

Polyneuropathy induced by carbon disulphide in viscose rayon workers

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Abstract

Objectives—To understand the prevalence of polyneuropathy and correlations among the clinical manifestations, electrophysiological findings, and degree of exposure to carbon disulphide (CS₂) in workers who were exposed to variable concentrations of CS₂ in a viscose rayon factory.

Methods—All the 163 workers received a detailed physical and neurological evaluation. Fixed point air samples were analysed for CS₂. Nerve conduction velocity was studied in 26 workers with symptoms similar to neuropathy.

Results—Nine workers (53%) with overt polyneuropathy from the fibre cutting department and 19 workers (13%) with oligosymptoms similar to polyneuropathy from various jobs were noted. The fixed point air concentrations of CS₂ were 150–300 ppm in the cutting areas and 15 to 100 ppm in the spinning areas. The estimated eight hour time weighted averages in the fibre cutting areas were 40–67 ppm. The occurrence of polyneuropathy was generally correlated with the degree of exposure to CS₂. Nerve conduction velocities (NCVs) were significantly different in the overt polyneuropathy and subclinical polyneuropathy groups from the normal controls. The sensitive indicators for CS₂ polyneuropathy were distal latency, motor NCV, and amplitude of sensory nerve action potentials in sensory NCVs.

Conclusion—The outbreak of polyneuropathy was attributed to higher concentrations of CS₂ in fibre cutting areas. Even in other jobs with relatively lower concentrations of CS₂, the hazard of subclinical polyneuropathy cannot be overlooked.

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For more than a century carbon disulphide (CS₂) toxicity has been recognised to be due to occupational exposure in vulcanisation of rubber, manufacture of cellophane, plywood, adhesives, various oil products, and viscose rayon.¹ This organic solvent can be absorbed through inhalation and skin contact. This may cause acute narcosis after exposure to more

than 1000 ppm of CS₂ or manic depressive psychosis after subacute exposure, and polyneuropathy, parkinsonism, and diffuse encephalopathy with cerebrovascular components after long term low concentration exposure.²⁻⁷ From experimental nerve biopsy studies, axonal swelling with accumulation of 10 nm neurofilaments and secondary demyelination were noted.^{8,9} Electrophysiological studies showed a reduction of amplitudes of compound muscle action potentials in motor nerve conduction velocity (NCV), decreased amplitudes of sensory nerve action potentials, and mild slowing of sensory NCV.^{10,11} The data suggested axonal degeneration of the “dying back” type. The correlation between electrophysiological study and various concentrations of exposure to CS₂ is not completely understood in humans. The current threshold limit value (TLV) for the eight hour time weighted average concentration is 10 ppm.¹² The current permissible exposure limit (PEL) is even lower (4 ppm) by the Occupational Safety and Health Administration (OSHA) in the United States, but is still 20 ppm in Taiwan.¹³ In this report, we investigate the prevalence of polyneuropathy and correlate the clinical manifestations, electrophysiological findings, and degree of exposure to CS₂.

Materials and methods

REPORT OF A CASE

A 48 year old man had worked at a viscose rayon plant as a fibre cutterman for 23 years. In June 1992, he developed progressive numbness of both feet that then ascended to both knees, associated with muscle weakness. Two months later, numbness and clumsiness of both hands were noted that made him unable to perform his job.

On evaluation, his muscle strength was diminished in all four limbs and he could not walk on his toes or heels. There was a generalised absence of tendon reflexes. Sensory impairments of the glove and stocking type were noted in tests that included pin pricks, temperature, touch, vibration, and sensations of position. Study of NCVs disclosed a prolonged distal latency (DL), decreased amplitudes of compound muscle and sensory nerve action potentials, and slowing of NCV in bilateral median, ulnar, peroneal, tibial, and sural nerves. The data suggested a mixed axonal and demyelinating polyneuropathy. There was no sign of diabetes mellitus, porphyria, Guillain-Barre syndrome, or

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radiculopathy. He had consumed alcohol socially for 10 years. His occupational history showed that he had worked in a poorly ventilated room with exposure to relatively high concentrations of CS₂. Gloves and respirators were not routinely used during the operation. Several of his coworkers had similar symptoms of numbness and weakness in distal limbs. Therefore polyneuropathy due to occupational exposure to CS₂ was suspected.

