Neuropsychological Function in Patients with Chronic Carbon Disulfide Intoxication

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Abstract- The aim of this study was to examine neuropsychological function in patients with carbon disulfide intoxication. Eight patients with carbon disulfide-induced polyneuropathy participated in the study of neuropsychological function. Each subject received a comprehensive neuropsychological examination. The patients' performance on the tests were compared with a group of healthy control subjects matched for age and education. The results revealed that the patients with carbon disulfide-induced polyneuropathy had deficits in visual perception of irregularly geometric figures, auditory sustained attention, visually selective attention, cognitive flexibility and concept formation, and manual dexterity of the nondominant hand, and depression. Our findings in Taiwanese patients, thus, were partially commensurate with the previous observations of defective neuropsychological function in individuals with carbon disulfide intoxication. Despite that our findings were based on such small sample of the patients, it appears that carbon disulfide-induced polyneuropathy had clinical implications.

Key Words: CS_2 intoxication, Neuropsychological function, Polyneuropathy

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INTRODUCTION

Carbon disulfide (CS_2) is a sweetish-smelling clear liquid, and the toxicity has been acknowledged for more than a century[1]. This chemical is conceivably the most extensive neurotoxin of all solvents, and therefore it seems that practically all nervous system functions are affected by CS_2[1-4]. Carbon disulfide intoxication due to occupational exposure has often been seen at working sites, such as vulcanization of rubber, in addition to manufacturing of cellophane, plywood, adhesive, various oil products, and viscose rayon[5]. Most clinical cases of CS_2 poisoning are the consequence of inhalation and skin contact that have caused acute nercosis after exposure of greater than 1,000 ppm of the organic solvent.

Neuropsychiatric images, such as manic-depressive psychosis after subacute exposure, polyneuropathy, parkinsonism, and diffuse encephalopathy with cerebrovascular components after chronic low concentration exposure, have been noted. However, very little is known regarding the CNS neuropathology of CS_2[2,6-10]. Neuropsychological function impairment of eye-hand coordination task in workers who had at least 1 year or more of a low level of CS_2 (generally below 20 ppm) exposure has been reported[11]. The deficits in Performance IQ, attention, cognitive tracking, concept

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formation, manual dexterity, motor speed, learning and memory, perceptual motor speed, retarded speech and visuospatial perception in workers with higher and longer exposures to CS_2 have also been noted[12].

However, the literature in regards to this subject in Taiwan is scarce. Thus, in the present study we made an attempt to document neuropsychological status of the patients with CS_2-induced polyneuropathy.

PATIENTS AND METHODS

Participants

Eight male patients with overt polyneuropathy worked in the fiber cutting department in a viscose rayon factory along with a total of 163 workers in a factory located in central Taiwan. The eight workers complained of muscle weakness which was brought a physician's attention, and the patients were then referred to a neurologist (i.e., the second author) to receive further neurological and neuropsychological examinations, and laboratory studies. The fixed-point air concentrations of carbon disulfide at the work site were 150 to 300 ppm and the estimated 8 hours time weighted averages were 40 to 67 ppm in the fiber cutting areas.

Table 1 shows demographic data of these eight workers and Table 2 indicates their clinical features. All of the workers had cortical atrophy, unilateral or bilateral basal ganglia, internal capsule, or unilateral or bilateral corona radiata abnormalities evident on computed tomography (CT) scans and magnetic resonance imaging (MRI) while their EEG results were within reference ranges. The lesions seen on CT and MRI scans were nonspecific, but they might be attributed to sclerosis of the intracranial small vessels. Polyneuropathy was diagnosed in the workers if neurological symptoms and signs of muscle weakness, sensory deficits, and diminished or absent tendon reflexes fulfilled the criteria of polyneu-

Table 1. *Demographic characteristics of subject groups*

	Age (years)			Education (years)			
	Mean	SD	Range	Mean	SD	Range	n
Patients	44.80	4.50	41-49	8.63	2.50	6-12	8
Normals	44.45	4.55	40-54	9.09	2.59	6-12	11
t value (p<0.05)	0.13			0.39			

