damaged patients; and performance on SDLT is dependent upon the mesial *temporal lobe* and hippocampus[16,19].

Stroop Color Word Interference Test-TBAG Form (SCWT)

It measures the ability to shift perceptual set with the changing demands, also measures to inhibit a habitual behavior pattern, and to behave in an unusual way. Defects in these abilities result in perseverations, stereotypic behaviors, and difficulty in controlling the behaviors. These functions are mainly the functions of the *frontal lobes*. Higher interference score indicates poorer performance. Stroop Color Word Interference Test-TBAG Form (SCWT) also assesses the information processing rate, and parallel processing of attended and non-attended stimuli, and attention[16,20].

Verbal Fluency Test (VFT) [The Initial Letter Verbal Fluency Test (FAS)]

It evaluates executive function of the *frontal lobe* and semantic memory store (a temporal lobe function). In a timed test (one minute), the patient generates words beginning with the letters K, A and S ("Association" score). We also provided a semantic category (animals) and scored the number of words generated ("Animals" score). Last, we combined letter fluency with category fluency in which the subject had to switch between words beginning with the letter "K" and names of animals ("Categories" score)[19].

Visual-Aural Digit Span Test-B (VADS-B)

Visual-Aural Digit Span (VADS) test was originally designed as a diagnostic tool for assessing reading and learning disabilities which are mainly functions of the *temporal lobes*; and it is specifically used for measuring attention span[16,17].

Statistical analysis

The study results were normally distributed and the variation was homogenous between groups. Therefore they were analyzed statistically using by parametric tests. Age, sex and aetiological factors were investigated using "Independent Sample t-test"; and p values less than 0.05 were considered to be significant. Effect of intelligence on test scores was investigated using by the "analyses of variance test" (ANOVA); and p values less than 0.05 were considered to be significant. Neuropsychological test points of the hydrocephalus and control groups were analyzed "Multiple Analysis of Covariance Test" (MANCOVA); and p values less than 0.05 were considered to be significant. All data were analyzed using SPSS for Windows Release 13.0.[27].

RESULTS

Demographic data was investigated using by "Indipendent Sample t-test". Age, sex and aetiological factors were not statistically significant difference between hydrocephalus and control groups ($p > 0.05$).

In the hydrocephalus group and control group, the effect of intelligence on test scores was investigated using by ANOVA. Significant differences among the groups were found in RSPM total score ($F = 16.58$, $df = 1$, $p < 0.001$) and time score ($F = 4.41$, $df = 1$, $p = 0.045$) (Table 2, Fig. 1).

