

ON THE ASSOCIATION OF FLUOROSIS WITH DEGENERATIVE-DYSTROPHIC LESIONS OF THE SKELETON IN WORKERS ENGAGED IN ELECTROLYTIC DEPARTMENTS OF ALUMINUM PLANTS

I. R. Kuzina

Chair of Roentgenology, Chair of Occupational Pathology of the Institute of Professional Advancement of Physicians (Submitted for publication on June 23, 1976)

SUMMARY: Workers of electrolytic departments at the Novokuznetsk aluminum plant were found to suffer not only from fluorosis (28.2) per cent), but also from degenerative-dystrophic affection of the skeleton (87.7 per cent). The workers of a control group who were not exposed to a chronic action of fluorine compounds the degenerative-dystrophic lesions of the skeleton are encountered on much rarer occasions (58.1 per cent). In workers of the aluminum plant there prevailed the affection of joints in the upper extremities, largely of a symmetric nature. Of decisive influence on the development of degenerative-dystrophic lesions of the skeleton was the service-record at the plant. A careful statistical analysis of the frequency of skeletal degenerative-dystrophic lesions in workers with fluorosis and in those who only had to deal with fluorides showed fluorosis to be of no significance in the development of degenerative-dystrophic affections of the joints and the spine.

The skeleton examinations of workers of electrolysis departments of aluminum plants typically places the emphasis on lesions of bones that might be associated with the effect of fluorine and its compounds on the body, i.e. the bone fluorosis (A. V. Grinberg; I. S. Sagitov; Roholm). At the same time, a number of authors (M. A. Aliev; I. I. Alekterov, and M. D. Gligstein; R. N. Volfoskaya et al.; T. D. Andreyeva and E. Ya Girskaia; E. V. Gotlib et al.; P. V. Mikhailov; Langi and Geryk) indicated the degenerative-dystrophic skeletal lesions, identified by them in workers of aluminum plants.

The examinations of workers of the electrolysis department of the Novokuznetsk Aluminum Plant (NkAP) were completed with the objective of establishing the rate of the degenerative-dystrophic skeletal lesions, and its possible link with fluorosis.

The proposed study summarizes the results of the 5-year clinical and roentgenological skeletal examinations in 365 workers. 60 workers underwent the dynamic clinical and roentgenological monitoring lasting from 1 to 5 years. The average age of the subjects constituted 39.9 ± 2.2 years, with the average work experience being 15.5 ± 2.3 years.

The control group included 277 workers engaged in physical labor and not exposed to the effects of fluorine and its compounds. The average work experience of the control group workers constituted 18.4 ± 2.4 years, with their average age being 42.7 ± 2.7 years. In view of the need to eliminate the effects of the age-specific difference with reference to the occurrence rate of the degenerative-dystrophic lesions in various skeletal sections in the workers of the study and control groups, we performed the indirect standardization of indicators.

The examination of the skeleton in the control group workers allowed us to establish the frequency and nature of the degenerative-dystrophic skeletal lesions in persons engaged in physical labor but not exposed to the effects of fluorine compounds, and to compare this data with the corresponding indicators in workers of the electrolysis department of the aluminum plant, and thus to establish the degree of effect of the exposure to fluorine compounds on the occurrence rate of the degenerative-dystrophic skeletal lesions in workers engaged in the aluminum production process.

The overview roentgenography covered the areas of the chest, the lumbosacral section of the spine in 2 standard projections, along with the forearm, shin, and hip bones. Since 1971, the scans of forearms, shins, and the lumbosacral section of the spine in the direct projection were made simultaneously with the reference aluminum split wedge. This allowed performing the objective

evaluation of the bone density. In the absence of the standard reference wedges, we manufactured our own split wedge (certificate for technical innovation proposal No. 4 dated May 28, 1973).

