ROENTGEN DIAGNOSIS OF INDUSTRIAL SKELETAL FLUOROSIS (A REPORT OF 100 CASES)

by

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SUMMARY: This paper presents X-ray manifestations of industrial fluorosis in 100 cases. It is recognized that increasing density, bony structure changes and periosseous hyperplasia with calcification or ossification, especially the process of hyperplastic calcification of the posterior margin of tibia and interosseous membrane of radius and ulna, constitute the main criteria for the diagnosis of this clinical entity. Often all the above-mentioned processes make their appearance in the early stage of the disease but they may be delayed until the later stages. Preliminary analysis of the causes of this manifestation and classification of the stages of this disease with its various types are herein discussed.

KEYWORDS: Industrial fluorosis; Roentgenological characteristics; Classification stage.

Introduction

Osteosclerosis and periosseous hyperplastic calcification or ossification in industrial skeletal fluorosis have been reported in the literature (1,2). The morphological characteristics of the periosseous tissues, the susceptible sites, and the etiological causes of this disease, however, are rarely mentioned. Often changes due to periosseous hyperplastic calcification have been considered a main diagnostic criteria in the late stage of this disease (3). Recently, in fluoride workers, changes due to periosseous hyperplastic calcification demonstrable by X-ray have been observed in the early stage of this disease which is of great diagnostic value to the clinician. This paper presents an analysis of 100 cases of industrial skeletal fluorosis with respect to its roentgenological characteristics and susceptible sites. To explore the causes of its formation as well as its diagnostic value, the findings were compared with 65 cases of normal workers.

Material and Methods

One hundred patients (99 males and 1 female), average age 42.6 years (28-60), had worked in contact with fluorides an average 15.9 years (9-28). Included were electrolysis workers, anode workers, aluminum tapping workers, furnace workers and raw material packaging workers. Twenty-six of them were diagnosed as Stage 0-I (cases reserved for further observation), 70 as Stage I and 4 as Stage II. Fifty-eight males and 7 females, average age 39.0 years

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(28-60), and average standing 16.3 years (3-29), whose work included administrative staff, fitters, lathe operators and forgers, served as controls.

The air fluoride concentration in their work place ranged, during the past few years, from 0.03 to 19.6 mg F/M^3. The drinking water contained less than 1 ppm fluoride. The main clinical symptoms presented by the 100 patients with industrial fluorosis were neurasthenic syndrome (52%), lumbar pain (72%), arthralgia of the limbs (58%), chronic infection of upper respiratory tract (47%) and restriction of motion of the joints. Among patients, urinary fluoride averaged 2.98 (0.4-11.6) mg/l; among controls, 1.02 (0.3-3.4) mg/l. The difference between the two groups ($p<0.01$) was statistically significant.

Changes in skeletal structure, observed by X-ray in the industrial fluorosis group, were chiefly manifested through changes of skeletal trabeculi. They were particularly significant in the lower lateral aspects of the sacroiliac joint and in the body of the ilium as well as in the vicinity of the symphysis pubis and were seen even in the wings of the ilium and in the vicinity of tibial tuberosities. The trateculi were thickened, increased in density, tortuous, uneven in degree of thickness and arranged in disorder.

Among patients, in 13.1% of the cases (Fig. 1) the trabeculi were significantly thickened with clear edge and markedly decreased in number. The net holes were increased in size, simulating coarse thin gunny cloths. In 50.5% of the cases, they were obscure in demarcation and slightly thickened; the net holes resembled thin dense gauze, obscure in contour. In 30%, tiny condensed mottling could be seen in the form of structureless sand grains (Fig. 2). The remaining 6.1% of the cases showed no change of any kind.

