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R. N. WHEELER JR.

Polyvinyl Chloride Toxicity in Fires

Hydrogen Chloride Toxicity in Fire Fighters

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Polyvinyl chloride, of all the plastic polymers, has been implicated primarily in causing the most serious problem in fire fighting today because it releases hydrogen chloride gas when burning. One hundred seventy fire fighters who experienced symptoms from its toxicity have been studied from 1970 to 1975. One died. (JAMA 235:393-397, 1976)

A RECENTLY identified hazard that is of paramount importance to practicing physicians is that of chemical injury incurred by persons exposed to fumes from fires. Specifically, such injuries are caused by the inhalation of vapors created by the thermal degradation of polyvinyl chloride, a plastic polymer. Such substances have now become widely used in the construc-

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tion of homes, furnishings, office equipment, electric wire, telephone and cable covering, and vehicles. A particular hazard exists in the case of the fire fighter, although it could be equally serious in any circumstance in which an individual might be exposed to such plastic combustion products.

THE FIRE

At 10:30 AM on Jan 6, 1970, an alarm sounded for a fire reported to be on the sixth floor of Building 219 at the Washington, DC, Navy Yard. Units of the District of Columbia Fire Department arriving on the scene found the floor filled with a heavy concentration of toxic fumes. Although all of the fire fighters carried masks, none were used, since neither the fire nor

the smoke was so excessive as to prevent entry without masks. The fire, which was confined to an office copying machine constructed of plastic and Teflon parts, was quickly extinguished.

The fire companies entered the building via the elevator, placed several portable fans for ventilation, and left the building about 20 minutes later. On returning to their quarters, many of the fire fighters experienced unusual and unexplainable symptoms, including a constricting tightness localized to the anterior part of the chest. This chest discomfort was described as a searing, burning sensation accompanied by dyspnea as well as a "burning sensation appearing to close off the throat." These symptoms were in addition to the usual headache, dizziness or vertigo, and nausea, which, in our experience, is frequently seen in cases of nonchemical smoke inhalation. Some symptoms persisted over a course of several days following exposure to the fumes. The dyspnea was noted on mild exertion and was associated with moderate apprehension by all of the affected fire fighters. A number of the fire fighters exposed at this fire experienced severe conjunctivitis, lacrimation, and dyspnea persisting for 24 hours after the fire. An intense headache, localized anteriorly and persisting about 24 hours, was also common.

REPORT OF A CASE

Approximately 24 hours after the fire, a 33-year-old fire fighter fainted in the sitting room of the truck company. It was also reported that he had a muscle spasm similar to an epileptic seizure, but recovered, was fully conscious, and got up immediately. His superior officer asked how he felt, and he replied that he was "fine" and walked into the kitchen. Following lunch, the acting sergeant on duty looked for the man to check his condition for driving and found him lying on the floor next to his bed. He was cyanotic and, despite all resuscitative efforts by an ambulance crew and the rescue squad, was pronounced dead on arrival by a fire surgeon at the George Washington University Hospital at 1:10 PM. Postmortem examination by the District of Columbia Department of Public Health Medical Examiner showed severe pulmonary hemorrhage and edema due to chemical pneumonitis secondary to exposure to chemical smoke and fire. The pathologist also reported coronary atherosclerosis.

EFFECT OF FUMES

It has been suspected for several years that the smoke and fumes from electrical fires produced greater injury now than similar fires in the past.^{1,2} It was strongly suspected that hydrogen chloride released by thermal degradation of PVC, a common electrical wiring insulation material, was the lethal product causing death in this instance. The medical examiner's report and the microscopic findings subsequently confirmed our original clinical impression of the cause of death.

Hydrogen chloride, inhaled either in the gaseous state or combined with water vapor, acts as an irritant to the mucous membranes of the eyes and

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in Table 2. In the group of firemen, spirometric values were normal in all but four subjects (firemen 2, 9, 11, and 18) who had mild to moderate abnormalities in FEF25-75%; in addition, fireman 11 also had a slight reduction in FEV₁. The Gaw/VL was moderately reduced in two of these four firemen and mildly reduced in two additional subjects. Single-breath nitrogen washout was normal in all subjects, whereas CV was abnormally increased in two subjects, neither of whom demonstrated spirometric abnormalities but both of whom were currently cigarette smokers. Two of the subjects with abnormal spirometric values were heavy smokers who had worked 5 and 12 years as firemen; the other two subjects were only occasional cigarette smokers but had served as firemen for 14 and 28 years. The fireman who complained of a chronic nonproductive cough and the fireman who complained of definite wheezing both had significant reductions in FEF25-75% and Gaw/VL.

