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Peripheral Neurologic Abnormalities among Roofing Workers: Sentinel Case and Clinical Screening

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ABSTRACT. Peripheral neuropathy developed in a 52-y-old roofer who was exposed to multiple solvents in one-ply roofing systems. Forty roofers who were exposed to various roofing systems were assessed by symptoms, occupational history, standardized physical examination, and measurement of vibrotactile thresholds of the upper and lower extremities. After exclusion of roofers who were predisposed to peripheral neuropathy, we detected abnormal vibrotactile thresholds in 42% ($p < .001$) of roofers' dominant toes and in 36% ($p < .001$) of roofers' nondominant toes; fewer roofers had abnormal sensory physical examinations or reported neuritic symptoms. Roofing workers may be at increased risk of peripheral neuropathy, perhaps resulting from exposure to solvents—particularly *n*-hexane, associated with one-ply roofing systems.

WORKERS in the roofing industry are at increased risk of developing lung and skin cancers, dermatitis, and ocular disease, all of which result primarily from exposure to coal tar pitch and asphalt.[1–5] In addition, roofing workers are exposed to asbestos.[6,7]

A relatively new roofing technology that uses rubber or other synthetic membranes as roofing materials can expose workers to organic solvents in adhesives, primers, sealants, hardening agents, and related products. The health effects of working with these new "one-ply " or "single-ply" roofing systems have not been well characterized.

Potential central neurotoxicants in one-ply systems include toluene, xylene, heptane, *n*-hexane, trichloroethylene, methylethyl ketone, and methyl-isobutyl ketone. In addition, *n*-hexane causes peripheral neuropathy.[8–11] Peripheral neuropathy caused by exposure to *n*-hexane is typically a mixed sensorimotor neuropathy that is initially characterized by hypoesthesia (diminished sensory acuity) of the lower extremities, with progression in a stocking-glove distribution.[12]

In our study, peripheral neuropathy was reported in a roofing worker who was exposed to *n*-hexane and other organic solvents. As a result of this case, a clinical

screening of roofers—originally intended to detect pulmonary disease—was modified to include assessment of neuritic symptoms, neurological physical examination, and vibrotactile threshold testing. A report of the index case and results of the neurological screening examination are reported below.

Case Report

The patient was a 52-y-old white male who had been a roofer for 16 y and who began applying one-ply roofing 4 y prior to evaluation. He had experienced loss of balance, lightheadedness, headache, irritability, and fatigue; during the 1.5 y prior to evaluation, all of these symptoms increased in intensity toward the end of the days he spent installing one-ply roofs. The symptoms were most prominent after he worked in areas where walls or high parapets limited ventilation. Approximately 4 mo prior to his examination, symmetrical paresthesias developed in his feet and hands; he described his sensation as "walking on pillows." He did not smoke, drank alcohol only rarely, and took no medications. He had no significant past medical history and had no family history of neurological disease.

During most of his career, he removed coal tar pitch roofs and applied hot coal tar pitch and asphalt roofs. During the 4 y prior to evaluation, he had begun installing one-ply roof systems with increasing frequency. During one-ply roofing, a layer of insulation was applied to roof decking, and a rubber membrane was laid over it. The rubber membrane was then cleaned with solvents, and solvent-containing glue was used to bond its edges to edges of adjacent rubber membranes. Caulking materials that contained organic solvents were used to seal pipes and other fixtures. Although the patient usually wore rubber gloves, a uniform, and a paper mask when he performed one-ply roofing work, he frequently worked in the immediate vicinity of open solvent containers. Review of material safety data sheets showed that regular exposures to cellosolve acetate, hexamethylene diisocyanate, hexane (including *n*-hexane), toluene, and xylene occurred.

Physical examination revealed that pin prick and soft touch were impaired in both feet and in both hands. Complete blood counts, blood chemistries, VDRL, and vitamin B12 and folate levels were normal. The electrophysiological diagnosis was *symmetrical distal sensory-motor axonal polyneuropathy*. After 1 additional y of exposure, physical examination revealed (a) a stocking-glove loss of temperature and a vibration sensation that was more acute in the lower extremities, and (b) development of a mildly positive Romberg test. Blood testing excluded Lyme disease, Sjogrens Syndrome, and thyroid disease. Repeat electrophysiological evaluation showed severe symmetrical sensory-motor axonal polyneuropathy. The patient died of an unrelated cause 1 y following his second evaluation.