Performances of the hydrocephalus and control groups

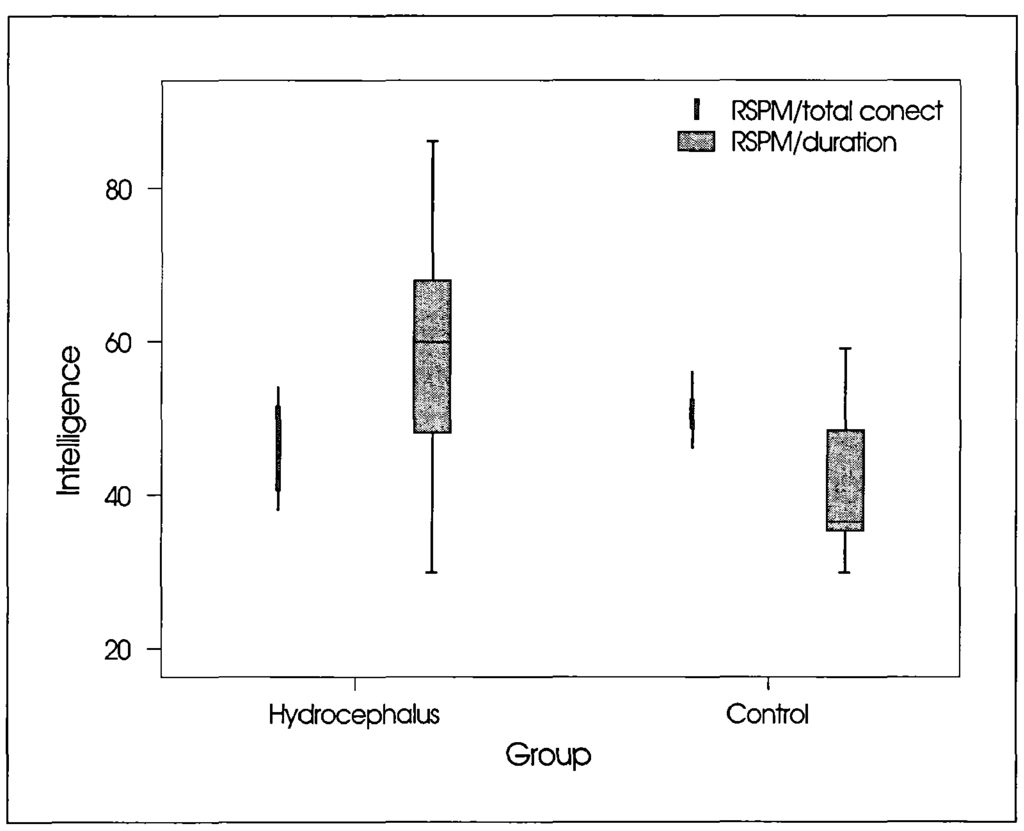

Fig. 1. Figure shows the mean values of the raven standart progressive matrices (RSPM) total correct and RSPM duration scores. Each error bar shows the minimum and maximum of the RSPM values.

Table 2. Comparison of the hydrocephalus and control groups with each groups of neuro-psychological test mean scores, F, and *p* values

