Relationship of Water Fluoridation to Bone Density in Two N.Y. Towns

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INTEREST in the relationship of water fluoridation to bone density was rekindled by a study of Bernstein and co-workers (*1*) that described osteoporosis in residents over 45 years of age in two areas of North Dakota. One had natural water fluoride levels of 4.0 to 5.8 parts per million (ppm) and the other, levels of 0.15 to 0.3 ppm. The study showed a significantly greater prevalence of osteoporosis in all age groups studied, especially among women, living in the areas with low fluoride levels. Another measure of osteoporosis (namely, collapsed vertebrae) was demonstrated by a significantly greater prevalence in women in the low-fluoride areas. A peculiarity of the groups under observation was the high prevalence of collapsed vertebrae among men, suggesting the possibility of inadvertent bias in the sample (*2*). An incidental observation showed significantly greater calcification of the aorta in all age groups and in both sexes in the areas with low levels of fluoride.

Earlier studies by Leone and associates (*3*) called attention to the bone status in populations of the Bartlett-Cameron area of Texas and in Framingham, Mass., purporting to show a greater prevalence of osteoporosis and associated disease in the low-fluoride areas. Ansell and Lawrence (*4*) aimed primarily at an assessment of rheumatic disease in two communities and attempted to relate their study results to the existence of 1 ppm of fluoride in the water supply of one community and its absence in another. The community experience with fluoridation covered only 5 years and the population sample was small, so definitive answers could not be obtained. The authors noted, however, in hand and cervical X-rays, a diminished prevalence of osteoporosis among women in the community with 1 ppm of fluoride.

P. A. Alffram and co-workers, University of Lund, Malmö, Sweden, in an unpublished paper, stated that bone mineral mass is directly associated with high levels of fluoride in the community water. They studied a sample of healthy women, 45 to 72 years old, in two cities. One city had natural water fluoride levels of 0.2 to 0.4 ppm and the other, 4.0 to 6.8 ppm. Bone mineral mass was determined by a combination of X-ray measurement of the relative cortical thickness and attenuation of a photon beam passing through the femur laterally in the epicondylar area.

Many studies have dealt with the relationship of fluoride to bone, primarily concerning heavy exposure to fluorides and the occurrence of osteosclerosis rather than osteoporosis. In recent years, large doses of fluoride have been used therapeutically for patients with Paget's dis-

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ease and extreme osteoporosis. The therapy is reported to be beneficial. It is therefore natural that the value of 1 ppm of fluoride in drinking water—the accepted level for artificial fluoridation—has been suggested as a means of preventing osteoporosis.

The opportunity to study the effect of this amount of fluoride on the prevalence of osteoporosis developed appropriately in Kingston and Newburgh, N.Y. These two cities were the site of the well-known controlled studies of the effect of fluoridation on dental caries, thus furnishing a wealth of information on the nature of the water supply and the health of the population. The level of fluoride in Newburgh's water supply, initiated May 2, 1945, has been maintained continuously since then at 1.0 to 1.2 ppm. Agitation to fluoridate the Kingston water supply caused a flurry of interest about 8 years ago but failed to receive public support, and today Kingston's water supply still is not fluoridated beyond its natural level of 0.05 ppm.

The Kingston-Newburgh studies, centering around dental caries (*5–8*), showed beyond question the beneficial effect of fluoridation in preventing this disease. Careful appraisal of the health of infants and children over a 10-year period also demonstrated that no observable detrimental effect had developed. During the course of these pediatric studies, bone status was assessed. The primary concerns were normal bone development and osteosclerosis, which was not detected. Osteoporosis was not seen and in any event is rare in young persons.

Several methods were considered for testing the hypothesis that 1 ppm of fluoride in a community water supply will reduce the prevalence and severity of osteoporosis. Initial attention was given to the careful examination of a properly selected sample of persons, over 45 years of age, who had resided in Newburgh or Kingston continuously since 1945. Adequate identification of this sample numbering perhaps 1,000 persons from each city, development of appropriate clinical facilities for interviewing and examining them, and anticipated difficulties in persuading the study subjects to participate all combined to suggest that this approach to evaluation be deferred at least until several intermediate studies were completed. These more limited studies included determinations of the incidence of hip and wrist fractures as well as prevalence of osteoporosis, vertebral fractures, and calcification of the aorta in comparable populations of the two cities.