Materials and Method

An occupational health screening examination that emphasized occupational pulmonary disease was offered to all members of Local 154, United Union of Roofers, Waterproofers, and Allied Workers. Approximately 300 currently active members of the union were invited, by letter, to participate, and 40 individuals subsequently underwent examination on June 6, 1989. Only results of evaluations related to peripheral nervous system function are presented in this study.

Demographics. Information was collected about age, gender, race, and number of years of education. Examinees were asked about current and prior alcohol consumption. Study participants were also asked about previous and current tobacco consumption habits.

Occupational exposures. Lifetime occupational histories and exposure information were obtained. Study participants were asked about employment prior to commencement of roofing work, as well as about employment subsequent to termination of roofing work. For each decade of roofing work, we asked the study participants to code the frequency of performing, or working in areas where others were performing, coal tar pitch application, asphalt application, single-ply roofing work, tear-off, and indoor waterproofing. In addition, we asked the roofers to respond, by decade, how often they personally handled hot coal tar pitch, how frequently they performed work in areas where others were handling hot coal tar pitch, how often they personally removed coal tar pitch or asphalt roofs, how often they worked in an area where others were removing coal tar pitch or asphalt, how often they handled hot asphalt directly and indirectly, how often they cut asbestos felt, how frequently they worked in an area where others were using asbestos in the installation of new roofs, and how frequently they used each of the most commonly employed one-ply roofing systems. Study participants were asked about use of a respirator on a regular basis at any time since they started roofing work and about their use of protective skin creams while at work.

Current symptoms and medical history. Examinees were asked about the following central-nervous-system symptoms: difficulty in concentration, difficulty with memory, headache, nausea, confusion, "having to make notes to remember," lack of coordination, feeling irritable, feeling light-headed or "high," and weakness. Participants were asked about the occurrence of numbness, tingling, weakness, and pain for each upper and lower extremity. Symptom frequency was coded as "not at all"; "a little" (i.e., a couple of times during the month); "a moderate amount" (weekly); or "quite a lot" (daily). For these analyses, we dichotomized the results, with "not at all" and "a little" being classified as negative responses and "a moderate amount" and "quite a lot" being classified as positive responses. In addition, the study participants were asked if their symptoms occurred most commonly at work and if the symptoms remitted on weekends and/or vacations. Study participants were also asked about history of health conditions potentially associated with impaired neurological function. In addition, participants were asked about nonoccupational exposure to neurotoxicants. Information about symptomatology and past medical history was

obtained by occupational medicine physicians who were blinded to details of the patients' occupational exposure histories.

Physical and neurological examinations. Physical examinations were performed, according to fixed protocols, by occupational medicine physicians. Neurological examination included standard assessment of mental status, cranial nerves, sensory function, motor strength, deep-tendon reflexes, gait, standing stability (Romberg), and coordination.

Laboratory evaluations. Laboratory tests included standard blood chemistry (SMA-18), complete blood count with differential, and urinalysis.

Vibrotactile threshold measurement. Vibrotactile thresholds were obtained with a Vibratron II (Physitemp Inc.; Clifton, NJ) electromechanical vibrometer. The instrument and associated calibration procedures have been described elsewhere.[13] A previously validated method-of-limits procedure for estimating thresholds was used to measure index finger and great toe thresholds bilaterally.[14,15]

Threshold abnormality was determined by comparing the subject's age- and height-corrected thresholds with published normative values obtained with identical equipment and methods in a blue-collar population.[14] Abnormal thresholds were defined as those that, after adjustment for age and height, exceeded the upper 95th percentile estimate of the normative population.

Statistical analysis. Statistical analysis was performed with the PC-SAS statistical package.[16] Calculations of statistical significance of the vibrotactile threshold results were performed, using standard methods for single proportions.[17]

Results

Subjects. Forty white male roofing workers (mean age = 45.7 y [standard deviation (*SD*) = 10.8 y]) participated in the examinations. These workers comprised approximately 15% of the local union membership at that time. The mean level of education completed was 11.5 y (*SD* = 2.3 y). Mean total alcohol consumption at the time of examination was 10 drinks/wk. Seventeen respondents (43%) reported that they abstained from regular consumption of alcohol at the time of examination. Eight (20%) respondents drank 1–5 alcoholic beverages/wk, 7 (18%) drank between 6 and 19 beverages/wk, and 8 (20%) drank more than 20 alcoholic beverages/wk. Four (10%) respondents described themselves as teetotalers, 16 (40%) as occasional drinkers, 12 (30%) as moderate drinkers, 8 (20%) as heavy drinkers, and 4 had a past diagnosis of alcoholism.