Dependent Variable	Hydrocephalus	Control	F	*p* value
Intelligence				
RSPM				
RSPM/duration	60.47 ± 16.15	41.04 ± 8.99	4.414	0.045
RSPM/total correct	45.13 ± 8.39	50.13 ± 3.81	16.577	0.000
Executive function (frontal lobe function)				
Stroop Color Word Interference Test - TBAG Form				
ST I/time	17.20 ± 3.43	12.87 ± 3.31	11.570	0.002
ST II/time	19.00 ± 4.02	13.33 ± 2.02	19.012	0.000
ST III/time	41.87 ± 18.57	21.33 ± 7.30	13.567	0.001
ST IV/time	49.07 ± 15.89	33.33 ± 10.73	8.701	0.006
ST V/time	72.20 ± 19.18	44.93 ± 13.68	15.795	0.000
Interference Score	60.48 ± 17.84	36.98 ± 13.00	13.190	0.001
Verbal Fluence Test				
Word Associations	20.67 ± 9.54	32.87 ± 7.30	12.682	0.001
Animals	15.00 ± 5.71	25.60 ± 4.92	25.860	0.000
Catagory fluence	5.93 ± 1.75	5.93 ± 1.75	0.351	0.559
Learning and Facial Recognition (Temporal lobe function)				
VADS-B				
Aural-oral	4.47 ± 0.74	5.33 ± 0.98	4.168	0.051
Visual-oral	4.07 ± 0.96	4.67 ± 1.11	1.384	0.250
Aural-written	4.27 ± 0.96	5.20 ± 0.68	6.859	0.014
Visual-written	3.93 ± 1.39	5.40 ± 0.74	11.001	0.003
Aural input	8.73 ± 1.33	10.53 ± 1.41	8.429	0.007
Visual input	8.00 ± 2.14	10.07 ± 1.58	6.817	0.015
Aural expression	8.53 ± 1.51	10.00 ± 1.77	3.322	0.079
Visual expression	8.20 ± 2.21	10.60 ± 1.18	10.901	0.003
Intrasensory integration	8.40 ± 1.68	10.73 ± 1.28	13.302	0.001
Intersensory integration	8.33 ± 1.72	9.78 ± 1.46	4.590	0.041
Total VADS-B	16.73 ± 3.26	20.60 ± 2.53	9.246	0.005
Serial Digit Learning Test				
Total Score	9.80 ± 3.63	14.80 ± 3.95	7.590	0.010
Facial Recognition Test				
Total Score	34.40 ± 6.28	40.40 ± 5.47	5.925	0.022
Visual & Visual Spatial Perception (Parietal Lobe Function)				
Cancellation Test				
Organized letters : correct responses	55.07 ± 6.46	59.87 ± 0.35	6.345	0.018
Organized letters : omission errors	4.93 ± 6.46	0.13 ± 0.35	6.345	0.018
Organized letters : commission errors	0.07 ± 0.26	0.00 ± 0.00	1.613	0.215
Organized letters : total errors	5.00 ± 6.41	0.13 ± 0.35	6.697	0.015
Organized letters : duration	167.20 ± 80.57	166.00 ± 36.70	0.061	0.807
Organized figures : correct responses	53.80 ± 8.31	59.67 ± 0.72	5.084	0.032
Organized figures : omission errors	6.20 ± 8.31	0.33 ± 0.72	5.084	0.032
Organized figures : commission errors	1.47 ± 3.25	0.53 ± 1.36	0.809	0.376
Organized figures : total errors	7.67 ± 10.90	0.80 ± 1.61	4.057	0.054
Organized figures : duration	175.87 ± 67.33	171.27 ± 35.86	0.046	0.832
Random letters : correct responses	55.07 ± 3.84	58.87 ± 2.50	8.570	0.007
Random letters : omission errors	4.93 ± 3.84	1.27 ± 2.49	8.107	0.008
Random letters : commission errors	0.00 ± 0.00	0.07 ± 0.26	0.847	0.366
Random letters : total errors	4.93 ± 3.84	1.33 ± 2.50	7.803	0.009
Random letters : duration	191.20 ± 84.29	180.53 ± 40.08	0.150	0.702
Random figures : correct responses	56.07 ± 3.69	59.33 ± 0.82	5.694	0.024
Random figures : omission errors	3.93 ± 3.69	0.67 ± 0.82	5.694	0.024

Table 2. Continued

Dependent Variable	Hydrocephalus	Control	F	*p* value
Random figures : commission errors	1.20 ± 3.86	0.00 ± 0.00	0.514	0.480
Random figures : total errors	5.07 ± 5.69	0.67 ± 0.82	3.998	0.056
Random figures : duration	149.20 ± 59.92	168.80 ± 38.97	1.345	0.256
Line Orientation Test				
Total Score	15.00 ± 4.42	23.53 ± 3.25	27.704	0.000
Bender-Gestalt Visual Perception Test				
Total Score	6.07 ± 2.96	1.47 ± 1.46	20.729	0.000
Clock Drawing Test				
Total Score	26.47 ± 7.66	32.13 ± 3.78	3.503	0.072

Multiple Analysis of Covariance Test, $p < 0.05$. F: Measurement of distance between individual distribution. RSPM : Raven Standart Progressive Matrices, VADS-B : Visual-Aural Digit Span Test-B