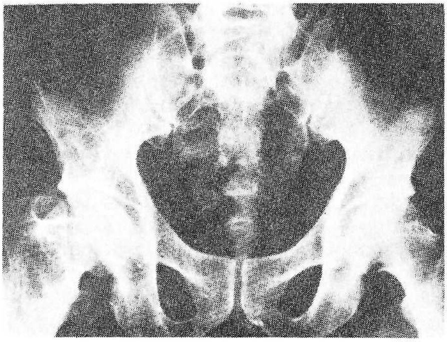
Skeletal changes in industrial fluorosis are generally much less intense than those in endemic fluorosis. The main bone changes increase in density even though the bony matrix structure was markedly sparse in some cases. Yet the trabeculi of the bones were comparatively thick with high density. In 6.1% of the patients bone density was markedly increased; in 35.4%, it was slightly increased; in 4.0%, bone density decreased (3).

Soft tissue changes in industrial fluorosis, were more marked. The formation of calcification and ossification in interosseous membrane, tendons or ligaments was seen frequently in the upper middle section of tibia, the interosseous ridge of the radius and the obturator foramen periosteum. Next in frequency the following occurred: calcification and ossification of periosteum, ulna and fibula, iliolumbar ligament, the sites of attachment of the sacrospinous ligament, sacrotuberous ligament and the paravertebral ligament.

Among patients, periosteal hyperplastic ossifications were mainly situated at the posterior margin of the sites of attachment of the tendons on the upper middle section of the tibia with a considerably wide range and polymophous in nature. The periosteum of the hyperplastic ossifications in some cases was shaped like a tape parallel to the cortex of the bone; the medial margin was less dense than that of the bone cortex, thus forming the so-called "double frame" shape; some of them were shaped like small bony spicules, some were undulatory; the remainder were saw-toothed. In severe cases, they appeared in the form of multiple disseminations with their bases attached to the cortex of the bone and their tips opposite the proximal joints in the form of "candle tears" (Fig. 3).

Figure 1

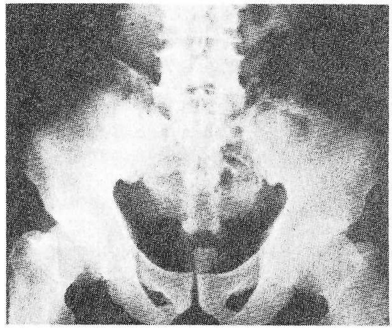
Male, aged 54, electrolysis worker.



Trabeculi significantly thickened, net-holes were increased in size, simulating course, thin gunny sack cloth.

Figure 2

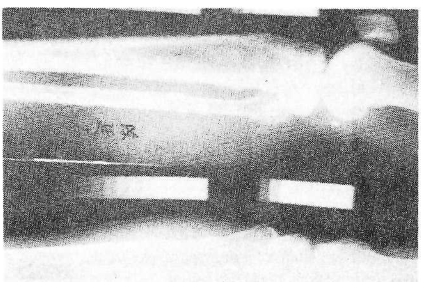
Male, aged 39, electrolysis worker.



Trabeculi slightly thickened, form structureless, simulating sand grains.

Figure 3

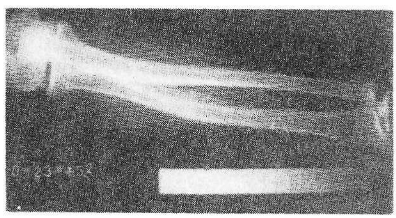
Male, aged 55, electrolysis worker.



Marked periosteal hyperplastic ossifications of upper middle section of femur, posterior margin.

Figure 4

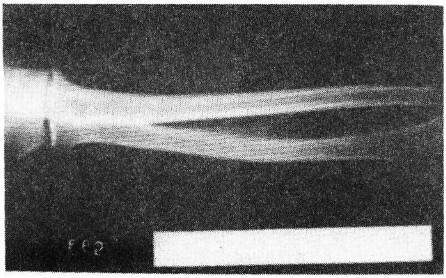
Male, aged 53, electrolysis worker.



Marked radial ridge increase in width, uneven density.

Figure 5

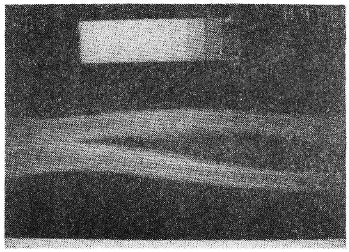
Male, aged 41
phosphoric fertilizer worker.



