SHORT COMMUNICATION

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Antioxidative stress response in workers exposed to carbon disulfide

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Abstract Objective: To study the effects of carbon disulfide (CS₂) on antioxidative stress systems of exposed workers. Methods: Enzyme-linked immunosorbent assay (ELISA) and thiobarbituric acid test (BAT) were conducted on 67 exposed workers and 88 controlled ones in a viscose rayon factory to determine their serum cuprozin-superoxide dismutase (CuZnSOD) and malonyldialdehyde (MDA) levels. Results: The average levels of CuZnSOD in workers exposed to CS₂ both above and below 10 mg/m³ were higher than those in the control group (P < 0.0001), showing some dose-effect and dose-response relationships. SOD levels increased when the exposure index (EI) was less than 300, and remained at a high level at the range of 300 to 900. When EI was higher than 900, SOD tended to decrease. Meanwhile, the serum MDA levels increased. Both CS₂ concentrations and exposure time contribute to the MDA levels. Conclusions: CS₂ exposure could influence the stress response of the oxidative-antioxidative system of workers. Increased SOD levels could be considered as the stress response of antioxidative system to CS₂ exposure in the early stages, and the influence of CS₂ on SOD might be bi-directional. SOD and MDA might become objective indices in workers’ health surveillance. The role of these two indices in the intoxication mechanism still needs to be clarified.

Key words Carbon disulfide · Superoxide dismutase · Malonyldialdehyde · Antioxidative stress · Exposure index

Introduction

Carbon disulfide (CS₂), a well-known volatile solvent, is widely used in the manufacture of viscose rayon, cellophane and carbon tetrachloride. It is also used to produce rubber chemicals and pesticides. Evidence of cardiovascular toxicity caused by CS₂ has been accumulated since World War II (Beauchamp et al. 1983; Sweetnam et al. 1987). The mortality of coronary heart disease increased in workers who were exposed long-term to CS₂ (Balcarova 1991; Swen et al. 1994; Peplonska 1996). However, the mechanism of it is still far from clear. Cardiovascular changes related to CS₂ exposure were similar to those of arteriosclerosis due to aging (WHO 1979). Nowadays, researches in senile arteriosclerosis have thrown light on the relationships between decreasing ability of scavenging free radicals and the disease (Jozwik and Jasnowska 1985). However there was a rare report of a relationship between CS₂ exposure and the oxidation-antioxidation systems in workers. In a recent cross-sectional study of viscose rayon workers, serum copperzinc-superoxide dismutase (CuZnSOD) and malonyldialdehyde (MDA) values were measured to see whether CS₂ exerted some influence on antioxidative responses.

Materials and methods

Subjects

Sixty-seven workers aged between 20 and 41 years who had been exposed to CS₂ for between 2 to 14 years (average 8 years) in a viscose rayon factory were divided into two groups [≤10 mg/m³ and >10 mg/m³, time weighted average (TWA)] and compared with 88 non-exposed workers, whose range of ages was 19 to 42 years. The smoking habits and alcohol consumption in both groups were matched and paralleled.

Methods

Serum CuZnSOD assay

Based on a cross-sectional study and health surveillance of 155 workers, an enzyme-linked immunosorbent assay (ELISA) was
conducted to detect their serum CuZnSOD values according to Wang et al. (1989). The reagents were supplied by the Laboratory of Blood Disease in the Medical College of Zhejiang University and the GD-3022A ELISA apparatus was made by Huadong Electron Tube Factory.

**Serum MDA assay**

The thiobarbituric acid test (BAT) was performed to detect serum MDA levels of workers (Zhou et al. 1991). Tetraethoxypropane (TEP) was purchased from the Sigma Chemical Company.

**Air monitoring**

Concentrations of CS₂ in workroom air were measured by personal monitoring pumps with series double tubes containing active charcoal for 8 h, for workers from the department of spinning, viscose filter maintenance and dewatering. Every 2 h, the charcoal tubes were replaced. The CS₂ in charcoal was eluted by benzene. Meanwhile, the gaseous CS₂ was collected at working sites with a manual-pump, and injected into a complex film-sampling bag. Amounts of absorbed CS₂ and its vapor in the sampling bags were determined by a gas chromatograph equipped with an electron capture detector.