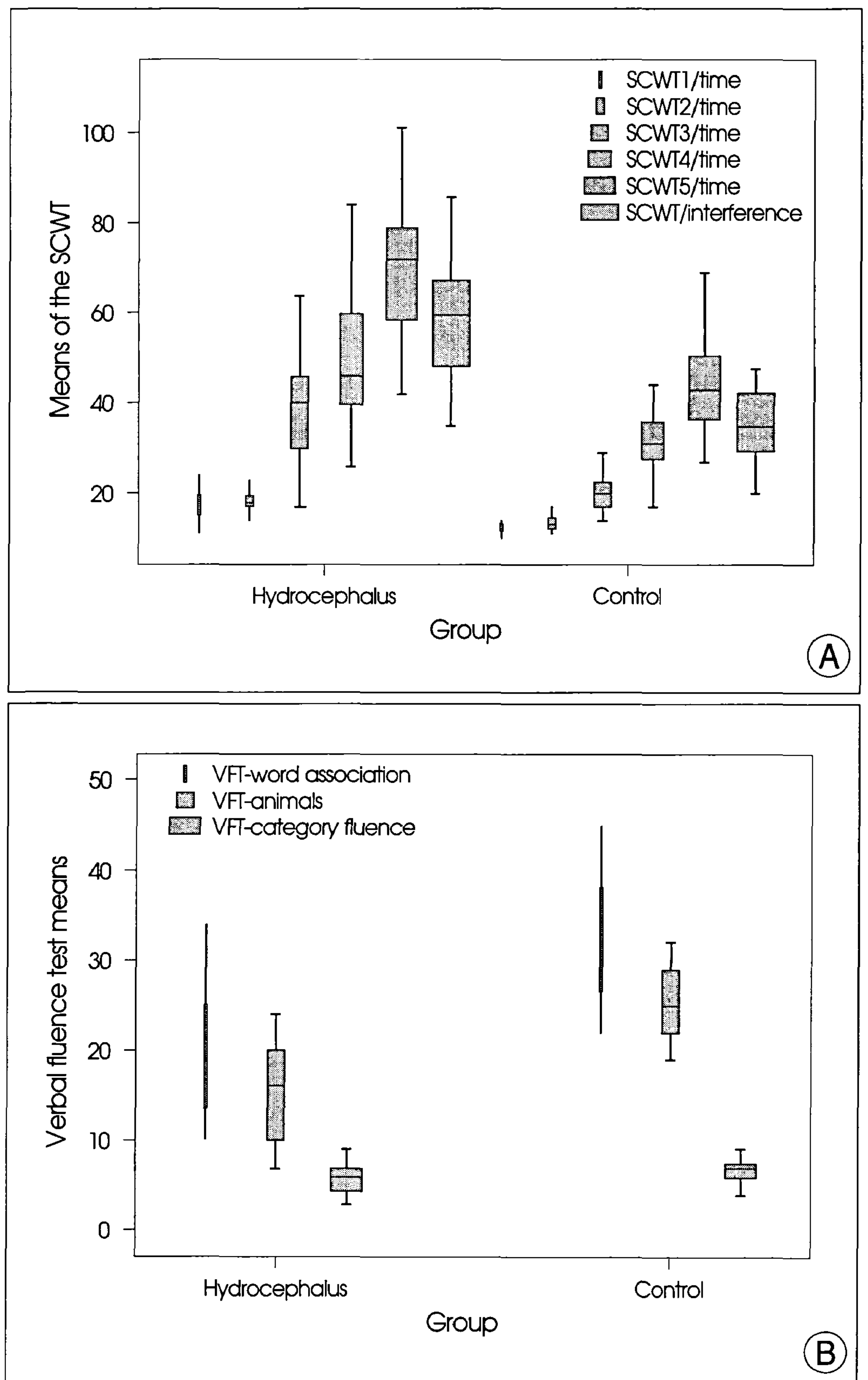

Fig. 2. (A) Figure shows the mean scores of the stroop color word test (SCWT) time and SCWT interference; and (B) mean scores of the verbal fluency test for subjects. SCWT : Stroop Color Word Test, VFT : Verbal Fluency Test.