In the event of any complaints on the part of other sections of the skeleton, the X-ray scans were made covering the cervical section of the spine, shoulder, talocrural joints, and hands. Some of the subjects were additionally examined with the use of functional spondylograms, CT scans of joints, and X-ray scans with the direct image zoom.

The X-ray assessment of bone lesions was evaluated with the use of A. V. Grinberg's classification: Stages I, II, III of fluorosis and the suspected fluorosis lesions. At the same time, a number of examinations had the roentgenological presentation of bone lesions which did not quite correspond to Stage I criteria, yet did not reach the marked manifestations of Stage II; we designated such lesions as Stage I-II, or transitional.

The suspected fluorosis was diagnosed in 50 subjects (13.8%), while fluorosis was diagnosed in 103 subjects (28.2%). Stage I was diagnosed in 80 subjects (21.9%), Stage I-II – in 10 subjects (2.8%), and Stage II - in 13 subjects (3.5%). Tenure experience at the plant was of critical importance for the fluorosis rate. The direct linear correlation coefficient between the relative share of persons suffering from fluorosis and the work experience duration (r) constituted 0.97.

The degenerative-dystrophic skeletal lesions were diagnosed in $87.7 \pm 3.4\%$ of the examined workers, while workers of the control group had such lesions diagnosed in the much lower rate ($58.1 \pm 2.9\%$). Both groups had lesions to the spine, joints, and individuals bones.

Among the degenerative-dystrophic lesions of the lumbosacral section of the spine, spondylosis was the most common one ($51.7 \pm 5.2\%$), followed by osteochondrosis ($49.8 \pm 5.2\%$). The workers of the control group had osteochondrosis ($73.0 \pm 8.8\%$) as the most common type of lesions, followed by spondylosis ($38.0 \pm 9.7\%$). We performed standardization of the spondylosis and osteochondrosis occurrence rate for the lumbosacral section of the spine based on the age and tenure of the workers of NkAP and those of the control group. It was shown that the spondylosis among workers of the aluminum plant was diagnosed more frequently than that among workers of the control group ($P < 0.05$ based on age, and $P < 0.05$ based on tenure). In the identical periods of the work experience, osteochondrosis was more common among workers of the control group ($P < 0.05$), while the age-based standardization of osteochondrosis demonstrated an insignificant variance for this lesion among workers of both groups ($P > 0.05$). The occurrence rate for spondylosis and osteochondrosis primarily depended on tenure at the plant. Specifically, the direct paired correlation coefficient (r) of the spondylosis rate and tenure experience constituted approximately 1.0, and 0.95 for osteochondrosis.

Depending on the extent of fluorosis rate diagnosed among the workers, we identified several groups of the study subjects: those contacting with fluorides, those with the suspected fluorosis, and those affected by fluorosis. The spondylosis rate among the workers contacting fluorides constituted $48.5 \pm 7.0\%$, with $63.1 \pm 9.6\%$ among the workers affected by fluorosis (see the Table). When the confidence intervals for the spondylosis rate are reviewed both for the workers contacting fluorides and the workers affected by fluorosis, they constitute the following: 41.5--48.5--55.5 and 53.5--63.1--72.7, i.e. may be 55.5 and 53.5. In order to exclude the effects of age on the spondylosis rate among the workers affected by fluorosis and the workers contacting fluorides, we performed standardization of indicators. As it turned out, there was no significant difference in the spondylosis rate between the groups of the same age ($P > 0.05$). Therefore, the effects of fluoride compounds had no significant impact on the spondylosis rate.

The simple percentage review seemed to indicate that the osteochondrosis rate was slightly higher among the workers affected by fluorosis than that among the workers contacting fluorides (see the Table). However, the standardization of osteochondrosis values based on age in these groups of workers showed that this difference is not significant ($P > 0.05$). Since the osteochondrosis rate among the NkAP workers was lower than that among the workers of the control group, and was identical among the workers affected by fluorosis and the workers contacting fluorides, its rate apparently did not depend on their actual contact with fluorides.

