2. Institute of Medicine. *Meeting Physicians' Needs for Medical Information on Occupations and Environments.* Washington, DC: National Academy Press; 1990.
3. Blanc PD, Remple D, Maizlish N, Hiatt P, Olson KR. Occupational illness: case detection by poison control surveillance. *Ann Intern Med.* 1989;111:238–244.
4. Blanc P, Olson KR. Occupationally related illness reported to a regional poison control center. *Am J Public Health.* 1986;76:1303–1307.
5. Blanc PD, Maizlish N, Hiatt P, Olson KR, Rempel D. Occupational illness and the poison control center: referral patterns and service needs. *West J Med.* 1990;152:181–184.
6. Bresnitz EA. A model system for occupational disease surveillance activities applying Centers for Disease Control guidelines to poison control centers. *J Occup Med.* 1990; 32:255–259.
7. Bresnitz EA. Poison control center follow-up of occupational disease. *Am J Public Health.* 1990;80:711–712.
8. Litovitz TL, Schmitz BF, Holm KC. *1988 Annual report of the American Association of Poison Control Centers National Data Collection System. Am J Emerg Med.* 1989; 7:495–545.
9. Litovitz TL, Manoguerra A. Comparison of pediatric poisoning hazards: an analysis of 3.8 million exposure incidents. A report from the American Association of Poison Control Centers. *Pediatrics.* 1992;89:999–1006.

Hip Fracture Incidence before and after the Fluoridation of the Public Water Supply, Rochester, Minnesota

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ABSTRACT

Recent ecological comparison studies have suggested a positive association between fluoridation and hip fracture. Using data from the Rochester Epidemiology Project, we found the incidence of hip fracture for the 10 years before the fluoridation of the Rochester, Minn, public water supply was 484 per 100 000, compared with 450 per 100 000 in the following 10 years. When the effects of calendar time and age were controlled for, the relative risk associated with fluoridation was 0.63. These ecologic trend data suggest that the fluoridation of public water supplies is not associated with an immediate increase in rates of hip fracture. Further studies of this association at the individual level are clearly required before public policy decisions can be made. (*Am J Public Health.* 1993;83:743–745)

Introduction

Since 1945, communities have added fluoride to public drinking water supplies in order to prevent tooth decay.[1] It was hypothesized that this added fluoride would strengthen bone as well,[2] yet most ecologic studies failed to detect a protective effect for fractures.[3–7] In contrast, Bernstein et al. found a decreased prevalence of vertebral fractures in areas with high natural concentrations of fluoride, and Simonen et al. found a lower incidence of hip fractures in a Finnish city with an artificially fluoridated water supply than in one with low fluoride levels.[8,9] Other investigators, however, were unable to duplicate the protective affect in the same area.[10,11] More recently, however, ecologic studies have suggested an increased risk of hip fracture associated with fluoridation.[12–16] The increased risk of fracture may occur immediately after fluoridation,[17] and the only study to date that has examined fracture incidence rates within a community did find a slight increase in the risk of hip fracture after fluoridation of the public water supply as compared with before fluoridation (5.8 per 1000 vs 5.4 per 1000, respectively).[4] Because that study was based on only 251 cases, however, it may have lacked the power to detect differences in fracture rates.

In order to address the question of an immediate effect of fluoridation on community fracture risk more directly and completely, we used data from the Rochester Epidemiology Project to determine the incidence of hip fracture among men and women aged 50 years and older for the 10 years prior to and the 10 years following the fluoridation of the public water supply in Rochester, Minn.

Methods

The data used in this study have been described previously in detail.[18,19] Briefly, epidemiologic studies are possible in Rochester because of the close correspondence between the few medical care providers and a well-defined catchment population. Furthermore, each provider maintains unit medical records that can be identified and retrieved for review. Mayo Clinic maintains a master index of all diagnoses and surgical procedures recorded among its patients, and the Rochester Epidemiology Project supports a similar index for other medical care providers serving the community.[20] This system makes possible the identification and confirma-