Table 2. *Clinical summary of the patients with carbon disulfide intoxication*

Patient no.	1	2	3	4	5	6	7	8
Age of onset (years)	41	40	33	46	45	44	31	42
Duration of exposure (years)	17	21	17	23	17	21	14	6
Hypertension	-	+	-	-	-	+	+	-
Smoking	-	+	+	-	-	-	+	+
Alcoholism	-	-	-	-	-	-	-	-
Symptoms								
Headache/Dizziness	+	+	+	-	+	+	+	+
Hearing loss	-	-	-	+	-	-	-	-
Unpleasant dream	+	+	+	-	+	+	+	-
Insomnia	-	-	+	-	+	+	-	+
Fatigue	+	+	+	+	+	+	-	-
Anorexia	-	+	-	+	+	+	-	+
Loss of libido	-	-	-	-	-	-	-	+
Emotional liability	+	+	-	-	-	+	-	-
Stroke episode	-	+	-	-	+	-	-	-
Tremors	-	-	-	+	-	-	-	-
Muscle cramps	-	+	-	+	+	+	+	-
Muscle weakness	+	+	-	+	+	+	+	+
Numbness or paresthesia	+	+	+	+	-	+	+	+
Signs								
Muscle weakness	+	+	+	+	+	+	+	+
Sensory impairment	+	+	+	+	+	+	+	+
Diminished or absent DTR	+	+	+	+	+	+	+	+

DTR: deep tendon reflex; + :present; - :absent

Table 3. Neuropsychological function tests

Orientation	
	Temporal Orientation (TO)[14]
	Orientation to Personal Information and Place (OPIP)[15]
Intellectual function	
	Wechsler Adult Intelligence Scale-Revised (WAIS-R)[16]
Learning and memory	
	Serial Digit Learning (SDL-12)[14]
	Word Sequence Learning-Revised (WSL)[17]
	Benton Visual Retention Test (BVRT)[18]
	Continuous Recognition Memory-Form I (CRM)[19]
Language and communication	
	Multilingual Aphasia Examination (MAE)[20]
	Visual Naming (VN)
	Token Test (TT)
	Semantic Association of Verbal Fluency (VF)[a]
Visuospatial and visuoperceptual Function	
	Judgment of Line Orientation (JLO)[14]
	Facial Recognition Test (FRT)[14]
	Visual Form Discrimination (VFD)[14]
	Three-Dimensional Block Construction-Model (3-DBC)[14]
Executive Function and manual Dexterity	
	Wisconsin Card Sorting Task-Modified (WCST-M)[21]
	Purdue Pegboard (PP)[22]
	Finger Tapping (FT)[23]
Attention	
	Gordon Diagnostic System (GDS)[24]
	Vigilance and Distractibility Subtests
	Paced Serial Addition Task-Revised (PASAT-R)[25]
Emotional State	
	Zung's Self-Rating Depression Scale (ZDS)[26]

[a]Used to measure associative verbal fluency for animals, fruit and vegetables, and replace the original subtest of Controlled Oral Word Association of the MAE.

ropathy and/or abnormal NCS (the details please see the reference section)[13].

There was no other significant medical or surgical history, in particular no history of alcoholic or drug abuse. The neuropsychological test scores of the workers were compared with a group of 11 healthy control subjects, who were volunteers selected from a nearby community, that were matched for age and educational level in years (Table 1). All subjects had no history of psychiatric problems nor had any psychiatric problems during the neuropsychological testing period. All subjects were right-handed: hand dominance was ascertained according to preferential use during writing, holding chopsticks and performing otherwise skilled activities.

