

Effects of lead on the visual system of occupationally exposed subjects

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CAVALLERI A, TRIMARCHI F, GELMI C, BARUFFINI A, MINOIA C, BISCALDI G, GALLO G. Effects of lead on the visual system of occupationally exposed subjects. *Scand j work environ health* 8 (1982): suppl 1, 148—151. A quantitative measurement of visual field in mesopic adaptation was performed for 35 workers occupationally exposed to lead and 35 referents matched for age, smoking, and alcohol consumption. The mean level ($\pm$ SD) of lead in blood was $47 \pm 16 \mu\text{g}/100 \text{ ml}$ ($2.25 \pm 0.77 \mu\text{mol/l}$) [range 21—82 $\mu\text{g}/100 \text{ ml}$ (1.01—3.94 $\mu\text{mol/l}$)]. In 10 exposed subjects a central scotoma was found that was not evidenced in any of the referents. A highly significant decrease in visual sensitivity was observed for the exposed subjects. The results point to damage of central and peripheral optic nerve fibers. In the most severe cases, central vision is preferentially affected, and therefore the results are suggestive of subclinical optic neuropathy.

Key terms: neurotoxicity, visual field, scotoma.

The visual system is a target of a number of toxic agents, and visual tests have proved highly sensitive in detecting low levels of exposure to neurotoxic environmental contaminants. Acute lead poisoning has been reported to produce visual system damage in humans (2, 3) and in the rhesus monkey (1).

Although available data concerning chronic exposure of humans are scanty and inconclusive (10), scotopic visual deficits have been found in monkeys exposed to lead for a period of 1 a after birth (4), and changes in visual evoked responses were evidenced in rats exposed to low levels of lead during their suckling period (7).

On the other hand the use of experimental animals has definite limitations in the study of neurotoxicity of the visual system, and direct investigations with humans, whenever possible with appropriate neurophysiological tests, seem preferable and offer more possibilities than are commonly utilized.

To detect early and subtle signs of neurological involvement induced by lead, we studied a group of occupationally exposed workers and a group of matched referents with a quantitative test of visual field measurement and the performance test of critical fusion frequency.

Material and methods

The group under investigation consisted of male workers exposed to lead stearate in a factory producing polyvinyl chloride pipes. All of the men worked in a small plant with a rather diffuse and homogeneous pollution, except in the mixing area, where the threshold limit value for lead was sometimes exceeded. Usually duties

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were rotated, and therefore a similar exposure can be reasonably assumed for all the exposed subjects. The 35 men who fulfilled the following criteria were included: age 20 to 60 a at the time of examination and more than 2 a of continued exposure to lead. They were individually matched with 35 referents with no history of exposure to lead, who were selected from metallurgic and textile industries in the same city. Age (within 3 a), smoking, and alcohol consumption formed the criteria for matching. Diabetics were excluded, and the differences between groups with respect to drug therapy were too small to have had any biasing effect. A normal ophthalmoscopic examination, normal visual acuity, and normal visual fields in photopic luminance were requisites for inclusion in both groups.

All the subjects underwent determinations of indicators of lead uptake and effects, namely, lead in blood (Pb-B), lead in urine (Pb-U), and lead in plasma by atomic absorption spectrophotometry with the chelation-extraction procedure (5, 8, 12); free erythrocyte porphyrin (FEP) according to the method of Chisholm & Brown (6); and zinc protoporphyrin (ZPP) by means of a portable hematofluorometer (ESA 4000).

The visual field measurements were investigated with the aid of a Bjerrum screen under mesopic adaptation conditions so that the threshold would be constant for the visual field portion explored.

For the quantitative evaluation, the area of the visual field was corrected according to the efficacy of the light stimulus used, and an index of visual sensitivity was calculated. Measures of blind spots and scotomas, if present, were similarly derived. The critical fusion frequency was obtained for both eyes in photopic adaptation and with the use of a central light stimulus.

Results and discussion

The data concerning the tests of uptake and effects are summarized in table 1. The differences between the exposed and reference group means were highly significant for all the parameters investigated. The mean level of Pb-B was rather low, and only for four of the 35 subjects did it exceed 60 $\mu\text{g}/100\text{ ml}$ (2.88 $\mu\text{mol/l}$). Neither were the Pb-U, FEP, and ZPP levels exceedingly high in the exposed workers. They thus indicated a medium-to-low level of exposure to lead.