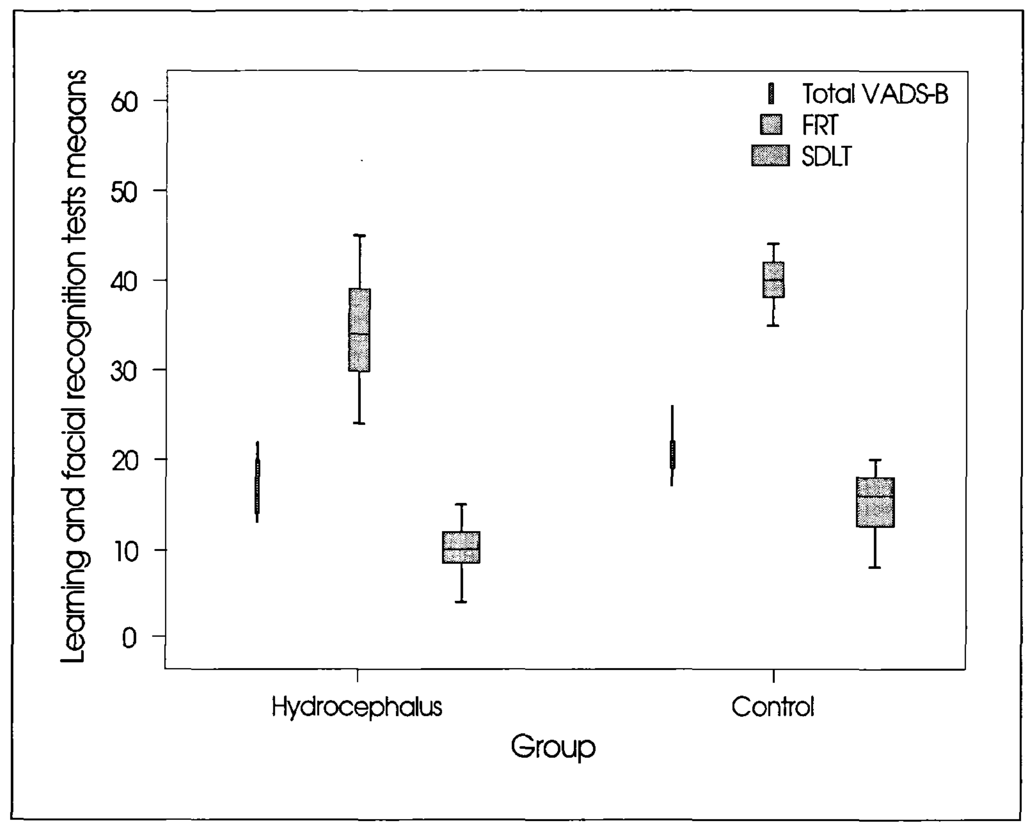

Fig. 3. Mean scores of the learning and facial recognition tests for subjects. FRT : Facial Recognition Test, SDLT : Serial Digit Learning Test, VADS-B : Visual-Aural Digit Span Test-B.

on neuropsychological tests were compared using by MANCOVA, controlling for the effects of intelligence scores. All the time points and interference scores of the Stroop Color Word Interference Test remained significant after the IQ scores was controlled (Fig. 2A). Verbal Fluency Test Word Associations (F = 12.68, df = 1, $p < 0.001$), Animals (F = 25.86, df = 1, $p < 0.001$) scores were significantly different between the hydrocephalus and control groups (Fig. 2B). There were statistically significant differences for all of the VADS-B subtest points except visual verbal and verbal expression section points. Serial Digit Learning Test (F = 7.59, df = 1, $p = 0.010$), Facial Recognition Test (F = 5.92, df = 1, $p = 0.022$) (Fig. 3), Line Orientation Test (F = 27.70, df = 1, $p < 0.001$), and Bender-Gestalt Test (F = 20.73, df = 1, $p < 0.001$) scores remained significant after the intelligence score was controlled (Fig. 4A). Cancellation Test organized/random letters and figures of correct responses and omission-error scores were also statistically significant (Table 2, Fig. 4B). These analytic results showed that the hydrocephalus group had poorer intelligence measured by RSPM than control group. Evenly, they had difficulties on the attention (especially sustained attention) which was measured by the CT, SCWT, SDLT, VADS-B. They also had problems on the visuospatial recognition, visual-perceptual/visual spatial discrimination, visuomotor perfor-