FIELD STUDY

A walk through survey was conducted at the factory, which consisted of seven departments of cellulose production, spinning, fibre cutting, CS₂ recycling, viscose II production, CS₂ production, and repairing. In the cellulose production department, cellulose is produced from wood pulp after treatment. With the addition of CS₂ in closed churns, cellulose is converted into cellulose xanthate. Workers had to clean the churns once a month. During that process, workers had to wear respirators. In the spinning department, cellulose xanthate is dissolved in dilute caustic soda to give a solution of viscose. The viscose solution is pumped through a platinum nozzle into a warm sulphuric acid bath and a continuous thread is made. In this department, workers may be exposed to CS₂ for a duration of one to two hours a day. In the fibre cutting department, the thread is cut into short lengths for various purposes. During the process of fibre cutting, workers are exposed to relatively high concentration of CS₂ because of the higher operating temperature. Also, workers usually stay in a room with closely controlled ventilation into which fresh air is pumped. If the job is not going well, workers have to go out, so they can be exposed to high amounts of CS₂ through inhalation and skin absorption. Some workers usually stay outside for two to three hours a day without personal protective devices. The departments of CS₂ recycling and viscose II and CS₂ production are in closed systems, but the workers stay inside a booth, which is located a short distance away from the spinning and fibre cutting departments. Repairmen may be exposed to CS₂ during the processes of spinning and fibre cutting if the production is not going smoothly.

The fixed point air concentrations of CS₂ were measured by a recommended sampling and analytical method.¹⁴ The samples were taken in the spinning and fibre cutting departments.

CLINICAL STUDY

All workers who may have been exposed to CS₂ in the plant were interviewed and classified into three groups according to their jobs and various degrees of exposure to CS₂: group 1, 17 workers in the fibre cutting department; group 2, 69 workers in the spinning and repairing departments; and group 3, 77 workers in other jobs including cellulose and viscose II production, CS₂ recycling, and CS₂ production departments. All 163 workers answered a questionnaire about age, sex, duration of employment, job title, duration of

current job, previous jobs, habits of smoking and alcohol consumption, family and medical histories, particularly hereditary motor and sensory neuropathy, diabetes, porphyria, alcoholism, motor neurone disease, and poliomyelitis. Twenty five questions about motor, sensory, and other related symptoms were asked. Detailed physical and neurological assessments were performed by at least two neurologists. Special attention was paid to muscle strength, sensory functions, and tendon reflexes. Impairments of sensations included pin prick, temperature, touch, vibration, and position. Muscle strengths were classified according to the Medical Research Council of Great Britain.

Twenty eight workers who had symptoms similar to polyneuropathy were selected for the NCV study. Two workers in the fibre cutting department with suspicious polyneuropathy were unavailable. Motor NCV of the bilateral median, ulnar, tibial, and peroneal nerves and sensory NCV of the bilateral median, ulnar, and sural nerves were measured. The normal control NCV data were obtained from 26 age and sex matched normal subjects. Student's *t* test and the χ^2 test were used for statistical analysis. Polyneuropathy was diagnosed if neurological symptoms and signs of muscle weakness, sensory deficits, and diminished or absent tendon reflexes fulfilled the criteria of polyneuropathy or abnormal NCVs.¹⁵

Results

FIELD STUDY

The fixed point air concentrations of CS₂ were between 150 and 300 ppm in the fibre cutting areas, and between 15 and 100 ppm in the spinning areas. The estimated eight hour time weighted average (TWA) in the fibre cutting areas were from 40–67 ppm.

CLINICAL STUDY

Table 1 shows the distribution of workers by jobs and numbers of workers with clinically definite and suspicious polyneuropathy. Nine out of 17 workers (53%) developed overt polyneuropathy in the fibre cutting department. Nineteen workers had some polyneuropathic symptoms in various jobs including cellulose production (1/28), fibre cutting (2/17), spinning (2/23), CS₂ recycling (2/16), viscose II production (3/15), CS₂ production (2/18), and repairing (7/46) departments. Table 2 shows the demographic data as well as clinical manifestations in the workers (nine with clinically definite and 17 with suspicious polyneuropathy). Muscle weakness and numbness in upper and lower extremities were significantly different at different exposures to CS₂ ($P < 0.05$). There was no rigidity, resting tremor, or bradykinesia compatible with parkinsonism.