The radial ridge increased in width, margin of the horny radial ridge simulating fish fins.

Figure 6

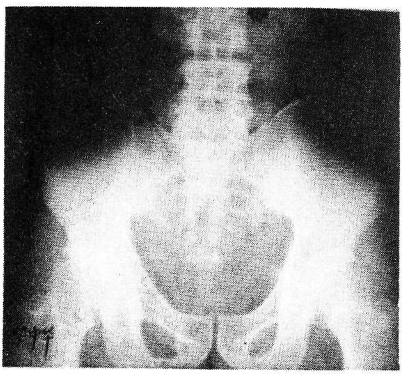
Male, aged 44,
phosphoric fertilizer worker.



Marked ossification of periosteum of ulna.

Figure 7

Male, aged 39,
phosphoric fertilizer worker.



Marked calcification of membrane of obturator foramen.

In the control group, although light and localized periosteum shadows were seen, most of them were localized on the lateral side of the upper section of the tibia. They presented themselves as hilly processes with smooth margins.

In the patient group, the periosteal hyperplastic ossification was situated on the upper middle part of the interosseous ridge of the radius; the radius ridge was increased in width; the measurement of its thickness averaged 8.38 (5.7-13.6) mm; thus the corresponding interosseous space was narrowed. Primarily, the margin of the hyperplastic interossous membrane was irregular with increased density forming a hairy calcified zone after which it developed into unevenness of the density of the radial ridge in the form of cloudy flakes; at the medial margin of the corresponding cortex of the bone there was also the presence of irregular hyperplasia and, in severe cases, the external margin of the radial ridge presented horny processes simulating fish fins, all of which protruded toward the distal side (Fig. 4,5). The periosteum of the corresponding ulna, likewise, showed hyperplastic changes, but they were generally less extensive (Fig. 6).

In the control group, although the ridge of the radius became widened, the density was even and homogeneous with smooth margins; no marginal horny processes were seen. The thickness of the radial ridge measured 7.22 (5-9) mm, a statistically significant difference ($p<0.001$) from the patients.

Among patients, calcification or ossification of the membrane of the obturator foramen appeared mostly in the inner margin. It could also appear in the outer as well as the upper and lower margins, presenting horny or hairy processes with irregular margins (Fig. 7). Such changes occurred in 56 cases (56.6%) of this group, in 42.6% of which the lengths of the processes were over 0.5 cm.

In the control group, 6 cases (92%) had hyperplasia of the membrane of the obturator foramen; in only 1 case was the length over 0.5 cm. Most of them manifested the presence of bilaterally symmetrical processes with triangular shape and smooth margins. Regarding joint changes, only slight hyperplastic sclerosis of the bone was seen namely, the intercondylar protuberance became sharp, protrusion of the margin of the iliac fossa was lip-shaped. The articular surface of the symphysis pubis was slightly sclerotic but the articular space was not narrowed.

To summarize the above manifestations, industrial fluorosis might produce such changes as osteosclerosis, structural bone changes and periosseous hyperplasia, calcification and ossification. All these changes might occur in different cases with varied intensities. The 100 cases have been classified into the following three types: bone matrix, periosseous and mixed, based on whether the main changes were in bone substance, periosseous, or both. There were 25 (25%) cases in the bone matrix type, 33 (33%) in the periosseous, and 42 (42%) cases in the mixed type.

Discussion

The skeleton and teeth are the main target organs most frequently affected by fluoride. More than 90% of fluoride in the human body is in the bones. Based on analysis of 100 cases presented in this paper, the main X-ray changes of the skeleton were increased bone density, thickening and increased concentration of the trabeculi, and structural disorder with the formation of network, all of which took place mainly in the body of the ilium and in the outer lower aspect of the iliosacral joint. With thickening of the trabeculi, their number was also decreased and the net squares were enlarged; some were compact and obscure; nevertheless the bone was denser. Better nutrition among fluoride workers, sufficient calcium intake as well as dose and duration of contact with fluoride may explain why osteoporosis and osteomalacia were rarely seen, an observation compatible with data reported by Dominok (4).

