ENDEMIC FLUOROSIS IN THE SAHARA

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In the Sahara, fluorosis is different from that encountered in other parts of North Africa, where it has been associated with natural phosphate deposits. In the Sahara where there are no phosphate deposits, fluoric intoxication is specifically attributable to drinking-water containing up to 4 mg F per liter. This level may not seem especially high in relation to concentrations reported from other countries. However, in desert regions high water intake suffices to induce widespread lesions among the inhabitants.

Water-borne F in the Sahara originates from soil composed of ancient volcanic deposits. This is probably an "in-depth" phenomenon, because vegetables grown in regions of endemic fluorosis contain only a minimal amount of F, i.e., 0.1 ppm. We are thus dealing with intoxication induced almost exclusively by F in solution.

In terms of geography, the endemic area is situated in the eastern region of the Sahara. To localize it, we have obtained complete chemical analyses of the waters of the different regions including their F content. The F content increases in a South-to-North and West-to-East trend, corresponding to the existence of an extensive subterranean water reservoir which broadens in the lower Sahara "Chott" region of the North-East.

By means of systematic inquiries in regions with diverse F concentrations in drinking-water, we have attempted to correlate F distribution with the health of the population.

**Dental Effects**

The most striking observation is the incidence of dental abnormalities. To establish the extent of the dental lesions as a function of F in drinking-water, 3,000 children between the ages of 6 and 14 were examined. We have noticed that:

(a) Where the drinking-water contained 0.5 ppm F, 25% of the children had dental lesions.

(b) Where the fluoride content of the children's drinking water was 1.0 ppm, 100% had dental lesions.

(c) The severity of the dental lesions was indisputably related to F levels of the drinking water. "Brown stain" motting is frequently seen when the water attains a concentration of 1.0 ppm F. Gingivitis is rarely observed below the level of 2.5 ppm.

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(d) Without exception, the deciduous teeth were not affected.

(e) The lesions predominate in the upper teeth.

Analysis of teeth in 29 cases for fluoride content was performed by Prof. Truhan, Paris. It revealed the following:

(i) The F content of deciduous teeth increases progressively, despite the apparent normal appearance.

(ii) The F content of permanent teeth increases gradually with the age of the individual, and with the fluoride content of the drinking water.

Skeletal Effects

The second phase of our studies was concerned with the distribution of waterborne F in relation to the skeletal system. X-ray examination provided a ready means to assess bone alterations. A total of 148 patients with osteosclerosis were X-rayed.

In summary:

(a) There were no detectable bone changes where the water content was less than 1.5 ppm F.

(b) The skeletal changes were most frequent and severe in the El Oued region, where the water contains up to 4.0 ppm F.

The pelvic bone was most frequently affected. The most common pattern was osteosclerosis with calcification of ligaments. The foramen obturatum showed ragged excrescences. Periosteal deposits were noted on the iliac and ischium bones (Fig. 1). These changes occur even in youthful subjects.

In 30% of our cases, we noted a generalized increased radio-density of the skeleton in which two features appear to be unique:

(1) Increased density in the sacrum, a feature present in all cases.

(2) Calcification of the articular capsule of the hip joint, a fairly specific sign of fluorosis, especially in the young adult.

In the spinal column, we noted a fairly advanced form of osteophytosis, an increased radio-opacity of the vertebrae without structural alteration and a peculiar form of lesion in which increased skeletal density is associated with a decreased height of the vertebrae (Fig. 2).

The spinal and cervical columns, ribs and shoulder bones are affected much later than the pelvis. Noteworthy is the fact that the cranium is rarely affected. Only two of our 148 cases showed signs of discrete cranial density.
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Fig. 1

Diagram of Pelvic Changes in Skeletal Fluorosis

Fig. 2

Diagram of Vertebral Changes

(A) Trabeculated vertebrae due to heterogeneous Ca deposition. (B) "Ivory" vertebra; uniform Ca deposition. (C) Osteomalacia of sclerotic vertebrae. (D) Sclerosis with osteophyte formation. (E) Sclerosis with marginal syndesmosis.
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**Fig. 3**
M. 66, Koulino (3 ppm F). Osteoporosis of pelvis; calcifications of ligaments; ragged outline of foramen obturatum; calcified capsule of hip joint.

**Fig. 4**

**Fig. 5**

**Fig. 6**
M. 65, Togga (2.5 ppm F). Diffuse osteoporosis of pelvis and spine.

F. 18, from Touggourt (3 ppm F). Calcification of capsule of hip joint.

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Fig. 7
Tomographic aspect of sclerotic vertebrae. Sclerosis originates at the vertebral plates.

Fig. 8
F. 44, Tiksept (3 ppm F) Osteoporosis of spine (iliac crest biopsy 6280 ppm ashed).

Fig. 9
M. 65, Tolga (2.5 ppm F). Periostosis of radius and complete calcification of interosseous membrane.

Generally, we do not observe osteosclerosis in the upper arm. In advanced cases, there can be slightly increased radiodensity in the proximal region of the humerus. Periostitis at the humeral site of the shoulder-muscle attachment is not uncommon.
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An important observation in the forearm is periostitis of the radius, which can proliferate in advanced cases with calcification of the intra-osseous membrane. In the early stages it can be localized as a small lump. This consistent feature, which appears early, is of great value in the diagnosis of fluorosis, especially when the skeletal density is not pronounced. Involvement of the cubital area is much rarer. The lesions are of the same type in the leg regions. Only one case of paraplegia was associated with osteosclerosis in a 79-year-old man.