Tests and Procedures

Each subject received a comprehensive neuropsychological examination at the Neuropsychological Lab of the Department of Neurology at the Chang Gung Memorial Hospital. The tests, including orientation, intelligence, learning and memory, language, spatial perception, visual perception, attention, concept formation, manual dexterity and motor speed, and mood state, are listed in Table 3. All of the tests[14-26] were conducted in Chinese. An interview scale, Standard Neurobehavioral Interview Inventory[27], was also used to examine the emotional status of the subjects.

The procedures and requirements of the study were explained to each participant. Consent forms were signed prior to data collection. Three hours were needed for each subject to complete the examination. All subjects completed the testing in one session.

Data Analysis

Because of the small sample size of our subject groups, the nonparametric statistical procedure, the Wilcoxon 2-independent sample test, was used for data analysis. This procedure was used to examine the neuropsychological test performance differences between the patients with CS_2-induced polyneuropathy and healthy control subjects.

RESULTS

The performances of the patients on most of the neuropsychological tests were inferior to those of their healthy counterparts except for the Token Test, Three-Dimensional Block Construction-Model, and Vigilance (the correct part). However, the scores for the following tests reached statistically significant levels, including the Visual Form Discrimination, the perseverative errors of the Wisconsin Card Sorting-moditied, Similarity subtest of the WAIS-R, Distractibility (the correct score), PASAT-R, nondominant hand of the Finger Tapping, and Zung's Self-Rating Depression Scale (Table 4).

On the Standard Neurobehavioral Interview

__Table 4.__ Comparisons of Neuropsychological Test Results

	Normals Healthy volunteers (n=11)		Patients(n=8)		
	Mean	SD	Mean	SD	Z Value[1]
Orientation					
TO	0.08	0.29	0.12	0.35	1.07
OPIP	12.00	0.00	12.00	0.00	0.08
Intellectual functioning					
WAIS-R					
VIQ	93.45	11.43	91.38	9.98	1.71
PIQ	90.27	10.72	87.62	8.33	1.04
FSIQ	91.30	11.54	88.88	9.46	1.83
Verbal learning and memory					
SDL-12	11.73	8.19	11.62	7.62	0.08
WSL					
Short-term memory	50.82	3.12	48.12	9.05	1.45
10-munute					
delayed recall	3.73	1.68	3.38	1.41	0.13
Non-verbal learning and memory					
BVRT					
Correct	7.00	1.55	6.12	1.64	1.11
Error	3.91	2.07	5.25	2.60	1.00
CRM					
Hit	38.82	3.20	37.38	4.27	1.85
False alarm	14.36	7.67	17.00	9.96	0.74
Total correct	83.27	8.63	80.38	8.31	1.58
Language and communication					
MAE					
VN	52.55	6.52	50.00	4.53	1.38
VF	32.18	6.67	30.25	13.85	0.67
TT	40.82	3.66	41.88	1.36	-0.62
Spatial perception					
JLO	23.64	4.08	23.00	2.50	0.04
3-DBC					
Correct	28.82	0.60	29.00	0.00	-0.28
Visual perception					
FRT	42.64	4.90	42.25	3.41	0.09
VFD	29.09	2.39	27.12	2.47	3.28*
Attention function					
GDS					
Vigilance task (6 min)					
Correct	28.14	2.09	28.75	1.20	-0.87
Commission	3.42	5.44	3.88	3.44	1.87
Distractibility task (6 min)					
Correct	29.86	1.93	27.62	1.00	3.62*
Commission	2.78	4.59	3.00	3.04	2.03
PASAT-R	83.12	10.69	77.88	13.72	3.61*

TO: Temporal Orientation; OPIP: Orientation to Personal Information and Place; WAIS-R: Wechsler Adult Intelligence Scale-Revised; SDL-12: Serial Digit Learning; WSL: Word Sequence Learning-Revised; BVRT: Benton Visual Retention Test; CRM: Continuous Recognition Memory-Form I; MAE: Multilingual Aphasia Examination; VN: Visual Naming; VF: Semantic Association of Verbal Fluency; TT: Token Test; JLO: Judgment of Line Orientation; 3-DBC: Block Construction-Model; FRT: Facial Recognition Test; VFD: Visual Form Discrimination.