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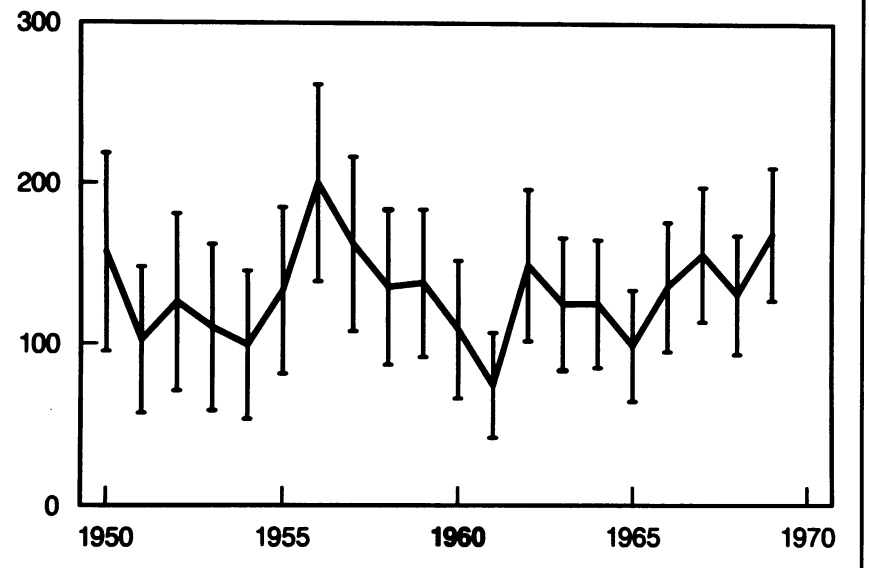

FIGURE 1—Age- and sex-adjusted annual incidence (per 100 000 person-years) of hip fracture: Rochester, Minn, 1950 through 1969.

TABLE 1—Results of Poisson Regression Analysis[a] of Hip Fracture Incidence: Rochester, Minn, 1950 through 1969

	Men		Women		Total	
Risk Factor	Relative Risk	95% Confidence Interval	Relative Risk	95% Confidence Interval[b]	Relative Risk	95% Confidence Interval
Age, y						
50–54	1.00	. . .	1.00[c]	. . .	1.00	. . .
55–59	3.01	0.58, 15.49	1.87	1.07, 3.28	2.06	1.21, 3.50
60–64	3.36	0.65, 17.32	2.76	1.61, 4.72	2.92	1.75, 4.87
65–69	11.16	2.52, 49.47	3.98	2.36, 6.71	4.89	3.00, 7.97
70–74	18.90	4.37, 81.77	6.18	3.71, 10.29	7.74	4.80, 12.49
75–79	38.76	9.11, 164.84	12.93	7.94, 21.06	16.76	10.57, 26.58
80–84	74.13	17.51, 313.74	18.37	11.22, 30.07	25.52	16.04, 40.59
85+	128.18	30.41, 540.25	31.99	19.68, 52.02	44.85	28.35, 70.96
Year[d]	1.05	0.98, 1.12	1.04	1.01, 1.07	1.04	1.01, 1.07
Fluoridation[e]	0.78	0.37, 1.66	0.60	0.42, 0.85	0.63	0.46, 0.86

[a]Models were constructed with all variables entered simultaneously, and results were adjusted for all other factors in the model.
[b]Relative risk estimates obtained from beta coefficients and their respective standard errors.
[c]The 50–54 age group serves as the referent category.
[d]Modeled as a continuous variable.
[e]1950–1959 = 0, 1960–1969 = 1.

tion of all diagnoses of proximal femur fracture among Rochester residents, whether made in emergency rooms, hospitals, outpatient clinics, or nursing homes or at autopsy.

This close correspondence between the community and its medical care providers is mirrored in Rochester's water supply. The city's water is supplied by 23 wells scattered throughout Rochester, each drawing from a contiguous groundwater source. The city began the fluoridation of its public water supply in April of 1960. Since that time, optimum levels of fluoride have been maintained at 1.1 ppm,[21] providing a nearly ubiquitous exposure among community residents.

For this study, we identified all incident hip fractures occurring from 1950 through 1969 among persons aged 50 years and older to determine the risk of fracture for the 10 years before and the 10 years after the fluoridation of Rochester's water supply. Year-, age-, and sex-specific incidence rates were calculated as the number of fractures divided by the person-years at risk.[22] Incidence rates were age and sex adjusted to the 1990 US White population. Poisson regression models were constructed to evaluate the independent effects of age, secular trend, and fluoridation simultaneously. In addition, a model was constructed to test the interaction between secular trend and fluoridation.