There was no evidence that livestock exposed to the highest levels of waterborne fluoride showed any sign of skeletal fluorosis. X-ray examinations revealed no changes in the skeletons of 2-year-old sheep.

Laboratory Data

Despite the definite diagnosis of osteosclerosis and narrowing of the marrow spaces of long bones, blood composition was not significantly affected. Twelve patients with increased skeletal radio-density had normal blood counts and leucocyte concentrations. No cellular abnormalities were observed in the cerebro-spinal fluid of 2 patients.

Six examinations of splenic biopsy material failed to reveal any disturbance related to hematopoeisis. The same was true of three liver biopsies.

In all cases, analysis of transaminase activity gave essentially normal values. In one patient a level of 58 units was found. However, it did not seem to have pathological significance.

Serum calcium in 15 cases ranged between 9.1 and 11.3 mg%. In 4 of these cases, the blood calcium was below 10 mg%, in 7 cases above 10.5 mg%.

Serum phosphorus was consistently elevated, ranging between 3.8 and 8.0 mg%. In 6 cases, it was below 5.0 mg%, whereas in 9 patients the concentrations were above this level.

Alkaline phosphatase in 14 subjects varied between 2.7 and 9.2 units. However, 11 of these values were below 5 units. It was therefore impossible to claim a significant increase in the alkaline phosphatase level.

Fluoride Assays

The F concentration in blood and urine was surveyed in 139 patients namely:

- Blood and urine analyses: 94 patients
- Blood analysis only: 45 "
- Urine analysis only: 8 "

Evaluation of the data led to the following conclusions concerning urinary F excretion in fluorosis:

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(a) There is a great variation among individuals. Urinary F concentrations varied between 0.5 to 12 ppm with an average of 3 ppm.

(b) There is no correlation between urinary F elimination and F content of drinking water, at least not when the water contained up to 1.0 ppm F.

(c) Urinary F elimination does not correlate significantly with the age of the patient. F essays in children and adolescents revealed essentially the same concentrations and the same variability as in adults and in the elderly.

(d) The irregularities persist whether we use 24-hour urine collections or individual samples of urine from each patient.

Serum F analyses gave values between 0.1 and 2.0 ppm with an average of 0.9 ppm. Only two cases showed higher values, namely 3.5 and 4.0 ppm. There was no consistent parallelism between F levels in blood and in the urine.

Appropriate therapy can markedly influence the F concentration in both blood and urine. Two of our patients were treated with an EDTA chelating agent (one 50,000 unit ampule per day). On the second day of this treatment, we observed a striking increase in the F concentration of both blood and urine. However, no detectable radiological improvement could be seen in these patients.

Analysis of F concentration in bone (performed by Prof. Truhaut) was possible in 14 cases, ranging in age from 32 to 79 years, all of whom exhibited various stages of skeletal fluorosis. In 12 of the 14 individuals the iliac crest served as test material. Bone F content varied between 1800 and 6280 ppm (on a dry, fat-free basis). Contrary to expectations, there was no absolute correlation between F content of bones and the degree of bone density, as indicated by X-ray.

Histology of Bones

In 10 cases, anatomical-pathological studies were conducted by Prof. Laftargue. Thickening of the osteoid seams was the most striking and most consistent feature. Cancellous bone was mainly involved. It was rarely observed in cortical bone. Morphologically, there were indications of a very active osteogenesis, often accompanied by large osteoblasts at the periphery of the bone lamellae and of the osteoid seams. The defense mechanism of direct osteolysis seems of little importance. However, the number of resorption sites, and their irregularity, are suggestive of the "mosaic pattern" often seen in bone disease, and attest to an activity that combines osteogenesis and osteolysis. The appearance of the bone marrow was either normal or adipose, but never fibrous.

In an attempt to relate the above clinical and radiological observations to the F content of water, we noted that the F concentration was not the only factor involved in fluorosis, particularly in the manifestation of skeletal lesions.
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Water Analysis

An examination of the log-scale diagrams relating to chemical composition of the waters reveals that the regions of endemic osteosclerosis present a consistent pattern.

The waters in these districts have a high calcium content and are relatively low in magnesium, thus yielding a high Ca/Mg ratio: they are also high in sulfate and low in alkaline components. In contrast, the waters with inverse characteristics typify regions in which osteosclerosis is extremely rare.

It would therefore seem that such factors as alkalinity, sulfate, and Ca/Mg ratio are important in determining the toxicity of waterborne fluoride. In the Sahara, the high level of calcium and sulfate in the "osteosclerosis" regions strikes us as being of prime importance.

Summary

In a fluorosis belt in the Eastern region of the Sahara, where drinking water contains between 1.5 and 4.0 ppm of fluoride and constitutes the predominant source of ingested fluoride, the authors report 148 cases of skeletal fluorosis.

Unlike in India, the authors encountered only one case of paraplegia associated with osteosclerosis. Only two individuals showed signs of increased cranial density. Calcification of the interosseous membrane was an early sign of the disease. Serum Phosphates were consistently elevated. There was no correlation between bone fluoride content and radiologically detectable increases in density. No significant increase in serum alkaline phosphatase was noted. Urinary fluoride ranged from 0.5 to 12 ppm.

Clinical and radiological findings were not solely dependent on F concentration of water. Thus, the "toxic" waters had a low Mg/Ca ratio, were low in alkaline components and high in sulfate. The reverse pattern was observed in non-toxic drinking waters.

Bibliography