Clinicians have presumed for a long time that fractures of the hip and wrist, particularly in older women, are related to osteoporosis; therefore, the incidence of these entities in the two cities was thought to be of interest. The most pertinent descriptions of the epidemiology of hip and wrist fractures appear in Swedish literature. Alffram (*9*) has discussed the occurrence of cervical and trochanteric fractures of the hip in Malmö, Sweden. He described the distribution of these fractures in a total population and factors underlying the relatively high incidence in women over 50 years of age.

Alffram and Bauer (*10*) discussed the striking increase of wrist fractures in women after menopause; the peak is reached at 65 years of age, where it remains on a plateau throughout life. In contrast, wrist fractures in men do not increase after the age of 45 years. These findings suggest that the fractures are related in some way to sex-linked metabolic changes rather than to differences in exposure of men and women to risk. One observation of the Swedish investigators was that wrist and hip fractures tended progressively to be more associated with minor injury as age increased, particularly among women. Under 45 years of age, the association with minor injury was not different for the sexes and was rare.

Goggin and associates (*11*) described the incidence of hip fracture in a city 5 years before and after the initiation of water fluoridation. No change was observed.

Iskrant (*12*) noted that mortality in the United States from hip fractures was lower in communities with high levels of natural fluoride in the water. No difference was observed for communities known to be using artificial fluoridation.

Study Design

Kingston and Newburgh were ideal communities for enumerating the total number of hip and wrist fractures since the acute medical needs of each city were met locally. All patients with

fractures of the hip were admitted to local hospitals and thus the injury became a matter of record. As it turned out, in recent years all patients with wrist fractures were referred to the orthopedic physicians in the two cities and, even more pertinent to this study, all X-ray examinations in Newburgh were channeled through one X-ray department at St. Luke's Hospital. (A small group of patients were examined privately in the office of the hospital radiologist.) The same arrangement existed in Kingston although the two hospitals, Benedictine and Kingston, had separate X-ray departments. Thus, complete rosters existed of all X-rays taken in the two cities.

Data processing entailed the identification of patients in the X-ray department logbook who had received X-rays of the wrist or forearm and listing those over 40 years of age who were residents of the two cities. Reports on X-rays of these residents were then examined to determine whether a fracture had occurred. Wrist fractures were classified according to the system followed by the Swedish researchers and included the classic Colles' fracture or other fractures of the distal end of the radius and ulna within 3 centimeters of the joint. Fractures of the wrist bones or more proximal on the shaft of the radius and ulna were not included.

City directories were searched to determine whether the patients had been residents of Kingston or Newburgh since 1945. Nearly 80 percent of the patients living in the cities at the time of their hip fractures (1964–66) lived there in 1945. To check further on population mobility in the two cities, random samples of residents in the 1946 directories were searched for in the 1968 directories. The proportions found in the 1968 directories for both cities were the same.

Success in identifying persons with wrist fractures was hampered to some extent by less information in the limited clinical records and an appreciably younger age group—the median age was 21 years under the age of the group with hip fractures. This age difference may reflect a greater mobility of the population and hence account for the more recent arrival in the two cities. In Kingston, 60 percent of the group was found in the 1946 directory, and in Newburgh, 57 percent. Three years of experience (1964 through 1966) were included for hip fractures and 1 year (1966) for wrist fractures to obtain adequate numbers for comparing incidence rates.

Hip Fractures

Hip fractures included in the enumeration were those clearly identified as cervical, intertrochanteric, or subcapital. Fractures labeled subtrochanteric, those of the shaft of the femur, and obvious pathological fractures were excluded. The pathological fracture group included two patients with multiple myeloma, two with metastatic cancer of the hipbones, two with Paget's disease of the hip, one with extensive long-standing poliomyelitis of the fractured leg

Table 1. Hip fractures in white residents over 40 years old living in Kingston and Newburgh, N.Y., in 1945 and at time of fracture, 1964–66, by sex and age groups

Age group	Kingston			Newburgh		
	Men	Women	Total	Men	Women	Total
Total	9	41	50	11	32	43
40–49	0	0	0	1	0	1
50–54	0	0	0	0	1	1
55–59	0	2	2	1	2	3
60–64	3	3	6	0	2	2
65–69	1	4	5	1	2	3
70–74	1	4	5	2	2	4
75–79	3	7	10	1	5	6
80–89	1	15	16	5	13	18
90–99	0	6	6	0	4	4
100 or over	0	0	0	0	1	1

where atrophy from disuse was a critical factor, and one who sustained a second fracture at the site of a previous cervical fracture in the left hip.