Why were such changes as periosseous hyperplastic calcification in our patients retricted chiefly to the upper middle section of the posterior margin of the tibia, radius and ulna? The periosteum and interosseous ridge of the radius are the site of attachment of many muscles of the forearm while the proximal end is finer in the radius, thus building mainly the wrist joint; and its distal end finer and proximal end of the ulna is thicker forming mainly the elbow joint. Such a specific structure pattern causes the line of stress to pass through the interosseous ridge of the radius. When the hand is straining, the strength will be transmitted mainly through the wrist joint to the radius, whence it passes through the interosseous membrane of the radial ridge to be again transmitted to the ulna and elbow joint. In this way the interosseous membrane of the radius ridge serves as the conduction medium to the force. Similarly, the upper middle section of the posterior margin of the tibia serves as the site of attachment to the varius muscles of the middle and deep layers causing thickening of the periosteum. With flexion movement of the leg, the periosteum and interosseous membrane are often brought into traction causing the above-mentioned sites to move and be subjected to the effect of strength, thus promoting local circulation and metabolism. Therefore, under the effect of fluoride, osteogenetic and osteoclastic activities are markedly activated. Hyperplasia of both inner and outer periosteum as well as thickening and roughening of the bony surface which result lead finally to ossification and formation of external osteophyte of various forms, thickening of the bone cortex and narrowing of the bone marrow cavity. These changes of crucial importance in the diagnosis of industrial fluorosis might be the main reasons for the appearance of early hyperplastic calcification and ossification in the above-mentioned sites.

Based on our criteria, industrial fluorosis has been clasified into the following four stages according to skeletal roentgenological changes: Stage 0-I (including candidates reserved for observation), Stages I, II and III. This classification is chiefly based on the extent of osteosclerosis, bony structures, and periosseous hyperplastic calcification. The main manifestations in stage 0-I consist of bone density within the normal range, slight thickening of the trabeculi and slight changes in the periosteum; in stage I, bone density is slightly increased with bone structure presenting changes simulating the shape of "gauze" and slight periosseous calcification; in stage II, bone density is markedly increased; trabeculi are markedly thickened, presenting a form of "gunny cloth" appearance with marked and extensive periosseous changes; in stage III, all the above-mentioned changes are more marked and prominent. They were not seen in the 100 cases herewith presented.

The following points constitute the differences in our classification and that of Roholm and Grinberg (3). According to these authors, periosseous changes are included in stages II and III. In such cases, however, we found periosseous hyperplastic calcification of different intensities. This change appeared early at a higher positive rate with identical sites of appearance, easily recognizable under X-ray and did not necessarily appear after the trabeculi changes. More and more studies of the preskeletal phase of this disease have been appearing in recent years (5). We believe that, due to progress in science and medical technology, it will be possible to find an early non-osteophasic diagnostic criterion.

Conclusion

Increase in density of bone, thickening and increased density of trabeculi, disorder in the arrangement of the structure and periosseous hyperplastic calcification and ossification are the main skeletal changes in industrial fluorosis, shown by X-ray. 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, have important diagnostic value for industrial fluorosis.

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BINDING OF FLUORIDE ION TO EGG ALBUMIN STUDIED WITH THE FLUORIDE ION SELECTIVE ELECTRODE

by

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SUMMARY: The binding of fluoride ion to egg albumin at pH 5.75 was studied with a fluoride ion selective electrode. Significant binding was found with this new technique. When the data were plotted according to the Klotz equation, a value of 1600 was obtained for the product nK, where n is the number of binding sites and K is the binding constant which is the same for all sites.

KEY WORDS: Egg albumin; Fluoride ion; Fluoride ion selective electrode

Introduction

It has been known for a long time that many enzymes are inhibited by fluoride ion. Usually the binding of the fluoride ion to the enzyme has been studied by kinetic methods. Only a limited number of enzymes have been

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