Six roofers had all sensory physical examination and vibrotactile threshold results removed from the analyses because of a history of alcoholism (n = 4), cancer (n = 1), or diabetes (n = 1), and 4 additional roofers had specific results removed because of significant back disease or focal nerve compression (this accounted for small differences in numbers in the various analyses). The 4 roofers who had a history of alcoholism were excluded from analyses of solvent-related symptoms.

Occupational history. Twenty-eight (70%) participants were working as roofers at the time of examination. Of the remaining participants, 3 (7.5%) were currently employed in another trade, 3 (7.5%) were retired, 3 (7.5%) were unemployed, and the remaining 3 (7.5%) were categorized as "other" or did not provide an answer. None had retired because of their age. Roofing workers reported that they had worked a mean of 20.7 y (*SD* = 10.2 y). Twenty-one workers had been employed at least 20 y as roofers, and the remainder had worked less than 20 y.

For each decade of employment, we asked roofers to provide the frequency with which they had applied coal tar pitch roofs, asphalt roofs, and single-ply roofs, as well as the frequency with which they removed old roofs. The proportion of roofers who performed various roofing tasks, either occasionally or frequently, is provided, by decade, in Table 1. The proportion of roofers who worked with single-ply roofing systems, either occasionally or frequently, increased monotonically over the four decades of employment recorded in this survey; 92% of those employed during the decade, 1980–1989, reported at least occasional exposure to this process. The proportion of roofers who performed roof removal was relatively constant over the four decades, increasing slightly from 77% during 1950–1959 to 84% during 1980–1989.

Survey participants were also asked about the use of respiratory protection at work. Among the entire group, only 8 (20%) reported ever using a respirator.

Neurological symptoms. The most commonly experienced potentially solvent-related symptoms were lightheadedness, headache, and irritability (Table 2). As de-

Table 1.—Frequency of Exposure to Roofing Tasks, by Decade

	Exposure								
	Coal tar		Asphalt		Roof removal		Single-ply roofing		Total exposure frequency
Decade	Frequency	%	Frequency	%	Frequency	%	Frequency	%	
1950–1959	12	92	11	85	10	77	0	0	13
1960–1969	20	91	22	100	18	82	4	18	22
1970–1979	23	68	34	100	28	82	13	38	34
1980–89	21	55	34	90	32	84	35	92	38

*Only roofers who performed roofing tasks "occasionally" or "frequently" were included in this analysis.

scribed earlier (see Materials and Method section), we categorized symptoms as being positive if they were reported to occur a "moderate" amount or "quite a lot." Among currently working roofers, 28% reported lightheadedness that occurred at work and improved on weekends and vacations, 21% reported experiencing headaches that occurred at work and improved on weekends and vacation, and 18% reported irritability that occurred at work and improved on weekends and vacations.

Symptoms of numbness, tingling, weakness, and pain in the extremities were reported by relatively few roofers (Table 3). Upper-extremity symptoms were reported slightly more frequently than lower-extremity symptoms.

Neurological examination findings. No abnormalities were found on routine mental-status evaluation, examination of motor strength, testing of deep-tendon reflexes, or Romberg testing. Diminished perception of sharp touch or vibration sensation was observed slightly more commonly in the nondominant upper extremity than in the dominant upper extremity and with approximately equal frequency in the lower extremities (Table 3).

Vibrotactile threshold testing. Vibrotactile threshold abnormalities (i.e., thresholds that exceeded the upper 95th percentile value from the normative population) occurred much more frequently in the lower extremities, compared with the upper extremities. Abnormal vibrotactile thresholds of the nondominant index finger and great toe were observed in 3 of 33 (9%) and 12 of 33 (36%) of the participants, respectively (Table 3). Abnormal vibrotactile thresholds of the dominant great toe were observed in 14 of 33 (42%) of the participants (Table 3). The proportion of participants who had abnormal dominant and nondominant toe thresholds was highly statistically significant ($p < .001$), compared with the expected proportion of threshold abnormality of 5%.

