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A comparative analysis of the results of multiple tests in patients with chronic industrial fluorosis

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Abstract For this paper, X-rays, intelligence testing, fingernail fluorine content testing, electroencephalographs, and tests of nervous system symptoms and signs were performed on patients with chronic industrial fluorosis, as well as on workers who had worked in the same environment for shorter periods of time and were not diagnosed with industrial fluorosis and healthy persons far removed from the environment of the aluminum production facility for comparison. The results found obvious differences between the fluorosis group and the non-fluorosis and healthy control groups, with changes in all indices closely related to the degree of fluorosis.

Keywords Industrial fluorosis; Intelligence; Electroencephalograph; Fingernail fluorine

There have been few domestic reports on the effects of chronic industrial fluorine poisoning on the adult nervous system. In order to understand the state of higher functions of the central nervous system in patients with chronic industrial fluorosis, in November 1993 we performed X-rays, intelligence testing, fingernail fluorine content testing, electroencephalographs, and tests of nervous system symptoms and signs on workers in the electrolysis workroom at an aluminum production facility on the outskirts of Guiyang, Guizhou province, an environment in which they were exposed to fluorine, as well as control groups.

1 Data and Methods

1.1 Case selection

Group A: The 72 patients suffering from industrial fluorosis were workers in the electrolysis workroom at an aluminum production facility on the outskirts of Guiyang, some of whom were currently employed and others of whom had retired at retirement age. The workers had worked in an environment with high concentrations of fluorine in the air for 16-25 years, a mean of 21.36 years. According to the standards of GB3234-82, fluorosis manifests in X-ray examinations of bone as thickening of the trabeculae and mild periosteal changes, with a "gauze-like" appearance; In Phase II, in addition to the trunk bones, other areas may also be involved, with obvious increases in bone density, and apparent thickening of trabeculae with a "linen-like" appearance, with periosteal changes more apparent and widespread; in Phase III, the majority of the skeleton throughout the body is damaged, bone density is markedly increased, trabeculae are indistinct and bone-structure "marble-like," there is cortical thickening of long bones, medullary cavity stenosis, periosteal changes are more apparent and widespread, and there may be formation of trabecular bone between vertebral bodies. Among the 72 subjects diagnosed with industrial fluorosis for this paper, there were 52 Phase I cases, 17 Phase II cases, and three Phase III cases. All subjects were males, with an age distribution of 43-62 years, 51.5 years on average.

Group B: Workers still working in the same environment as Group A with the period of work ranging from 4-16 years, the mean age being 15.4 years. There were 43 subjects, all male, ranging in age from 35-53 years, the mean age being 43.2 years. According to the standards of GB3234-82, they did not meet the standards for diagnosis of industrial fluorosis.

Group C: 42 healthy persons from the urban center of work conditions, economic status, lifestyle habits and other traits were similar to those of groups A and B.

There was no difference ($P>0.05$) in the levels of education of groups A, B, and C.

1.2 Monitoring data

At the facility, bauxite was used to produce $A1_2O_8$, with cryolite reaching 54% fluorine content, aluminum fluorine, and calcium fluorine acting as solvents in the electrolytic production of metallic aluminum. All electrolysis cells were divided between two factory buildings, and were 80kA top-insert self-baking anode cells. As the bell-shaped closed exhaust flue and purification equipment had long been disused, the fluorine-containing smoke given off during the production process was widely dispersed throughout the workroom and vented through the skylight, leading to high concentrations of fluorine in the workroom and low pass rate. Results of tests of the concentration of fluorine in the air (mg/m^3) ranged from 0.3-18.99, the mean result being 2.21, and the pass rate being 36.36%, exceeding the limit by 1.21 times (the permitted concentration being <1 mg/m^8).

1.3 Assessments of cognitive ability employed the Wechsler Adult Intelligence Scale revised by Professor Gong Yaoxian of Hunan Medical Sciences University (WAIS-RC). Assessments were performed by neurologists trained in the administration of the test, and tested the subcategories of information, comprehension, arithmetic, similarities, digit memory span, vocabulary, letter-number sequencing, picture completion, block design, picture sequencing, and visual puzzles. The separate IQ scores were calculated using each scale.

1.4 High-temperature ashing was used to test fingernail fluorine levels. Groups A, B, and C underwent conventional electroencephalographs. The three groups all underwent neurological history-taking and physical examinations.

2 Results

Electroencephalographs: In Group A, four cases (5.6%) were moderately abnormal, 13 cases (18%) were mildly abnormal, 19 cases (26.4%) were borderline, and 36 cases (50.0%) were normal. In Group B, five cases (11.6%) were mildly abnormal, eight cases (18.6%) were borderline, and 30 cases (69.8%) were normal. In Group C, other than three borderline cases, the remaining cases were normal.