Distribution of hip fractures among white residents over 40 years old, living in Kingston and Newburgh since 1945, is presented in table 1 by sex and age groups. Records of hip fractures sustained from 1964 through 1966 were used. The median age of the Kingston group was 78 years, with a range from 57 to 92. In Newburgh, the median age was 79 years, with a range from 43 to 100.

Striking differences are apparent in the distribution of hip fractures by sex. Women had roughly three or four times as many hip fractures as men in these age groups. Because the city directories indicated that a similar percentage of persons living in Kingston and Newburgh in 1966 were residents of the cities in 1945, it seemed appropriate to use the 1960 census population as a denominator to calculate hip fracture rates in the two cities. The groups were limited to white residents because including the relatively small nonwhite population would have added a complicating variable. Only one hip fracture occurred in a Negro over 40 years old in Kingston and three in Newburgh during 1964–66.

Hip fracture rates for 1964 through 1966, by number of cases and census population groups over 55 and over 65 years of age, are presented in table 2. There were no significant differences in hip fracture rates between the two cities although the difference in rates between men and women was strikingly confirmed. Distribution of hip fractures by month of occurrence is presented in table 3 along with similar data for wrist fractures, which are discussed next. No striking variation occurred in distribution except for a concentration of hip fractures in January. Most fractures were sustained indoors, and the winter weather apparently played only a relatively minor part.

Table 3. Distribution of hip and wrist fractures in white residents over 40 years old, living in Kingston and Newburgh, N.Y., in 1945 and at time of fracture, 1964–66, by month of occurrence

Month of occurrence	Hips		Wrists	
	Kingston	Newburgh	Kingston	Newburgh
Total for year	50	43	24	29
January	12	6	3	4
February	3	4	2	3
March	3	3	1	4
April	5	4	3	3
May	3	3	1	2
June	5	3	3	1
July	6	3	3	1
August	3	3	3	2
September	3	3	0	2
October	2	4	2	1
November	3	5	1	4
December	2	2	2	2

An attempt was made from data on hospital records to describe the severity of injury that produced the hip fracture. Occasionally the record was unclear concerning the accident, but it was learned that 80 percent of the hip fractures occurred during a minor fall to the floor or ground from a standing position. Other types of injury included three falls from ladders (fourth or fifth rung), five falls down flights of stairs, one injury by a car, three falls from

Table 2. Hip fractures and rate per 1,000 white residents living in Kingston and Newburgh, N.Y., in 1945 and at time of fracture, 1964–66, by sex and age groups

Age group	1960 census population		Cases		Rate per 1,000		Rate per 1,000 residents
	Men	Women	Men	Women	Men	Women	
Over 55 years	6,032	8,060	19	72	3.2	8.9	6.5
Kingston	3,119	4,317	9	41	2.9	9.5	6.7
Newburgh	2,913	3,743	10	31	3.4	8.3	6.2
Over 65 years	3,173	4,709	15	63	4.8	13.3	9.9
Kingston	1,707	2,585	6	36	3.5	13.9	9.8
Newburgh	1,466	2,124	9	27	6.1	12.7	10.0

chairs, and two falls out of beds. By any definition, such injuries would be considered modest, except the injury caused by a motor vehicle.

Wrist Fractures

Data on wrist fractures in 1966 among long-time city residents were obtained in the same way as for hip fractures. The number of X-rays taken in each X-ray facility included in the study is given in table 4. Scanning of the X-ray department logbooks identified all X-rays of the wrist and forearm. Patients were necessarily limited to those over 40 years old, those who were residents of the cities at the time of X-ray, those with wrist fractures, and those who were residents of the same city in 1945. The number of cases appropriate for comparative analysis was slightly less than one per 1,000 X-ray examinations. The private office records of two radiologists at St. Luke's Hospital also were examined. Their practice differed considerably from hospital practice, but the private records were reviewed to assure that no wrist fractures were overlooked. One wrist fracture case appropriate for inclusion in the study sample was discovered through this procedure.