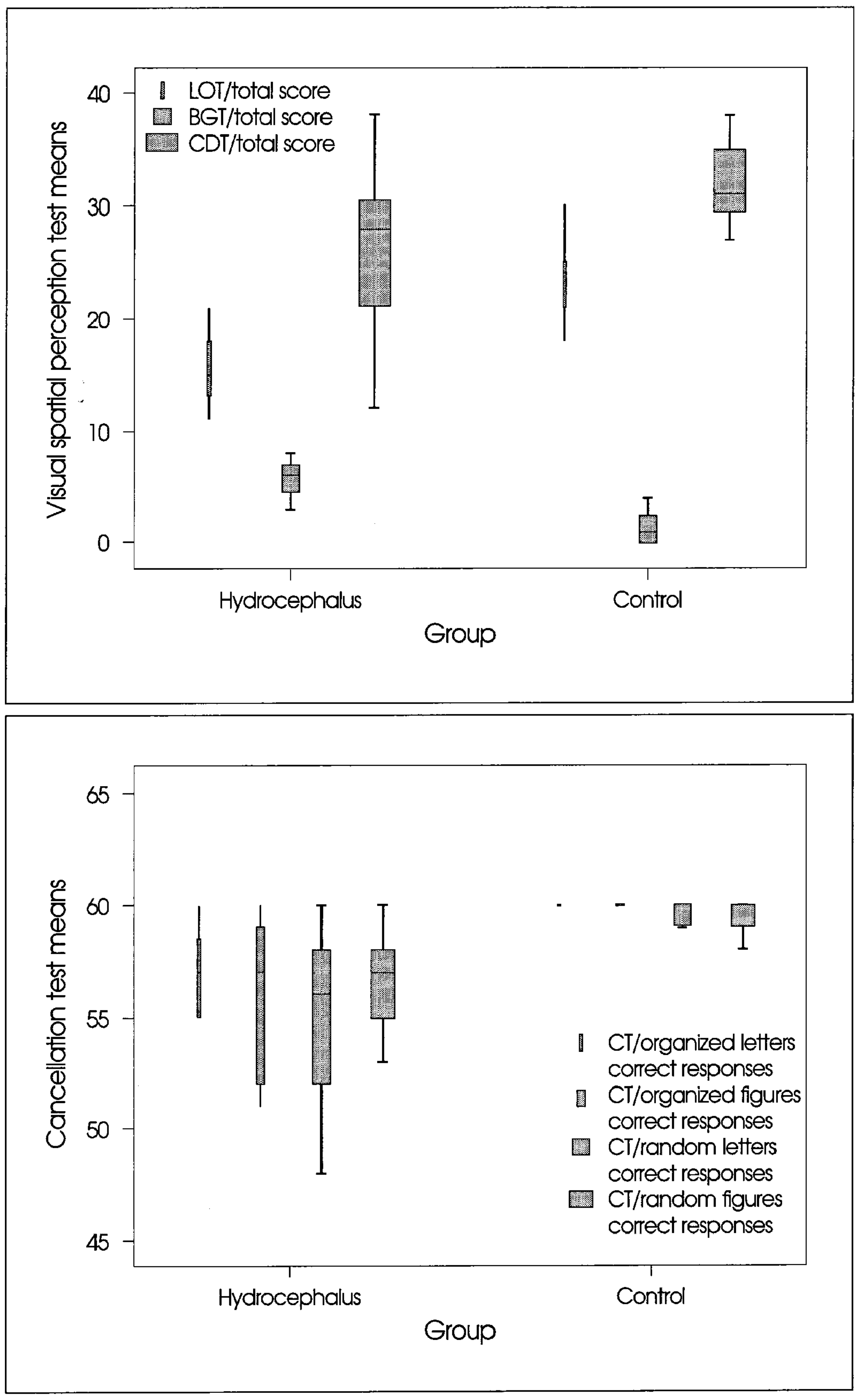

Fig. 4. Mean scores of the visuospatial perception tests for subjects. BGT : Bender-Gestalt Test, CDT : Clock Drawing Test, LOT : Line Orientation Test, CT : Cancellation Test.