***Table 4.** (Continued)*

	Normals Healthy volunteers (n=11)		Patients(n=8)		
	Mean	SD	Mean	SD	Z Value[1]
Concept formation/ cognitive flexibility					
WCST-M					
No. of complete categories	4.82	2.32	3.25	2.49	0.13
No. of perseverative errors	3.15	1.38	6.25	4.63	3.61*
No. of non-perseverative errors	6.85	5.34	10.50	5.61	1.05
No. of unique errors	0.91	1.58	1.88	2.09	0.98
Similarity (WAIS-R)	9.64	2.46	6.00	1.66	3.44*
Manual dexterity/ motor speed					
PP					
Dominant hand	14.66	2.67	13.50	1.94	1.35
Non-dominant hand	13.83	2.58	13.00	1.80	1.87
Both hands	12.33	1.88	10.50	1.41	1.37
FT					
Dominant hand	47.82	5.85	43.50	9.22	2.20
Non-dominant hand	45.63	4.56	36.75	8.91	3.60*
Digit symbol substitution (WAIS-R)	9.20	1.23	8.50	2.06	1.00
Emotional status					
ZDS	38.65	7.23	49.88	10.53	3.61*

[1]: Wilcoxon 2-independent sample test;* p<.001; GDS: Gordon Diagnostic System; PASAT-R: Paced Serial Addition Task-Revised; WCST-M: Wisconsin Card Sorting Test-Modified; PP: Purdue Pegboard; FT: Finger Tapping; ZDS: Zung's Self-Rating Depression Scale.

Inventory, no remarkable evidence of personality or behavioral changes, with the exception of depression, was noticed in the patients.

DISCUSSION

Our patients with carbon disulfide-induced polyneuropathy showed remarkable changes in both cognitive and emotional functions. These changes consisted of visual perception of irregularly shaped geometric figures, auditory and visual attention, concept formation/cognitive flexibility, manual dexterity of the non-dominant hand, and depression. The impairment of visual perception of irregularly shaped geometric figures was mainly reflected by their poor performance on the Visual Form Discrimination Test. Attention problems were specifically evident on auditory sustained and visual selective attention. The former was primarily reflected by their defective performance on the PASAT-R while the latter was associated with an impaired performance on the Distractibility subtest of the Gordon Diagnostic System. The impairment of concept formation and cognitive flexibility was primarily reflected by their poor performance on the similarity subtest of the WAIS-R, and by numerous perseverative errors on the Wisconsin Card Sorting Task. Our results seem partially consistent with those in previous reports of individuals chronically exposed to carbon disulfide[2,12,28], and with those in reports of individuals poisoned by carbon disulfide[2,29].

Hanninen[2] reported that the individuals poisoned by carbon disulfide had impaired abilities of visualization when they were compared with carbon disulfide non-exposed and exposed workers. Our result of defective functioning in visual discrimination of irregularly shaped geometric figures in the carbon disulfide-induced polyneuropathy patients appears to be consistent with this earlier observation. The manifestation of vigilance and attention problems in our polyneuropathy patients due to carbon disulfide intoxication is in concert with the findings by Tuttle et al[28] in carbon disulfide-exposed workers and with the findings by Hanninen[2] in the poisoned patients. Cognitive flexibility/concept formation difficulties have also been previously reported in the carbon disulfide-exposed and poisoned workers[2]. Similar problems were also seen in our polyneuropathy patients resulting from carbon disulfide poisoning. Defects in motor speed/manual dexterity mainly measured using the Finger Tapping, Grooved Pegboard and Digit Symbol Substitution subtest of the WAIS-R, as well as the Santa Ana formboard task have been seen in agricultural and in rayon workers exposed to carbon disulfide, respectively[2,29]. Our patients with carbon disulfide-induced polyneuropathy also manifested these function problems; however, for our patients the deficit only involved the non-dominant hand performance on the Finger Tapping test. Whether the exposed workers in a study in Wisconsin[29] also had the similarly impaired pattern as ours is not known because they only reported the pooled mean score for both the dominant and non-dominant hands, rather than for the unilateral hand.