Table 1 Results of Cognitive Testing of Groups A, B, and C

Group	Verbal IQ (VIQ)	Performance IQ (PIQ)	Full-scale IQ (FIQ)
Group A	72.30 ± 12.36(1)	71.46 ± 11.05(1)	71.94 ± 13.84(1) (2)
Group B	88.46 ± 13.19(2)	82.46 ± 12.28(2)	84.51 ± 13.19(1) (2)
Group C	104.82 ± 15.24(2)	95.31 ± 10.21(2)	99.42 ± 16.84(2)

(1) denotes P<0.05. (2) denotes P<0.01. (3) denotes P<0.005.

Table 2 Fingernail Fluorine Content and IQ Distributions of Groups A, B, and C

Group		Fingernail Fluorine Content (ug/g)	Full-Scale IQ (FIQ)
Group A	Phase I	21.864 ± 20.961	72.13 ± 13.05(2)
	Phase II	68.183 ± 44.462(3) (2)	71.21 ± 11.23(2)
	Phase III	82.183 ± 39.110(3) (2)	68.73 ± 4.65(2)
Group B		19.464 ± 18.082	84.51 ± 13.19(2)
Group C		12.037 ± 7.865(3)	99.42 ± 16.84(2)

Nervous system symptoms and signs: Symptoms were present in all 72 cases in Group A, with dizziness, weakness, degradation of memory, sleep disorders, and joint pain present in 72 cases (100%), headaches in 60 cases (83.3%), waist pain in 70 cases (97.3%), blurred vision and heavy perspiration in 57 cases (79.2%), numbness of the extremities in 54 cases (75%), paroxysmal syncope in 20 cases (27.8%), increased muscular tension in 41 cases (56.9%), reduced pain sensation throughout the body in 40 cases (55.6%), reduced muscular strength in the extremities in 24 cases (33.3%) ocular-facial reflexes and orbicularis oculi reflex positive in 21 cases (29.1%), Babinski sign positive in eight cases (11.1%), and joint deformities or scoliosis in 60 cases (83.3%). In Group B, symptoms were present in 23 cases (53.5%), with dizziness present in 12 cases (27.4%), weakness and degradation of memory in 10 cases (23.3%), sleep disorders in nine cases (21.2%), and joint pain in 20 cases (46.5%). All 42 cases in Group C were without signs and symptoms.

3 Discussion

In recent years, a study of endemic fluorosis in China found that in fetuses with fluorine poisoning, the nerve cells of the cerebrum, hippocampus, and cerebellar cortex are poorly developed, with cells small in volume and densely distributed; and fetuses at all gestational ages showed significantly lower mitochondrial number density, volume density, and surface density of cortical cells of the precentral gyrus of the cerebellum obviously lower than in fetuses of the same gestational age in the group from unaffected areas.(1) There are few reports, however, on the effects of high concentrations of fluorine on adults with mature central nervous systems. Through our investigation, we found that medium and low-amplitude theta waves, slowed alpha rhythms, lowered alpha index average values, and reduced alpha wave amplitude occurred more commonly in patients in Group A. In IQ testing, verbal IQ, performance IQ, and full-scale IQ were reduced in Group A. Nearly all subjects in Group A showed signs of non-specific poisoning, such as dizziness, weakness, degradation of memory, sleep disorders, and headaches, while some patients also had reduced muscular strength, increased muscular tensions, and even pathological signs, reflecting the breadth of the damage done to the adult nervous system by fluorine poisoning.

As the average length of work in a high-fluorine environment was shorter for those in Group B than in Group A, their fingernail fluorine content was lower than in Group A, and their results in intelligence testing were better than those of Group A (P<0.05). In terms of clinical manifestations, the percentage of people in Group B displaying non-specific poisoning symptoms was markedly lower than in Group A, and the rate of EEG abnormalities was lower than in Group A, reflecting a close relationship between the degree of damage suffered by the nervous system when fluorine poisoning occurs and the degree of fluorosis. As a protoplasmic poison, fluorine in excessive quantities has certain toxic effects on human and animal cells. Fluorine can pass through the blood-brain barrier and accumulate in brain tissue, resulting in harm to the nervous system, interfering with cerebral function and leading to pathological changes in the nervous system.(2) These pathological processes affect the functioning of the nervous system, causing gradually progressing damage to the nervous system. It can be seen from the comparison of Group A and Group B that the longer the exposure in a high-fluorine environment, the more severe the degree of fluorine poisoning, the more obvious the decline in IQ, the greater the frequency of EEG abnormalities, and the more positive neurological signs.

Through comparative analysis of groups A, B, and C, it may be determined that industrial fluorine poisoning has gradually progressive effects on the normal function and metabolism of the adult brain and other aspects of the nervous system. With the progression of the course of fluorosis, neurological damage gradually worsens, with the degree of damage closely related to the length of exposure to fluorine, nail fluorine content, and other factors. Damage from high concentrations of fluorine not only affects bones and ligaments, tendons, and other soft tissue, but is also quite widespread throughout the entire nervous system. This is of major significance for worker protection and other areas.

References

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