Comparing the results of studies of pulmonary function in the firemen with those obtained in the computer-matched sample of individuals residing in the same area, spirometric and plethysmographic indices and single-breath nitrogen washout were comparable in the two groups, but CV was significantly lower in the firemen than their matched controls ($P < 0.05$); however, the latter difference may not be real since values for CV obtained in the laboratory at the University of California, Los Angeles, were poorly correlated with those obtained in the field laboratory on the population from which the matched sample was drawn ($r = 0.06$).

There was no apparent relationship between the degree of hypoxemia which developed following an episode of smoke inhalation one month previously⁶ and the presence or absence of chronic cough, production of sputum, wheezing, or abnormalities on pulmonary function testing.

DISCUSSION

Comparison of symptoms elicited by a standardized questionnaire from the present small group of firemen who had a mean of 16 years (range, 2 to 33 years) of exposure to fighting fires with those obtained in a group of healthy nonfiremen residing in Los Angeles matched for race, height, age, sex, and smoking history revealed the same frequency of respiratory symptoms among the nonfiremen. Moreover, results of tests of pulmonary function, including FEF25-75% and CV, which are considered relatively sensitive indicators of early obstructive airway disease,^{19,20} were no worse in the firemen, compared with their matches. These findings suggest that, at least in the small sample evaluated, fighting

fires did not lead to clinically apparent respiratory disease or functional respiratory impairment. Twenty of the 21 firemen studied had normal values FEV₁, and 17 of the 21 had statistically normal values for FEF25-75%, based on published predicted values. It is of interest that all four firemen with abnormal values for FEF25-75% were cigarette smokers, suggesting that smoking is an important contributor to pulmonary abnormalities noted in firemen, as suggested by previous studies.¹⁻³

The paucity of respiratory symptoms and abnormalities of pulmonary function noted in this group of firemen is surprising for two reasons. First, the firemen were selected for study because one month earlier, they had developed significant hypoxemia (arterial oxygen pressure [PaO₂], 71 ± 13 mm Hg [SD]), despite hyperventilation (PaO₂ 31 ± 4 mm Hg), following exposure to the combusted product of polyvinylchloride.⁶ Secondly, our findings are in variance with the results of a questionnaire and studies of pulmonary function performed in Boston firemen,¹⁻³ which suggested that fighting fires contributed to the development of chronic pulmonary disease. The discrepancy between the findings in the present group of firemen and those reported for Boston firemen could be related to the small size of our sample, which may not be representative of Los Angeles firemen as a whole, to geographic differences, to ethnic differences,²¹ or to the difference between the prevalence of current cigarette smoking in the Los Angeles and Boston firemen (33 percent vs 48 percent, respectively). Since more than half of our sample of Los Angeles firemen had more than ten years of experience fighting fires, it is not likely that the minimal respiratory symptoms which we noted were due to an insufficient length of exposure for the clinical exhibition of respiratory disease.

These findings in an admittedly small sample of Los Angeles firemen suggest that fighting fires may result in discrete episodes of bronchopulmonary injury secondary to repeated bouts of inhalation of dense smoke without resulting in sustained functional impairment or chronic respiratory symptoms. Our data do not support the hypothesis that the occupation of fighting fires poses a significant risk for the development of chronic obstructive pulmonary disease and are in agreement with recent findings of a three-year follow-up study of Boston firemen;⁴ however, longitudinal studies of respiratory symptoms and pulmonary function in a representative and much larger sample of firemen and a suitably matched group of nonfiremen are required to answer the question of whether or not fighting fires in itself contributes to the development of chronic pulmonary disease.

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A NOTE OF APPRECIATION

Space at the end of articles has frequently been used for the inclusion of "filler material." We have been fortunate to have had the skillful and dedicated participation of Dr. Andrew L. Banyai in the last decade *vis-a-vis* such material. Dr. Banyai, a distinguished teacher, is also a noted bibliophile and has shared with us a variety

of his own interests in medicine, history and the arts. We wish to express via this "filler" our gratitude to Dr. Banyai for the many pages of *Chest* his comments have graced.

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