HEALTH SURVEY OF WORKERS OF AN ALUMINUM PLANT IN CHINA

IV. X-Ray Examinations of the Skeletal System

by

Yu-Min Li[1], Shigenao Nakaya[2], Hirokazu Kudo[2], Humio Tsunoda[2], Masanobu Tatsumi[2], Shiro Sakurai[2], Kazuyoshi Itai[2], Hui-Xian Ma[1], Chuan-Jie Mu[1], Jun-Peng Xu[3], Feng Liang[3], Fang-Ping Chen[3], and Ming-Ho Yu[4]
Tianjin and Changsha, China; Morioka, Japan; and Bellingham, Washington, USA

SUMMARY: X-ray examinations of 98 potroom workers at an aluminum refinery plant in China have been carried out to study skeletal disorders that might be related to F-exposure. The examinations included the pelvis, lumbar vertebrae, radius, ulna, tibia, and fibula. Changes in skeletal system, such as bone density and trabeculae structure, the appearance of osteophytes and exostosis, and the calcification of interosseous membranes and ligaments were assessed by two orthopedic surgeons with the double blind test. No cases of typical skeletal fluorosis were found among the study group, but the appearance of lumbar vertebral osteophyte in the 45-54 year group, exposed to fluoride for more than 20 years, was significantly more frequent than that in the respective control groups. No significant differences in other aspects of osteosclerosis between the F-exposed and the control groups were observed.

KEY WORDS: Aluminum refinery; Potroom workers; Skeletal disorders; X-ray examination.

Introduction

It is well known that workers, following prolonged exposure to fluoride in the work environment, can manifest osteosclerosis, a form of industrial fluorosis (1). Recent studies (2-4) have indicated that China, a country afflicted with a high prevalence of endemic fluorosis (5-6), also faces serious problems of industrial fluorosis. In 1983, the Chinese government established diagnostic criteria and principles of management of industrial fluorosis. According to these guidelines, a new employee to be assigned to work in a fluoride-contaminated work environment must receive a skeletal X-ray examination. In addition, a follow-up examination is required once every 3-5 years following the initial employment.

* [1] Institute of Radiation Medicine, Chinese Academy of Medical Sciences, Tianjin, 300192 CHINA.
[2] Iwate Medical University, Morioka 020 JAPAN
[3] Institute of Labor Protection, CNNC, Changsha, CHINA
[4] Western Washington University, Bellingham, WA 98225 USA

Presented at the 17th ISFR Conference in Budapest, Hungary, June 22-25, 1989.

We carried out a health survey of the workers at an aluminum plant in China in 1987 and reported that the airborne F levels were higher than those found in many other industries (7). The serum and urinary F levels of the potroom workers were found to be higher than those of the office workers who served as controls (7). In an attempt to correlate the airborne F levels with changes in skeletal system, a radiological study on the F-exposed workers has been carried out and the results are reported in this paper.

Materials and Methods

The participants in this study consisted of 98 potroom workers (F-exposed) and 46 office workers (controls) employed at an aluminum plant in southern China (7). The subjects in the F-exposed group were subdivided into four age groups, A through D (Table 1).

The subjects were examined for restriction in body motion and the presence of pains as they stretched their body, hands, and feet. X-ray examinations were performed on the pelvis, lumbar vertebrae, radius, ulna, tibia, and fibula. Changes in bone density, structure of trabeculae, appearance of osteophytes and exostosis, and calcification of interosseous membranes or ligaments were studied. Assessment of the fluoride-induced changes from X-ray results is often difficult, especially in early stages of fluorosis commonly encountered. Every radiograph was assessed by two orthopedic surgeons with the double blind test. The two specialists carried out a separate examination of each of the radiographs, without the knowledge of the worker's age or exposure history, and recorded the observed skeletal changes. An epidemiologist's determination based on these records would then follow. For each of the films under study, skeletal fluorosis was considered implicated if both doctors determined occurrence of a definite change, or if one of them observed a definite change whereas the other recorded possible. Determination of the severity of skeletal fluorosis was based on Roholm's classification (8).

Results

A preliminary physical examination revealed a higher prevalence of restricted movement of the spine and/or many joints among the F-exposed workers. In addition, the prevalence increased with age and length of exposure

Table 1

Prevalence of Restricted Movement of the Spine and/or Joints Among Aluminum Plant Workers

Group	Age	Exposure period (yr)	n	Observed no. of cases	%
Control	25-54	0	46	17	37.0
F-exposed, A	25-34	5-9	29	22	75.9
F-exposed, B	25-34	10-14	22	20	90.9
F-exposed, C	35-44	15-19	19	18	94.7
F-exposed, D	45-54	20-	28	27	96.4

to the pollutant (Table 1). While about a third of the control group showed some symptoms, 76-96% of the F-exposed groups manifested the disorders. However, limited movement of many joints was generally of small degree, and no extreme spinal ankylosis was observed.

No cases of skeletal fluorosis belonging to stages 1-3 in Roholm's classification were observed in any of the groups studied. However, several cases of slight osteosclerosis with ossification of obturator foramen or sacroiliac joint in pelvis were identified among the F-exposed and the control groups (Table 2). There were no significant differences in the incidence between these two groups. A mild lumbar vertebral osteophyte in some subjects was found in Groups B, C, and D and in the 45-54 age group of the controls (Table 3).