mance, reaction time and ability to analyze and synthe-size visual form and spatial relations which were measured by BGT, CT, FRT, LOT. They were unsuccessful on the executive function (i.e., ability to plan, initiate, inhibitory control, verbal fluence, perseveration and modulating impulsive responding) which was measured by SCWT, and VFT. They had learning and reading disabilities, and memory problems which were demonstrated by SDLT and VADS-B.

DISCUSSION

In recent literature, severeal studies have reported that raised ICP can produce mechanical stress. This stress may develope impaired cerebral metabolism by decreasing of the cerebral blood flow which may cause to reduce the concentration of neurotransmitters and peptide neuromodulators, and to reflect the neuronal dysfunction and neurocognitive disruption/deficits[5,6,12]. Fletcher et al. (1992) showed that the hydrocephalic children have low points at their performance tests which measure the functions of the right hemisphere of the brain (known as the non-dominant hemisphere). They also had low performances at their verbal tests which measure functions of the left hemisphere (known as the dominant hemisphere)[9]. Rourke et al.[25] described the hydrocephalus as a syndrome of non-verbal learning disabilities which could be described by impairments in visual and tactile perception, visual and tactile attention, visual and tactile memory, conceptualization, and problem solving. They also considered that these patients has difficulties on school achivement, and has social maladaptation with maladaptive behaviour[25]. In our study, the statistical analyses disclosed that all patients with shunted hydrocephalus presented poorer performance on most of the neuropsychological measures than the control group. Overall, neuropsychological assessment of hydrocephalic patients demonstrated that they had poor performance on visual, semantic and working memory, visuoconstructive and frontal functions, reading, attention, motor coordination and executive function of parietal lobe which related with complex and perseverative behaviour. Eventually, the patients with hydrocephalus had significant impairment on the neurocognitive functions of their frontal, parietal and temporal lobes. On the other hand, the statistical analyses performed on demographic data showed that the aetiology of the hydrocephalus, age, sex and localization of the shunt (frontal or posterior parietal) did not affect the test results, as reported in the literature[12]; it could therefore be said that these difficulties may be caused by hydrocephalus itself and not the aetiological factors.