The distribution of wrist fractures in patients over 40 years old living in Kingston and Newburgh in 1945 and at time of fracture in 1966, is presented in table 5 by sex and age groups. The sex difference is even more striking for wrist fractures than for hip fractures. In Newburgh only two men had wrist fractures as compared with 22 women—an elevenfold difference. Age distribution of cases was roughly comparable in the two cities. The median age of Kingston patients with wrist fractures was 60 years, ranging from 45 to 78. The median age in New-

Table 4. Distribution of X-rays and wrist fractures in study population in 1966, by X-ray facility, Kingston and Newburgh, N.Y.

X-ray facility	Total X-rays done in 1966	Total wrist X-rays of city residents over 40 years old	Total wrist fractures found	Total wrist fractures in 1966 in 1945 residents
Total	68, 347	244	93	55
Kingston Hospital	30, 000	71	32	18
Benedictine Hospital	12, 500	40	16	11
St. Luke's Hospital	24, 000	123	44	25
Private office	1, 847	10	1	1

Table 5. Wrist fractures in 1966 in residents over 40 years old, living in Kingston and Newburgh, N.Y., since 1945, by sex and age groups

Age group (years)	Kingston			Newburgh		
	Men	Women	Total	Men	Women	Total
Total	5	24	29	2	22	24
40–44					1	1
45–49	2	3	5		3	3
50–54		3	3	1	2	3
55–59	3	3	6		4	4
60–64		5	5		1	1
65–69		6	6		6	6
70–74					2	2
75–79		4	4		2	2
80 or older				1	1	2

burgh was 58 years, ranging from 43 to 82. These median ages are 21 years under those of patients with hip fractures. Rates for wrist fractures were calculated as for hip fractures, using 1960 census populations of appropriate age and sex groups. Since the information on wrist fractures includes both whites and nonwhites, we used the census data that included both categories. This procedure was necessary because X-ray and clinic records did not identify race. The 1966 rates of wrist fractures per 10,000 population over 45 years old were as follows:

Kingston	25.2
Men	9.9
Women	37.2
Newburgh	21.0
Men	4.0
Women	35.4

There is no statistically significant difference in wrist fracture experience in the two cities. Distribution of wrist fractures, by month of occurrence, are presented in table 3. There was no striking seasonal trend.

Osteoporosis and Other Conditions

As another step in the study—short of carefully examining an adequate sample of healthy individuals in the two cities—it was considered useful to review existing hospital X-ray files for evidence of differences in bone density. For this purpose, routine lateral X-rays of the chest were selected that allowed visualization of the thoracic vertebrae and assessment of the bone for osteoporosis and compression fractures. A portion of the aorta also could be seen, and calcification could be determined. (Radiologists tended to take routine lateral chest X-rays whenever a standard anterior-posterior film was ordered.) Since all the X-ray work in these cities was performed in the hospital X-ray departments, it was thought that proper selection of cases could identify comparable groups of patients with a minimum of chronic disease affecting the status of the bone.

Actually, it was impractical to segregate a group of healthy persons since most X-rays were requested because of an accident or illness. Excluding patients from this study because of metabolic diseases and chronic debilitating illnesses such as cancer, emphysema, and duodenal ulcer presented the problem of defining who was "healthy" in a population of men and women over 55 years of age.

In addition, neither chest survey X-rays nor routine examinations of presumably healthy persons included lateral chest films. Clinical records of patients selected for comparative study indicated that they represented similar categories of patients of the same age and sex distribution. Although Newburgh is rapidly becoming a nonwhite city and Kingston is not, restricting the comparison to patients who were city residents in 1945 essentially eliminated any bias.

The procedure followed was similar to that described for the study of wrist fracture. It consisted of the use of the X-ray logbook as the initial source of subjects and limited consideration to persons for whom only a chest X-ray was requested. This method was used to exclude all major accidents or illnesses that by nature might suggest the likelihood of vertebral fractures or extreme osteoporosis. The study group was then limited to persons of both sexes who had been residents of the cities and used the municipal water since 1945. The study sample included 2 years of experience (1966 and 1967) at the Benedictine Hospital in Kingston and most of the 1967 experience at St. Luke's Hospital in Newburgh. Sampling in Kingston was restricted to the Benedictine Hospital because of its recordkeeping procedures. A total of 2 years of experience was needed to produce the number of patients required for comparative analysis. Careful review of the X-ray department procedures and routine X-ray techniques for lateral chest films used in each study hospital showed them to be essentially similar.