Table 2

Osteosclerosis of the Pelvis Among Aluminum Plant Workers

Group	Age	Exposure period (yr)	n	Observed no. of cases	%
Control	25-54	0	20	1	5.0
A		5-9	29	1	3.4
B		10-14	22	2	9.1
Control	35-44	0	13	0	0
C		15-19	19	1	5.2
Control	45-54	0	14	0	0
D		20-	29	5	17.2

Table 3

Osteophyte of Lumbar Vetebrae Among Potmen Groups

Group	Age	Exposure period (yr)	n	Observed no. of cases	%
Control	25-34	0	NA	—	—
A		5-9	17	0	0
B		10-14	19	1	5.3
Control	35-44	0	NA	—	—
C		15-19	19	1	5.3
Control	45-54	0	10	2	20.0
D		20-	25	16	64.0

NA: Data not available
* $p < 0.05$; ** $p < 0.01$

Although no significant differences in the prevalence of lumbar vertebral osteophyte were found among Groups A, B, and C (Table 3), there were significant differences between Group D and its counterpart. Whereas 64% of Group D were found to be with the disorder, only 20% of the control group were identified as symptomatic. Only one individual in Group B and three in Group D were found to have a slight pelvis and spine osteosclerosis, and none showed osteosclerosis in the forearm and lower leg.

Discussion

Increases in bone density, coarsening and thickening of trabeculae, disorder in the arrangement of the structure, and periosseous hyperplastic calcification and ossification have been reported as the main skeletal changes in industrial fluorosis (3). Calcification and ossification at the sites of muscular attachment, on the interosseous membrane of the middle section of the radius and the upper middle part of the posterior margin of the tibia were considered to have important diagnostic value for industrial fluorosis (3).

Several authors have stressed a positive correlation between increased exposure period and the degree of fluorosis (3,4). Our study tends to support these observations. As shown previously, no significant osteosclerotic changes in the skeletal system could be demonstrated in Groups A, B, and C, and their respective control, all being less than 40 years of age and the exposure time relatively short. However, more than 60% of the subjects in Group D, ages 45-54 years and with an exposure time of 20 years or more, were found to suffer from mild osteophyte of lumbar vertebrae (Table 3). In contrast to the observations made by other workers (2,3), no cases of skeletal fluorosis were found in this study. It is possible that under the existing working conditions, where the airborne F levels were only slightly below the TLV, significant skeletal disorders may not result. It should be pointed out that the observed changes in the skeletal system shown previously were not found to be correlated with the levels of serum and urinary fluoride reported previously (7). This suggests the complexity with respect to factors that may cause changes in skeletal system of the F-exposed subjects. Variations in sensitivity to fluoride have been known in cases of industrial and neighborhood fluorosis (9). The importance of nutritional status of the subjects in relation to incidence and severity of bone disorders has been shown (10). In addition, the general health status including absorption capacity of fluoride through the gastrointestinal tract and renal function of the individuals may also be important (9,11). Guminska et al. (12) reported that the erythrocyte and urinary magnesium levels were lowered in human subjects chronically exposed to environmental fluorides and that administration of magnesium, even at doses as low as $^1/_3$ to $^1/_5$ of the daily recommended levels, was able to raise them.

Acknowledgement

We thank the China National Nonferrous Metals Industry Corporation for their support during the course of this study.

References

1. Franke, J., Rath, H., Fengler, F. et al.: Industrial Fluorosis. **Fluoride**, 8:61-83, 1975.

2. Yang, Z., Luo, Y., Zhang, L. et al.: A Preliminary Investigation of Industrial Fluorosis in a High Fluoride Area of China. **Fluoride**, 18:46-53, 1985.
3. Wang, J., Gong, T., Zhen, C. et al.: Roentgen Diagnosis of Industrial Skeletal Fluorosis. (A Report of 100 Cases.) **Fluoride**, 19:80-86, 1986.
4. Yang, Z., Luo, Y., Zhang, L. et al.: Industrial Fluoride Pollution in the Metallurgical Industry in China. **Fluoride**, 20:118-125, 1987.
5. Zhou, L., Wei, Z., Liu, S. et al.: Preliminary Studies on Factors Contributing to Prevalance of Endemic Fluorosis in Guizhou, China. **Fusso Kenkyu**, 6:26-30, 1985.
6. Yu, M.H. and Tsunoda, H.: Environmental Fluoride Problems in China (Editorial). **Fluoride**, 21:163-166, 1988.
7. Tsunoda, H., Itai, K., Sakurai, S. et al.: Health Survey of Workers of an Aluminum Plant in China. I. Airborne Fluoride Levels in Work Environment and Body Fluoride Burden of Workers. **Fluoride**, 24:62-65, 1991.
8. Roholm, K.: **Fluorine Intoxication.** H.K. Lewis and Co., Ltd., 1937, pp. 141-145.
9. Franke, J.: Differences in Skeletal Response to Fluoride in Humans and Animals: An Overview. **Fluoride**, 22:10-19, 1989.
10. Teotia, S.P.S., Teotia, M., Singh, D.P. et al.: Environmental Fluoride and Metabolic Bone Disease. An Epidemiological Study (Fluoride and Nutrition Interactions). **Fluoride**, 17:14-22, 1984.
11. Whitford, G.M. and Pashley, D.H.: Fluoride Absorption: The Influence of Gastric Acidity. **Calcif. Tissue Internat.**, 36:302-307, 1984.
12. Guminska, M., Sterkowicz, J. and Sterkowicz, A.: Magnesium, Calcium, and Phosphorus in Blood and Urine of Humans Chronically Exposed to Fluorine Prior to and Following Prophylactic Administration of Magnesium Salts. **Folia Medica Cracoviensia**, 26:77-92, 1985.

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