**Statistical analysis**

The SPSS version 6.0 package was used to conduct t-test, one-way analysis of variance (ANOVA), least-significant difference (LSD) test, correlation, stepwise regression and standardized partial regression coefficient. Average SOD levels were expressed as geometric mean (G) (G = log₁₀(SOD)) and exposure levels of CS₂ were expressed as TWA concentrations and exposure index (EI, EI = TWA × working year).

Cutoff point of SOD and MDA levels was set at G (SOD) or \( \bar{x} (\text{MDA}) + 1.96 \text{ SD} \) according to that of the control group, and divided into two degrees: normal (≤ G (SOD) or \( \bar{x} (\text{MDA}) + 1.96 \text{ SD} \)) and high (> G (SOD) or \( \bar{x} (\text{MDA}) + 1.96 \text{ SD} \)). Chi Square in “EPINFO” software was used to analyze the linear trend.

**Results**

There was no distinct abnormality found in any of the workers under health surveillance. Their serum CuZnSOD and MDA levels were measured and compared by gender with the t-test. Work periods in the exposed and non-exposed groups were also compared by t-test. All of the above-mentioned appeared to show no significant difference (P > 0.05).

**Serum CuZnSOD and MDA levels in workers exposed to various concentrations of CS₂**

The workers were divided into two groups according to CS₂ concentrations (TWA): >10 mg/m³ (11 to 100 mg/m³) (group 3) and ≤10 mg/m³ (1.2 to 10 mg/m³) (group 2) and compared with the control group (group 1). The results of one-way ANOVA of SOD and MDA were shown in Table 1. Meanwhile, Chi-square (\( \chi^2 \)) linear trend analysis showed that the SOD levels of the workers were significantly related to CS₂ concentrations (\( \chi^2 = 13.937, P = 0.00019 \)), but the MDA levels demonstrated no such linear trend (\( \chi^2 = 0.600, P = 0.74049 \)).

**Table 1** Serum cuprozin-superoxide dismutase CuZnSOD (μg/l) and malondialdehyde (MDA) (nmol/ml) levels in workers exposed to various concentrations of carbon disulphide (CS₂) in workroom air. Comparisons between groups (least-significant difference): 1:2 P < 0.05; 1:3 P < 0.05. G Geometric mean, SD standard deviation

<table>
<thead>
<tr>
<th>Groups</th>
<th>CS₂ (mg/m³)</th>
<th>n</th>
<th>SOD (G ± SD)</th>
<th>P</th>
<th>MDA (x ± SD)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&gt;10</td>
<td>88</td>
<td>2.314 ± 0.197</td>
<td>9.60 ± 1.61</td>
<td>2</td>
<td>≤10</td>
</tr>
<tr>
<td>3</td>
<td>&gt;10</td>
<td>39</td>
<td>2.541 ± 0.171</td>
<td>10.04 ± 2.37</td>
<td>3</td>
<td>&gt;10</td>
</tr>
</tbody>
</table>

**Serum CuZnSOD and MDA levels in workers exposed to various EI levels**

When exposure levels of CS₂ were expressed as EI (0 ~ 1400), the level of SOD increased when EI was higher than 300 and remained at a high level up to an EI of 900. When EI was higher than 900, SOD levels tended to decrease. Meanwhile, the serum MDA levels increased (see Table 2). Linear trend analysis showed a similar result for SOD (\( \chi^2 = 15.284, P = 0.00009 \)) while MDA had no significant trend (\( \chi^2 = 0.279, P = 0.5975 \)).

**Serum CuZnSOD and MDA levels in workers at different workplaces**

Serum CuZnSOD and MDA levels in workers at different workplaces showed no significant difference except for SOD levels in comparison with those of the controls (see Table 3).

**Serum CuZnSOD and MDA levels in workers exposed to CS₂ during different work periods**

In order to observe the influence of exposure duration of CS₂ on the levels of serum SOD and MDA, we divided the workers into three groups in terms of work period (≥2 and <7 years, ≥7 and <10 years, and ≥10 years). Their serum CuZnSOD and MDA levels were shown in Table 4.

**Serum CuZnSOD and MDA levels in exposed workers at different ages**

The influence of age on the levels of serum SOD and MDA in exposed workers were shown in Table 5.

**Correlation analysis**

Bivariate correlation analysis showed that workers’ ages were correlated with their lengths of service (r = 0.607, P = 0.000). Controlling the variable age, partial correlation analysis revealed that SOD levels were signifi-