The motor NCVs were slow in all four nerves tested in group 1 and considerable prolongation of DL and reduction of amplitudes of compound muscle action potentials were also found. In groups 2 and 3, there was a

Table 1 Distribution of workers by jobs in a viscose rayon plant

Departments	Index of CS ₂ exposure (groups)	Workers n	Polyneuropathy patients n	Suspicious polyneuropathy patients n
Fibre cutting	1	17	9	2
Spinning	2	23	0	2
Repairing	2	46	0	7
Cellulose	3	28	0	1
Viscose II	3	15	0	3
CS ₂ recycling	3	16	0	2
CS ₂ production	3	18	0	2
Total		163	9	19

Table 2 Prevalence of neurological features among workers with suspected polyneuropathy

	Group 1 Fibre cutting (n = 9)	Group 2 Spinning repairing (n = 9)	Group 3 Other jobs (n = 8)	P value*
Age (y)	45.2 (2.3)	49.0 (4.8)	48.9 (5.2)	
Duration of employment (y)	18.6 (2.2)	21.0 (3.1)	21.5 (6.4)	
Air CS ₂ concentrations (ppm)	150-300	15-100		
Duration of illness (y)	1.6 (1.7)	2.5 (1.7)	2.5 (2.1)	
Symptoms:				
Headache	6	8	3	
Dizziness	4	5	2	
Fatigue	5	4	6	
Unpleasant dream	5	4	4	
Memory impairment	5	4	6	
Emotional lability	3	1	1	
Insomnia	3	2	4	
Profuse perspiration	4	5	3	
Body weight loss	4	3	0	
Muscle weakness	4	1	0	
Numbness in extremities	4	3	5	
Prickling sensation	3	4	0	
Signs:				
Muscle weakness:				
UE	6	1	1	<0.05
LE	6	1	0	<0.05
Numbness:				
UE	8	2	4	<0.05
LE	8	3	2	<0.05
Hyporeflexia or areflexia:				
UE	7	6	2	
LE	7	3	4	

* χ^2 test for trend; y = year; UE = upper extremities; LE = lower extremities.

significant prolongation of DL in the median nerve and slowing of motor NCV in all nerves tested compared with the normal controls ($P < 0.05$). There was no significant difference between group 2 and group 3 (table 3). The mean sensory NCVs in group 1 were slow and the DLs were prolonged in the median and ulnar nerves. In all three groups the sensory nerve action potentials were reduced *v* normal controls in the three nerves tested (table 4). There was a significant difference between group 1 and groups 2 and 3 in all nerves tested except for the NCVs of the sural nerve.

Table 3 Motor nerve variables among workers exposed to CS₂

	Median			Ulnar		
	DL (ms)	Amp (mv)	NCV (m/s)	DL (ms)	Amp (mv)	NCV (m/s)
Group 1 (n = 18):						
Mean (SD)	4.4*†‡ (0.7)	7.4*†‡ (3.2)	48.8*†‡ (5.7)	3.1*†‡ (0.5)	7.7*†‡ (1.6)	48.0*†‡ (6.1)
Group 2 (n = 18):						
Mean (SD)	3.7* (1.0)	10.3 (2.5)	54.6* (4.5)	2.5 (0.5)	9.2 (1.7)	54.2* (4.0)
Group 3 (n = 16):						
Mean (SD)	3.5* (0.4)	9.3 (2.6)	55.3* (3.5)	2.6 (0.6)	9.3 (2.2)	55.1* (3.6)
Controls (n = 52):						
Mean (SD)	3.0 (0.4)	10.9 (2.4)	60.4 (4.0)	2.4 (0.4)	9.1 (1.8)	60.5 (4.2)

* $P < 0.05$ 1, 2, or 3 *v* controls; † $P < 0.05$ 1 *v* 2; ‡ $P < 0.05$ 1 *v* 3.

DL = distal latency; Amp = amplitude of evoked muscle action potential; NCV = nerve conduction velocity.

Discussion

Our study showed that nine patients developed overt polyneuropathy due to exposure to high concentrations of CS₂ (150-300 ppm) in the fibre cutting department. Furthermore, another 17 workers in various departments exposed to relatively lower concentration of CS₂ also had some symptoms related to polyneuropathy. From the field and clinical studies, the severity of polyneuropathy was found to be proportional to the degree of exposure to CS₂, although air concentrations at some worksites were not measured. Interestingly, the plant had been established for 23 years, but all nine patients only developed polyneuropathic symptoms in the past two years. Discussion with the workers revealed that two patients had also had previous episodes of muscle weakness six to eight years previously and then recovered one to two years later. Some workers were forced to retire due to progressive weakness and mental changes. We found several changes that indicated an increased exposure to CS₂ in the past two years; (a) the number of workers was decreased, which led to increased working hours, so longer exposure to CS₂; (b) the number of machines was increased in the past two to three years to maximise profits and products; (c) patients with polyneuropathy in the fibre cutting department did not usually wear gloves and respirators at work because of a high operating temperature; and (d) education about industrial hygiene was not adequately emphasised. During working hours, CS₂ is not the only hazardous volatile material; byproducts of hydrogen sulphide may also be evaporated into the upper air stream of spinning areas. Hydrogen sulphide may induce hypoxia but not induce toxic effects on the peripheral nerves.^{16,17} Therefore, we considered that the polyneuropathy was mainly due to exposure to CS₂ during the process of fibre cutting in a poorly ventilated room.