A change of emotional function has often been associated with some other cognitive function decadence[3]. Depression, insomnia, irritability, neurasthenic syndrome, and stereotyped behavior have been reported in individuals chronically exposed to the lower levels of carbon disulfide at the workplace[2,30]. For our patients, depression, which was mainly reflected using Zung's Depression Scale and Standard Neurobehavioral Interview Inventory, was the primary personality syndrome. This evidence of depression was congruous with previous observations.

In a study of grain storage workers, exposure to the carbon disulfide-based pesticide has been indicated to be related to deficits in Performance IQ[29]. Our patients with carbon disulfide-induced polyneuropathy, however, did not have such a deficit compared with their healthy counterparts during this examination. Likewise, an association between carbon disulfide exposure and diminished functions in visuospatial perception[8,12], memory [6], and language[2] was previously reported while we did not observe such a relationship in our study. The discrepancy between our results and the findings in other studies is not clear. Whether this could be due to the different types of participants, varying duration of exposure, or diverse neuropsychological measures was not explored. This issue, thus, merits further investigation.

The difficulty in visual perception of irregularly shaped geometric figures, mainly reflected using poor performance on the Visual Form Discrimination Test, has often been associated with left anterior, right parietal, and bilateral-diffuse brain lesions[31]. Our patients with chronic CS_2 had problems in processing this type of visual perceptual information, thus, was attributed to bilateral-diffuse brain involvement. Diverse neuropsychological deficits have often been observed in patients with lesions of the basal ganglia though movement problems may be the most common and prominent symptoms. The presentation of defective neuropsychological function depends upon which structure(s) within the basal ganglia was damaged[32]. In general, cognitive deficits may include attention, learning and memory, core linguistic function and speech production, visuospatial skills, conceptual formation, mental flexibility, and generative thinking[31]. Alterations of emotional status, including agitation, depression, and emotional flattening, as well as tense and disruptive personality changes have also been noticed[31]. Along this line, it appears that lessened abilities in cognitive flexibility and concept formation, defects in visual and auditory attention, and depressed mood in our patients may be due to bilateral lesions of the basal ganglia from chronic CS_2 intoxication.

Lesions in the cerebral white matter caused split associations between lower and higher brain structures or between cortical regions. Researchers have reported that deficits of attention function were frequently associated with lesions in the white matter, particularly in demented patients[33, 34]. Accordingly, it appears that visual and auditory attention impairments in our patients may also be attributed to bilateral lesions of the corona radiata other than the basal ganglia, resulting from chronic CS_2 intoxication. Brain lesions, particularly involving the motor system, often but not necessarily, lead to have a slowing effect on the patient's performance on the manual dexterity tasks, such as the Finger Tapping Test. Usually, diminished manual dexterity of the contralateral hand manifested in patients with lateral brain lesions[31]. The defective manual dexterity, however, was only evident in the nondominant hand of our patients where most of them had bilateral-diffuse brain lesions. Whether the small sample size of our patients contributed to the present incongruous findings is not known, and awaits further investigation.

Some limitations of our study should be noted and await further investigation. First, there might be a limited ability to make generalizations from our findings because our sample size was quite small. Thus, a replication of the present results on a large scale is necessary. Second, for medical intervention needed, it is mandatory to procure a comprehensive evaluation of every aspect of emotional status, rather than one specific aspect, in the patients with carbon disulfide encephalopathy.

In summary, the aim of this study was to document neuropsychological function in a group of Taiwanese patients with carbon disulfide-induced polyneuropathy. The prevailing impairments of our patients seem to partially support prior findings in workers or individuals poisoned due to chronic exposure to carbon disulfide. Thus, it appears that our findings have clinical implications though further investigation on a large scale is merited.

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