The degenerative-dystrophic lesions of joints among the examined NkAP workers were identified in 57.8±5.0%. The direct link was established between the degenerative-dystrophic lesions of joints and age of the workers ($r=0.7$) as well as their tenure ($r=0.8$). In order to establish

The rate of the degenerative-dystrophic lesions of different sections of the skeleton among the workers of NkAP with consideration for the marked fluorosis nature (in % to the number of the examined subjects; P±Δ)

Type of the lesion and its localization	Group of the study subjects				
	Contacting fluorides	Suspected fluorosis	Affected by fluorosis	Total subjects	Control
Spondylosis of the lumbosacral section of the spine	48.5±7.0	40.0±12.6	63.1±9.6	51.7±5.2	38.0±9.7
Osteochondrosis of the lumbosacral section of the spine	45.2±6.8	44.0±13.4	63.1±9.4	49.8±5.2	73.0±8.8
Deforming arthrosis of the joints:					
Shoulder	50.0±9.0	71.4±17.0	46.4±6.4	68.5±4.9	20.0±10.7
Elbow	80.5±9.0	68.9±17.0	79.4±9.0	78.2±6.0	52.4±7.5
Radiocarpal	19.0±12.0	30.4±6.4	28.5±11.6	25.6±7.8	4.6±5.2
Hip	5.6±3.0	0	4.8±4.0	4.6±2.0	31.2±2.0
Knee	30.7±8.6	30.0±6.8	38.5±11.4	33.9±2.0	50.6±10.9

Note: Δ is calculated with the confidence interval of 0.9545.

which factor had the most effect on the rate of joint lesions – age or duration of the work experience, we studied the lesion rate in the age group of 40- to 44-year-olds, taking into consideration duration of their work experience. The occurrence rate of the joint lesions increased with the increased duration of the work experience at the plant: When the work experience lasted for 1-5 years, there were no lesions; with 6-10 years of the work experience, these lesions were identified in 25.0% of the workers; with 11-15 years of work – in 48.9%, with 16-20 years of work – in 64.2%, and with 21-30 years of work – in 66.6% of the workers. Thus, years of work at the plant was the primary factor affecting the occurrence rate of the degenerative-dystrophic lesions of the joints.

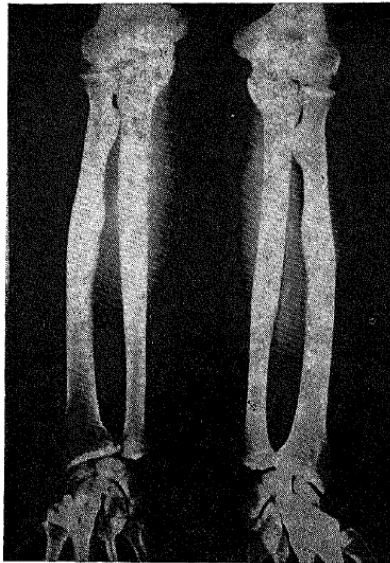
The X-ray presentation of the degenerative-dystrophic lesions of the joints had signs of deforming arthrosis (see the image), predominantly of Stages I and II, and rarely – Stage III; of the degenerative-dystrophic lesions of the joints with the cyst-like restructuring of articulate bones and aspects of osteonecrosis.

Among the NkAP workers we primarily identified lesions of the joints of the upper extremities. The deforming arthrosis of the shoulder joint was diagnosed in 68.5% of all examinations; that of the elbow joint – in 78.2%, and that of the radiocarpal joint – in 25.6% of all examinations. The joint lesions were predominantly of the symmetrical nature: 70% of the examined workers had lesions in the shoulder joints, 90% - in the elbow joints i.e., the workers of electrolysis departments of the aluminum plants had lesions of the joints, which during the working process were subjected to the biggest functional load.