Because of concern that preexisting medical conditions or alcohol use contributed to these results, we performed analyses in which vibration thresholds of roofers at risk of peripheral nerve dysfunction from nonoccupational factors were removed from the analyses. The proportion of participants in this subgroup who had abnormal results is presented in Table 4 (Category 2); proportions were similar to those found before the exclusions were made.

Table 2.—Potential Solvent-Related Symptoms

Symptoms	Frequency*	%
Lightheadedness	7	19.4
Headache	5	13.9
Irritability	11	30.6
Difficulty with memory	5	13.9
Make notes to remember	4	11.1
Nausea	1	2.8
Poor coordination	1	2.8

*Number who reported that the symptom occurred a "moderate" amount or "quite a lot."

Discussion

An index case of probable occupational peripheral neuropathy in a roofing worker prompted inclusion of measures of peripheral nervous system function in an occupational health-screening examination of roofing workers. Impairment of lower-extremity sensory function was common among the roofers examined in this survey. Approximately 40% of the participants had abnormal (i.e., in excess of the upper 95th percentile of normal values) vibration perception in the toes, as measured by objective, quantitative, vibrotactile threshold testing. In addition, lower-extremity sensory abnormalities were identified on physical examination in approximately 15% of the participants. Slightly less than 10% of the roofers reported lower-extremity dysesthetic symptoms.

Abnormal vibrotactile thresholds have been associated with slowed peripheral nerve conduction velocity.[15] The symmetric pattern of vibrotactile threshold elevation and high prevalence of elevated thresholds in the lower extremities observed in the current study are compatible with a distal axonal neuropathy. Peripheral neuropathy of this type is associated with a number of exposures and conditions, including (a) exposure to certain solvents, metals, and pesticides; (b) illness (e.g., diabetes); and (c) possibly, alcohol abuse in the setting of malnutrition. This pathologic process can be caused

Table 3.—Prevalence of Symptoms, Sensory Examination Abnormalities, and Abnormal Vibrotactile Thresholds, by Extremity

	Symptoms		Sensory examination abnormality		Vibrotactile threshold abnormality	
Extremity	Frequency	%	Frequency	%	Frequency	%
Upper						
Dominant ($n = 31$)	2	6.5	2	6.5	2	6.3
Nondominant ($n = 33$)	6	18.2	4	12.1	3	8.8
Lower						
Dominant ($n = 33$)	3	9.1	5	15.1	14	42.4*
Nondominant ($n = 33$)	3	9.1	4	12.1	12	36.4*

*$p < .001$.

Table 4.—Prevalence of Vibrotactile Abnormality, by Digit and Exclusion Category

Symptoms	Category 1		Category 2	
	Frequency	%	Frequency	%
Preferred digit 2	3/40	7.5	2/32	6.3
Preferred digit 5	3/40	7.5	2/33	6.1
Preferred toe	17/40	42.5	14/33	42.4
Nonpreferred digit 2	3/40	7.5	3/34	8.8
Nonpreferred digit 5	3/40	7.5	2/33	6.1
Nonpreferred toe	15/40	37.5	12/33	36/4

Notes: Category 1 = no exclusions (all roofers), and category 2 = exclusions based on medical history (see text).

by overexposure to the hexacarbon solvents (e.g., *n*-hexane) to which roofers may be exposed when they perform one-ply roofing work. We speculate that exposure to organic solvents or other unidentified neurotoxic substances during roofing work may have been responsible for the findings observed in this series.

Caution is required when interpreting results from such a self-selected study group. The participants, who represented only about 15% of those solicited for participation, may have chosen to participate because of health concerns. If roofers with preexisting health problems participated more frequently than those without such problems, results from the current study population might overestimate disease prevalence. However, because this screening was originally designed and promoted primarily as a program for the detection of pulmonary disease, increased participation by roofers with neurologic disease was less likely to have occurred.