Hetherington et al.[17] however, suggested that spinal lesion level affects adult outcome. Fletcher et al.[8] also suggested that regional variations in brain tissue composition in children with spina bifida-shunted hydrocephalus correlate with a variety of cognitive and visuomotor functions. They also observed that a higher level of spinal lesion in children with spina bifida-shunted hydrocephalus is related with more severe anomalous brain development, and this is also associated with poorer neurobehavioral outcome[8]. To corroborate this thesis, they performed diffusion tensor tractography to delineate and quantify bilaterally four major association pathways (arcuate, inferior longitudinal, inferior fronto-occipital, and uncinate fasciculi) of the patient with spina bifida meningomyelocele (SBM); and they showed that these patients have abnormal development, impairment in myelination as well as abnormalities in intrinsic axonal characteristics and extra-axonal/ extracellular space in their association pathways. At the end of this study they hypothesized that the differences in the diffusion metrics observed in the children with SBM are suggestive of abnormal white matter development and persistent degeneration with increased age[9,10]. On the other hand, there are few data on the adult hydrocephalus without SBM. Donnet et al.[7] concluded in their study that most neuropsychological difficulties of adult patients with aqueduct stenosis are related with fornix damage secondary to third ventricle enlargement. These difficulties are seen especially on the immediate memory and planning and consolidation of newly learned information. They also declared that adult patients with normal pressure hydrocephalus have prefrontal lobe disconnection and their executive function is more severely impaired than patients with aqueduct stenosis[7]. Additionally, Mataro et al.[22] investigated 23 adult patients with SBM, and they found that shunt placement improves the neuropsychological difficulties especially verbal and visual memory and attention. But they did not compare the neuropsychological test results of these patients to the other type hydrocephalic patients (such as occurring secondary to tumour or infectious diseases)[22]. Another study demonstrated that endoscopic third ventriculostomy substantially improves the neuropsychological deficit in the late onset idiopathic aqueduct stenosis. These patients achieved normal or near normal cognitive function[4]. However, there has been still no report about comparison of neurocognitive function of hydrocephalic patients whose diseases are related with different aetiologies. On the other hand, Mataró et al.[22] found no significant result of comparison of patients with active versus compensated hydrocephalus in their study, however they found association between magnitude of the ventricular dilatation and verbal and visual memory. They suggested that larger ventricles are associated with poor performance on verbal and visual memory, and less improvement after surgery in a cued recall task. However, they found after shunt surgery that the neuropyschological test results were well than preoperative results but still worse than control group[22]. They reviewed in 2001 that shunt surgery could only incompletely reverse the brain damage and they said that "appropriate indications and timing for the surgery are as yet not known"[21]. Although our study has not contained preoperative neuropsychological or morphological assessment of hydrocephalic patients, the results of our study compared with healthy control group results confirm the findings of Mataró et al.[22]. Actually, we can speculate that the shunt surgery could not improve the neuropsychological impairment as much as control group. So, we also agree with these authors that more studies are required to resolve the pathophysiology and management of the hydrocephalus. On the other hand Burtscher et al. (2001) showed that the deficit pattern of the patients with late onset idiopathic aqueduct stenosis (LIAS) was similar to that found in other hydrocephalic disorders, but was very dissimilar to hydrocephalic dementia known as "normal pressure hydrocephalus" in older patients; and they declared that third ventriculostomy improved the neuropsychological function near to normal in five of six patients with LIAS[4]. Therefore, we think that the effectiveness of the shunt surgery and third ventriculostomy on the neurocognitive function of the hydrocephalic patients should be evaluated and also compared in future studies.

There are several limitation of this study. Firstly, although this prospective study has no neuropsychological or morphological evaluation of hydrocephalic patients preopertively, it can demonstrate that they have serious problems on their neuropsychological performances behind neurological deficits in the postoperative period. In the light of these findings, we can hypothesize that all of these problems could produce maladaptation on the social, cultural, behavioral and academic areas; and this maladaptation also may produce psychiatric problems such as depressive mood[12,13]. Actually, Hetherington et al.[11] showed that numeracy is an important predictor of quality of life and more relevant to personal independence such as managing money, estimating amounts, or shopping for oneself. They also suggested that in children with spina bifida and hydrocephalus reduced health related quality of life may produce psychiatric disorders[11]. In this way our study may open a way to evaluate the psychiatric problems of the adults patients with hydrocephalus by future studies. Secondly, this study does not contain the evaluation of the memory, so memory difficulties of such patients should be also investigated in future studies. On the other hand, this study highlights the need to determine the effects of the developmental anomalies on the neurocognition by comparison of neuropsychological difficulties of the patients spina bifida-hydrocephalus and aqueduct stenosis-hydrocephalus. Overall, this study also highlights the need to evaluate and describe the neurocognitive difficulties of the hydrocephalic adults by using more specific neuropsychological tests in future investigations.

CONCLUSION

This prospective study showed that patients with hydrocephalus have serious neuropsychological problems which might be directly caused by the hydrocephalus; and these problems may cause serious adaptive difficulties in their social, cultural, behavioral and academic life. Although this study does not explain more details of the neurocognitive deficits of adults with hydrocephalus; its results suggest that the hydrocephalic patients should be evaluated and detailed for their neuropsychological problems before and after shunt surgery, and they should attend rehabilitation programs to improve their quality of life.

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