The assumption that these lesions are related with the type of the industrial burden is also corroborated by the fact that the lesions to the joints of the upper extremities developed predominantly after 10 years of work at the plant, and were of the group nature. Taking into consideration all of the above, we classified the degenerative-dystrophic lesions of the joints of the upper extremities as an occupation disease.

The study of the occurrence rate of the deforming joint arthrosis among the workers contacting the fluorides, and among the workers affected by fluorosis showed that rate lesions to the joints of both the upper and the lower extremities among the workers affected by fluorosis was not different than that of the workers contacting the fluorides (see the Table). Therefore, the chronic

fluoride exposure did not have any direct effect on the rate of the degenerative-dystrophic lesions of the joints.



Overview X-ray scans of forearm bones.

The symmetrical lesion of both elbow joints is identified with Stage II deforming arthrosis, as well as lesions of both proximal, distal radioulnar and radiocarpal joints – Stage I deforming arthrosis; with the marked hyperostosis of both forearms, while the density of the external semi-cylinder of the right and left radial bones corresponds to the 12th level of the reference split wedge.

The workers of NkAP demonstrated predominantly combinatory degenerative-dystrophic lesions of the skeleton. Among all examined subjects, the combinatory lesions were diagnosed in $43.6 \pm 2.7\%$, while $64.1 \pm 4.8\%$ of all the workers affected by fluorosis had such combinatory lesions. The combination of the marked degenerative-dystrophic skeletal lesions and Stages I and I-II fluorosis was the cause of disability in 3 workers. At the same time, in the workers affected by Stage II fluorosis in its “pure” form, it did not result in their disability.

Conclusions: 1. The clinical and roentgenological examination of 365 workers of electrolysis departments of the NkAP, showed 103 (28.2%) patients suffering from fluorosis and 50 (13.8%) from the suspected fluorosis.

2. The degenerative-dystrophic skeletal lesions were identified in 87.7% of the examined subjects. The combinatory skeletal lesions were predominant.

3. There was no direct link confirmed between the degenerative-dystrophic lesions of the spine and the joints and fluorosis.

4. The combination of fluorosis and the degenerative-dystrophic skeletal lesions is unfavorable and mutually aggravating. In a number of cases, the marked degenerative-dystrophic skeletal lesions combined with fluorosis may become the factor for the worker incapacitation.

REFERENCES: M. A. Aliev – Works of the Azerbaijan Research and Scientific Institute of Radiology and Oncology. Vol. 8, Part 2, Baku, 1970, pp. 103-110; -- T. D. Andreyeva, Ye. Ya. Girskeya – In: Issues of Public Health and Occupational Pathology in the Color and Black Metallurgy. Sverdlovsk, 1971, pp. 52-54. – I. I. Alektserev, M. D. Gligshein – Occupational Health, 1972, No. 4, pp. 45-47. – R. N. Volfoskaya, I. M. Velikson, L. E. Gorn et al. – The

Publications of the Research Session of the Leningrad Institute of Occupation Health and Safety based on work results of 1957. Leningrad, 1959, pp. 194-200. – A. V. Grinberg – In: X-ray diagnostics of professional diseases of bones and joints. Leningrad, 1962, pp. 162 – 173. – Ye. V. Gotlib, P. G. Sumakhina, S. V. Miller et al. – In: Issues of Public Health and Occupational Pathology in the Color and Black Metallurgy. Sverdlovsk, 1971, pp. 25-32. – P. V. Mikhailov – In: Fluorosis and its prevention. Sverdlovsk, 1967, pp. 56-58. – I. S. Sagitov – In: Current issues of the occupational health, industrial toxicology, communal hygiene, in the oil and chemical industries. Ufa, 1969, pp. 78-80. – R. Langi, B. Geryk – *Csi. Radiol.*, 1968, v. 22, pp. 94-100. – K. Roholm – In: Heffter A. (Ed.) *Handbuch der experimentellen Pharmakologie*, Bd.7, Berlin, 1938, S. 1-62.