After the study subjects were identified, specific lateral chest films were assembled, labels identifying hospitals and patients were masked out, and new code numbers were assigned. These things were done to be certain that the films subsequently could be read on a double-blind basis. One radiologist read the entire set of films twice, using the following criteria to interpret the X-rays:

Osteoporosis

Mild: Suspicious osteoporosis without evidence of vertebral deformity.

Moderate: Osteoporosis with evidence of some

kyphosis due to early wedging of one or more of the vertebral bodies.
Severe: More obvious osteoporosis with moderate to severe wedging.

Fractures

Obvious fractures, most of which were traumatic; a few were from the severe osteoporosis group, where they were quite marked.

Aortic Calcification

Mild: Calcification less than 3 centimeters in length (adding all the noted segments of calcification).
Moderate: Calcifications totaling 3 to 10 centimeters in length.
Severe: Calcification more than 10 centimeters in length.

First Reading of X-rays

Samples totaling 210 persons from Kingston (nonfluoridated water supply) and 219 from Newburgh (fluoridated water supply) were studied. The age and sex distributions of these samples were similar. Since the films that were satisfactory for interpretation differed for each variable examined (that is, osteoporosis, vertebral fractures, and aortic calcification), the numbers of study subjects in each table differ slightly.

Osteoporosis. Measurement of bone density by visual inspection of lateral chest films is highly impressionistic but because the examiner did not know the source of each film his comparison between the two cities seemed to be valid. For table 6 purposes, the categories of normal and mild have been designated as "normal," and of moderate or severe, as "osteoporotic." Because of the small number of patients in each category, only two age groups (55 through 64 years and 65 years and over) were presented for each sex. No significant differences were observed between the cities. Great or greater differences would have occurred by chance 70 percent of the time. Increased osteoporosis with age and excessive osteoporosis in older women was apparent.

Vertebral fractures. The frequency of one or more dorsal vertebral fractures in the study sample is presented in table 7. Such fractures represent obvious bony defects that would be so classified by any capable examiner. No significant differences between cities were observed. Increased prevalence of fractures with age was evident.

The percentages of thoracic vertebrae visualized that were found to be fractured is shown in table 8. A need for this analysis was suggested because the numbers of vertebrae observed varied to some extent with size of the patient and quality and positioning of the film. No significant differences between the cities were seen. The increased number of fractures with age was striking.

Aortic calcification. Lateral chest films do not afford the best technique for visualizing aortic calcification; obviously the positive findings included but a fraction of actual preva-

Table 6. Number and percentage of residents with osteoporosis living in Kingston and Newburgh, N.Y., since 1945, by sex and age groups, 1966–67

City	55–64 years		65 years and over		Total	
	Number of X-rays read	Percent of total osteoporotic	Number of X-rays read	Percent of total osteoporotic	Number of X-rays read	Percent of total osteoporotic
Kingston (191 X-rays):						
Men, normal	18		20		38	
Men, osteoporotic	13	41.9	33	62.3	46	54.8
Women, normal	18		18		36	
Women, osteoporotic	12	40.0	59	76.6	71	66.4
Newburgh (204 X-rays):						
Men, normal	27		30		57	
Men, osteoporotic	19	41.3	30	50.0	49	46.2
Women, normal	19		17		36	
Women, osteoporotic	14	42.4	48	73.8	62	63.3

lence. Nevertheless, comparison seems valid in view of the double-blind design of the study. Increased calcification with age was evident. There was no consistent or significant difference between the two cities (table 9).

Second Reading of X-rays

The radiologist interpreted the 429 lateral chest X-rays the second time without knowledge of his first interpretation. He made conscious efforts to utilize the same classification system. Comparison of the two readings is presented in table 10. Disagreement is most striking in the assessment of osteoporosis. Of 167 films that were read as normal the first time, 79 or 47 percent were said to show osteoporotic changes on the second reading. On the other hand, of 228 films read as showing osteoporosis the first time, only 25 or 11 percent were read as negative the second time. In addition to different interpretations, the data seemed to indicate that the system of classification was unconsciously modified between readings. Of 34 films deemed inadequate for interpretation the first reading, 11 were classified as normal and 11 as osteoporotic the second reading. Only 12 films were found to be inadequate for both readings; one classified as osteoporotic on the first reading was deemed inadequate on the second reading.