Other possible causes of the high prevalence of vibrotactile threshold abnormality observed among the participants include the use of inappropriate normative data, nonoccupational exposures to neurotoxicants (including alcohol), and medical illness. The population used to derive the normative values employed in this series were asbestos-exposed blue-collar workers whose socioeconomic status generally mirrored the current population. No important differences between the current group and the group from which the normative values were derived were identified. Materials and methods used to obtain data from that group were identical to those used in the current group. Furthermore, in the current study, adjustments were made for height and age—the major covariates of vibrotactile threshold—thus ensuring that they would not bias the results. In addition, when roofers with a history of alcohol abuse or medical conditions predisposing to neuropathy were excluded from the analyses, we observed essentially no change in the prevalence of vibrotactile threshold abnormality. We do not, therefore, believe that inappropriate comparisons, nonoccupational exposures to neurotoxicants, or medical illness are likely explanations of the results of the current series.

Because of the limited number of participants in this series, we made no attempt to stratify participants on the basis of duration of exposure to one-ply roofing systems. Such analyses in a larger series might reveal useful dose-response information.

The results of this series of roofers suggest a previously unreported health hazard for roofing workers. In addition, the results underscore the importance of recognizing possible sentinel health events among individual patients in the clinical setting.[18] Because of the self-selected composition of the study group, the absence of a comparison group for evaluation of symptoms and examination results, and the small number of study participants, we maintain that the results of this series should be considered as hypothesis generating, at best. These results indicate a need for formal epidemiologic study of peripheral nerve function among roofing workers.

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References

1. Emmett EA. Phototoxic keratoconjunctivitis from coal tar pitch volatiles. Science 1977; 198:841–42.
2. Hammond EC, Selikoff IJ, Lawther PL, Seidman H. Inhalation of benzpyrene and cancer in man. Ann NY Acad Sci 1976; 271:116–24.
3. Emmett EA. Cutaneous and ocular hazards of roofers. Occup Med 1986; 1:307–22.
4. Linstedt G, Sollenberg J. Polycyclic aromatic hydrocarbons in the occupational environment. Scand J Work Environ Health 1982; 8:1–19.
5. Wolff MS, Herbert R, Marcus M, Rivera M, Landrigan PJ. Polycyclic aromatic hydrocarbon (PAH) residues on skin in relation to air levels among roofers. Arch Environ Health 1989; 44:157–63.
6. Brown SK. Asbestos exposure during renovation and demolition of asbestos cement clad buildings. Am Ind Hyg Assoc J 1987; 48:478–86.
7. Rodelsperger K, Waitowitz HJ. Estimation of exposure to asbestos cement dust on building sites. IARC Sci Publ 1980; 30:845–53.
8. Baker EL, Smith TJ, Landrigan PJ. The neurotoxicity of industrial solvents: a review of the literature. Am J Ind Med 1985; 8:207–17.
9. Spencer PS, Schaumburg HH. Organic solvent neurotoxicity: facts and research needs. Scand J Work Environ Health 1985; 11:53–60.
10. Baker EL. Organic solvent neurotoxicity. Ann Rev Public Health 1988; 9:223–32.
11. Gerr F, Letz R. Solvents. In Rom WN, Ed. Environmental and Occupational Medicine. Boston, MA: Little, Brown and Company, 1992; 2nd ed.
12. Schaumburg HH, Spencer PS, Thomas PK. Disorders of Peripheral Nerves. Philadelphia, PA: FA Davis Company, 1983.
13. Gerr FE, Letz R. Reliability of a widely used test of peripheral cutaneous vibration sensitivity and a comparison of two testing protocols. Br J Ind Med 1988; 45:635–39.

14. Gerr F, Hershman D, Letz R. Vibrotactile threshold measurement for detecting neurotoxicity: reliability and determination of age- and height-standardized normative values. Arch Environ Health 1990; 45:148–54.
15. Gerr F, Letz R, Hershman D, Farraye J, Simpson D. Comparison of vibrotactile thresholds with physical examination and electrophysiological assessment. Muscle Nerve 1991; 14:1059–66.
16. SAS User's Guide. Statistics (Version 5). Cary, NC: 1985.
17. Fleiss JL. Statistical methods for rates and proportions. Second ed. New York: John Wiley & Sons, 1981; p 13.
18. Rutstein DD, Mullan RJ, Frazier TD, Halperin WE, Mellius JM, Sestito JP. Sentinel health events (occupational): a basis for physician recognition and public health surveillance. Am J Public Health 1983; 73:105462.