Several neurophysiological studies have shown that chronic exposure to CS₂ can produce toxicity in peripheral nerves.¹⁸⁻²² In our study, a significant difference between the polyneuropathy group and the controls was found in DL, action potentials, and NCVs of both motor and sensory fibres. For oligo-symptomatic patients in groups 2 and 3, the sensitive indicators were DL and NCV in motor nerves and action potentials in sensory

Table 4 Sensory nerve variables among workers exposed to CS₂

	Median			Ular			Sural		
	DL (ms)	Amp (µv)	NCV (m/s)	DL (ms)	Amp (µv)	NCV (m/s)	DL (ms)	Amp (µv)	NCV (m/s)
Group 1 (n = 18):									
Mean (SD)	3.1*†† (0.5)	22.8*†† (14.4)	56.3*†† (6.0)	2.7*† (0.5)	17.6*†† (10.5)	60.0*†† (11.5)	2.9*†† (0.6)	14.2*†† (11.1)	51.5 (10.7)
Group 2 (n = 18):									
Mean (SD)	2.6 (0.7)	32.7* (10.7)	63.0 (3.5)	2.3 (0.3)	27.5* (10.0)	61.2 (4.5)	2.5 (0.3)	22.2* (7.8)	60.8 (12.6)
Group 3 (n = 16):									
Mean (SD)	2.6 (0.2)	32.6* (11.3)	64.0 (3.0)	2.8* (1.4)	29.3* (14.0)	62.0 (4.0)	2.4 (0.2)	22.2* (8.2)	48.6 (9.0)
Controls (n = 52):									
Mean (SD)	2.5 (0.4)	42.0 (18.0)	65.8 (3.6)	2.1 (0.3)	41.0 (14.4)	66.0 (5.0)	3.0 (0.3)	29.0 (15.1)	49.4 (4.2)

*P < 0.01 1, 2, or 3 v controls; †P < 0.05 1 v 2; ††P < 0.05 1 v 3.

DL = distal latency; Amp = amplitude of antidromic evoked sensory nerve action potential; NCV = nerve conduction velocity.

nerves. In a previous study the decrease in the sensory nerve action potentials of the digital fibres, mild slowing of the sensory nerve action potentials, and decrease in the compound muscle action potentials of distal muscle suggest a primary distal axonopathy.¹¹ Our study, although there are some discrepancies, also suggests an axonopathy with secondary demyelination compatible with the pathological findings.^{8,9} Furthermore there was a relation between the degree of exposure to CS₂ and alteration of the NCV.¹⁰ An experimental study also showed that the reduction of NCV is directly related to the duration of exposure and concentration of CS₂ vapour.²³ In the study of Hirata *et al.*,²⁴ a significant reduction of both motor and sensory NCVs was noted even in workers who were exposed to extremely low concentrations of CS₂ (<2 ppm). In conclusion, the outbreak of polyneuropathy was attributed to a high concentration of CS₂ in the fibre cutting areas. Even in other jobs with relatively lower concentrations of CS₂, some workers had oligosymptoms with abnormal neurological variables suggesting that the hazard of subclinical polyneuropathy cannot be overlooked.

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Peroneal			Tibial		
DL (ms)	Amp (mv)	NCV (m/s)	DL (ms)	Amp (mv)	NCV (m/s)
6.0*†† (1.6)	3.4*†† (1.4)	37.4*†† (8.5)	5.8*†† (1.6)	7.0*†† (5.0)	38.8*†† (7.4)
4.0 (0.8)	6.0 (2.1)	47.0* (4.5)	4.4 (1.0)	13.7 (4.2)	45.4* (3.0)
4.2 (1.2)	5.8 (2.5)	45.7* (2.9)	4.2 (0.8)	13.7 (4.0)	45.6* (4.5)
4.2 (0.5)	5.9 (2.5)	51.0 (3.2)	5.3 (1.0)	9.8 (2.9)	49.0 (3.4)