Less striking changes are seen in table 10 with respect to calcification of the aorta and collapsed vertebrae; however, the data verify the weakness of the method for measuring all three abnormalities. Two statistical questions may be

Table 7. Number and percentage of residents with one or more dorsal vertebral fractures living in Kingston and Newburgh, N.Y., since 1945, by sex and age groups, 1966–67

City	55–64 years		65 years and over		Total	
	Number of X-rays read	Percent of total with fractures	Number of X-rays read	Percent of total with fractures	Number of X-rays read	Percent of total with fractures
Kingston (207 X-rays):						
Men, none	34	----------	53	----------	87	----------
Men, 1 or more	2	5.6	7	11.7	9	9.4
Women, none	27	----------	66	----------	93	----------
Women, 1 or more	4	12.9	14	17.5	18	16.2
Newburgh (217 X-rays):						
Men, none	47	----------	59	----------	106	----------
Men, 1 or more	3	6.0	8	11.9	11	9.4
Women, none	32	----------	53	----------	85	----------
Women, 1 or more	2	5.9	13	19.7	15	15.0

Table 8. Thoracic vertebrae visualized and those found to be fractured in residents living in Kingston and Newburgh, N.Y., since 1945, by sex and age groups, 1966–67

City	55–64 years		65 years and over		Total	
	Number of vertebrae	Percent of total fractured	Number of vertebrae	Percent of total fractured	Number of vertebrae	Percent of total fractured
Kingston (1,908 vertebrae):						
Men, vertebrae visualized	315	----------	541	----------	856	----------
Men, number of fractures	2	0.6	15	2.7	17	1.9
Women, vertebrae visualized	292	----------	760	----------	1,052	----------
Women, number of fractures	4	1.4	26	3.3	30	2.8
Newburgh (2,007 vertebrae):						
Men, vertebrae visualized	457	----------	588	----------	1,045	----------
Men, number of fractures	5	1.1	14	2.3	19	1.8
Women, vertebrae visualized	329	----------	633	----------	962	----------
Women, number of fractures	2	.6	28	4.2	30	3.0

asked: First, is the probability of diagnosing osteoporosis the same for both trials? The McNemar test is appropriate for testing this proposition and indicates a probability of less than 0.01 for both osteoporosis and vertebral fractures that differences as great or greater could have occurred by chance alone. Second, is frequency of like diagnoses no greater or less than can be attributed to chance? Tests of statistical significance show that concurrence of like diagnoses is far beyond the likelihood of chance for each of the three abnormalities.

It may be inappropriate to compare the prevalence of osteoporosis, fractured vertebrae, and aortic calcification in Kingston and Newburgh residents by limiting the analysis to those persons having like X-ray readings on both examinations. Nevertheless, this procedure was used, and again no significant or consistent differences between the two cities were seen.

Table 9. Calcification of thoracic aorta visualized in X-rays of residents living in Kingston and Newburgh, N.Y., since 1945, by sex and age groups, 1966–67

City	55–64 years		65 years and over		Total	
	Number of X-rays	Percent of total with calcification	Number of X-rays	Percent of total with calcification	Number of X-rays	Percent of total with calcification
Kingston (199 X-rays):						
Men, X-rays visualized	36		56		92	
Men with calcification	2	5.6	9	16.1	11	12.0
Women, X-rays visualized	30		77		107	
Women with calcification	3	10.0	32	41.6	35	32.7
Newburgh (215 X-rays):						
Men, X-rays visualized	49		66		115	
Men with calcification	3	6.1	15	22.7	18	15.7
Women, X-rays visualized	34		66		100	
Women with calcification	2	5.9	24	36.4	26	26.0

Table 10. Comparison of two independent readings for osteoporosis, calcification of aorta, and collapsed vertebrae of the same lateral chest X-rays of 429 patients

Condition on first reading	Second reading			
	No osteoporosis	Osteoporosis	Inadequate film	Total
Total	124	292	13	429
No osteoporosis	88	79	0	167
Osteoporosis	25	202	1	228
Inadequate film	11	11	12	34
	No calcification	Calcification	Inadequate film	Total
Total	329	93	7	429
No calcification	302	19	3	324
Calcification	20	70	0	90
Inadequate film	7	4	4	15
	No collapsed vertebrae	Collapsed vertebrae	Inadequate film	Total
Total	398	29	2	429
No collapsed vertebrae	369	5	0	374
1 or more collapsed vertebrae	29	24	0	53
Inadequate film	0	0	2	2