Table 2 shows the comparison of the visual sensitivity index of the two groups. A highly significant reduction in the index was found for the visual fields of the exposed workers, but not for the blind spot area. No correlation was found between the index and any of the parameters of lead absorption and effects, with the possible exception of the lead-in-plasma values which, when tested versus the index

Table 1. Indicators of lead uptake and effects in the exposed subjects and pair-matched referents.

	Exposed subjects			Referents		
	Mean	SD	Range	Mean	SD	Range
Number of subjects	35			35		
Age (a)	45	14	21—59	44	11	22—59
Exposure (a)	13	6	2—22			
Lead in blood ($\mu\text{g}/100\text{ ml}$)	46	14	21—82	23	4	21—37
Lead in plasma ($\mu\text{g}/100\text{ ml}$)	1.01	0.6	0.27—2.42	0.37	0.1	0.21—0.75
Lead in urine ($\mu\text{g/l}$)	71	18	44—118	30	5	21—42
Free erythrocyte porphyrin ($\mu\text{g}/100\text{ ml}$ of blood)	102	44	40—180	35	13	15—67
Zinc protoporphyrin ($\mu\text{g}/100\text{ ml}$ of blood)	32	18	8—95	18	11	3—48

Table 2. Index of visual sensitivity in mesopic vision and blind spot area expressed in arbitrary units.

	Exposed subjects	Referents	p-Value
Number of subjects	35	35	
Visual sensitivity index	1,988 ± 13	2,391 ± 583	0.003
Blind spot area	99 ± 13	102 ± 30	NS ^a

^a NS = not significant.

Table 3. Evaluation of scotomas in the mesopic visual field of the referents and exposed subjects according to the length of exposure.

	Number of subjects	Blood lead ($\mu\text{g}/100\text{ ml}$) ^a		Number with scotoma
		Mean	SD	
Referents	35	23	4	0
Subjects exposed < 5a	6	48	18	0
Subjects exposed 5–15 a	12	46	15	3
Subjects exposed > 15 a	17	44	13	7

^a 1 $\mu\text{g}/100\text{ ml}$ = 0.048 $\mu\text{mol/l}$.

values, almost attained the conventional level of statistical significance ($p = 0.07$).

In 10 exposed subjects a central scotoma was evidenced (bilateral in 8, unilateral in 2) during the evaluation of visual field under the mesopic condition (table 3), whereas none was found in the reference group. A relationship between the appearance of scotoma and the length of exposure was found, scotomas not appearing before 5 a of exposure and with an increasing frequency after more than 15 a of exposure. Even in these cases none of the biochemical indicators bore a significant relationship to the neurophysiological measures.

No differences were found between the exposed and reference groups for the critical fusion frequency test.

From the reported results, we have derived the following conclusion: chronic exposure to lead at medium-to-low levels can induce a subtle impairment in the visual system of adult men. With the neu-

rophysiological tests used, we were not able to localize the site of lesion exactly, but the optic nerve fibers seem the most probable target.

We know of no toxic substances (with the exception of the experimental use of iodoacetate) affecting photoreceptors (11). Cell lesions in the visual cortex cause characteristic constriction of the visual field, as in the case of methylmercury poisoning. Besides, optic neuritis was recognized to be the most common form of visual disturbance from lead in cases of severe poisoning (9). On the grounds of these considerations it seems that occupational exposure to lead affects central and peripheral optic nerve fibers, as demonstrated by the significant reduction found for the visual field, but a selective loss of central vision also occurs, as indicated by the presence of a unilateral or bilateral central scotoma in the mesopic adaptation of 28 % of the exposed subjects. The normal findings obtained in these same subjects during classical tests of visual field measurement, ophthalmoscopy, and critical fusion frequency suggest that we are dealing with an early and subtle impairment of the visual function which can be considered subclinical optic neuropathy. These neurotoxicological changes seem more related to the length of exposure than to biochemical indicators, but further investigations are needed to evaluate the site of action of lead in the visual system, the mechanism of action, and the clinical significance of the reported findings.

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