Discussion

As indicated earlier, these studies were undertaken with a foreknowledge of their inadequacies and as preliminary work to a more definitive examination of an appropriate sample of comparable populations in the two cities. The inconsistencies revealed in two readings of 429 lateral chest X-rays emphasize the limitations of the approach used. Significant differences were not observed, however, between the two cities for any of the variables studied. Somewhat similar methods of determining the presence of osteoporosis, fractured vertebrae, and aortic calcification by lateral lumbar X-rays were used in the North Dakota study (*1*).

If the study data are accepted as evidence of the lack of an observable effect on bone density of 1 ppm of fluoride in the community water supply for a period of 22 years, several possible explanations for the negative results should be considered.

Perhaps 22 years of exposure to 1 ppm of fluoride is too short a period to determine the effects on bone density. Jackson and Weidmann (*13*), in their study of the fluoride content of bone collected at autopsies of residents of two English cities—one with a water supply having natural fluoride levels of 0.8 and 1.9 ppm and one without fluoride—showed that the level of fluoride in the bones increased with age and reached a plateau at 51 years, where it remained stabile in the older groups. This finding suggested to the authors that it may take 51 years, perhaps including infancy, to achieve a fluoride equilibrium in bone.

The level of 1 ppm of fluoride in water may be too low to produce the effect observed by Bernstein and others (*1*).

The population studied may have been too old to register differences in genesis of osteoporosis owing to differences in fluoride intake since fluoridation was instituted after they had already reached adulthood.

Other characteristics significant to the pathogensis of osteoporosis may have been distributed unequally between the study and control population in such a way as to neutralize any positive effect of fluoridation on bone density; for example, chronic illness, calcium in diet, hormonal intake, and so on.

Different X-ray techniques and statistical limitations, introduced by the small number of persons studied, also must be considered.

Because of the potential significance of fluoridation to public health, it seems important to develop an adequate, well-controlled study in populations with lifetime exposure to a negligible level and to 1 ppm of natural fluoride in drinking water. In the battery of applied clinical tests, a method like that devised by Sorenson and Cameron for assessing bone density is essential (*14*). Their technique, using an iodine-125 radiating source and spectroscopic determination of the degree of bone penetration, allows accurate and reproducible assessment of osteoporosis. The test can be performed in the clinic setting in about 5 minutes per patient.

Summary

The New York State Department of Health has studied the incidence of hip fractures (1964–66) and wrist fractures (1966) in persons over 40 years of age living in the cities of Kingston and Newburgh, N.Y., since 1945. Kingston has negligible amounts of fluoride in the community water supply; Newburgh's water supply has been fluoridated at 1 ppm since 1945.

All hip fracture cases listed in records of the hospitals in the two cities were used for study purposes; wrist fracture cases were ascertained from records of central X-ray facilities in the two communities where all such work is done. No significant sex and age specific differences were observed in fracture rates between the two cities; however, striking increases occurred among women and with aging.

The age and sex specific prevalence of osteoporosis, collapsed vertebrae, and calcification of the aorta in persons over 55 years of age in the two cities also was studied. The samples consisted of 210 persons from Kingston and 219 from Newburgh who had resided in the cities for more than 22 years and who had a lateral chest X-ray during 1966–67. The status of chronic disease in the two comparison groups was roughly the same. The study variables were assessed by a radiologist without knowledge of the city of residence. No significant or consistent differences in prevalence of these three conditions were seen between the two cities although,

again, increased incidence with age, especially among women, was observed.

The same radiologist read the 429 lateral chest X-rays twice without knowing the city of residence or his first interpretation. A comparison of these two readings revealed the major inconsistencies inherent in this diagnostic technique. However, the prevalence of osteoporosis, by age and sex, collapsed vertebrae, and aortic calcification, among persons for whom there was agreement on both readings again failed to show significant or consistent differences between the two cities.

A more meaningful research design is needed to assess whether a community water level of 1 ppm of fluoride has any effect on the prevalence and severity of osteoporosis.

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