Results

During the 20-year study period, Rochester residents experienced 751 incident hip fractures, 268 among men and 383 among women. From 1950 through 1959, the age- and sex-adjusted incidence of hip fracture was 484 per 100 000 person-years (95% CI = 370, 597); the rate was 450 per 100 000 person-years (95% CI = 362, 537) for 1960 through 1969. Among women, the incidence of hip fracture before 1960 (728 per 100 000 person-years; 95% CI = 628, 828) was higher than afterward (631 per 100 000 person-years; 95% CI = 559, 703). Among men, however, this incidence rate was slightly lower before 1960 (172 per 100 000 person-years; 95% CI = 118, 226) than afterward (219 per 100 000 person-years; 95% CI = 168, 269). Rates by year (Figure 1) show a strong secular trend that increases over time. There is, however, an offset in the secular increases in fracture rates associated with the time of fluoridation. Poisson regression models (Table 1) demonstrate a strong effect attributable to fluoride (relative risk = 0.63; 95% CI = 0.46, 0.86), as well as significant year and age effects. The interaction between yearly effects and fluoridation was not significant (data not shown). After adjusting for the other factors, the relative risk associated with fluoridation was 0.60 (95% CI = 0.42, 0.85) among women and 0.78 (95% CI = 0.37, 1.66) among men.

Discussion

These data demonstrate no increase in the risk of hip fracture associated with fluoridation of the public water supply in Rochester, Minn. This finding contrasts sharply with several recent ecologic studies that have all suggested a slight increase in risk of hip fracture associated with water fluoridation. Fluoridation in these studies has been measured in several ways, including the percentage of the population served with fluoridated water,[12] fluoride concentrations in public water supplies,[15] and presence or absence of fluoride exposure.[14,16] Only two studies have related fracture incidence temporally with fluori-

dation. One, involving a design similar to that of the present study, could not demonstrate any association between fluoridation and hip fracture,[4] whereas the other suggested that the risk of hip fracture may be initially increased and decline toward unity thereafter.[16] In the latter study, however, the more recently fluoridated counties were not followed over time; thus, one cannot distinguish geographic from temporal factors. The present study demonstrates no such immediate effect of the fluoridation of the public water supply, suggesting that the previous results may have been due to confounding by some other factor related to geography rather than time. The apparent negative association between the onset of fluoridation and hip fracture is difficult to interpret. There are no data available to suggest that fluoride, even at pharmacologic doses, has a beneficial effect at the hip.[23,24] Furthermore, the data suggest that the decrease in fracture rates started before the introduction of fluoride to the Rochester water supply, raising the possibility that the decrement in risk may not be due to a causal association.

There are, nonetheless, some limitations of our data. While case ascertainment is believed to be complete,[19] the sample size was small and resulted in wide confidence intervals about the point estimates, especially among men. Second, the data were derived from a small midwestern city, and the results may not be generalizable to other areas. Hip fracture incidence rates from Rochester are, however, comparable to those for the United States generally.[25] Third, this analysis is ecological, but, as in the study by Goggin et al.,[4] one needs to be concerned only about potential confounders that are temporally associated with fluoridation. Thus, this study provides a somewhat stronger test of the association between fluoridation and hip fracture than do the ecologic studies comparing diverse communities.[12-14,16]

In summary, these data suggest that there is no positive association between water fluoridation and hip fracture risk. Given the disparate results of this and other ecologic studies, it is apparent that future studies of the association of water fluoridation and hip fracture will need to be conducted at the individual level. Such work is clearly required before public health policy decisions can be made. □

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References

1. *Review of Fluoride Benefits and Risks.* Washington, DC: Ad Hoc Subcommittee on Fluoride of the Committee to Coordinate Environmental Health and Related Programs, Public Health Service; 1991.
2. Leone NC. The effects of the absorption of fluoride. I. Outline and summary. *Arch Ind Health.* 1960;21:324–325.
3. Madans J, Kleinman JC, Cornoni-Huntley J. The relationship between hip fracture and water fluoridation: an analysis of national data. *Am J Public Health.* 1983;73: 296–298.
4. Goggin JE, Haddon W Jr, Hambly GS, Hoveland JR. Incidence of femoral fractures in postmenopausal women. *Public Health Rep.* 1965;80:1005–1012.
5. Korns RF. Relationship of water fluoridation to bone density in two N.Y. towns. *Public Health Rep.* 1969;84:815–825.
6. Avorn J, Niessen LC. Relationship between long bone fractures and water fluoridation. *Gerodontics.* 1986;2:175–179.
7. Alffram PA, Hernborg J, Nilsson BER. The influence of a high fluoride content in the drinking water on the bone mineral mass in man. *Acta Orthop Scand.* 1969;40: 137–142.
8. Bernstein DS, Sadowsky N, Hegsted DM, Guri CD, Stare FJ. Prevalence of osteoporosis in high- and low-fluoride areas in North Dakota. *JAMA.* 1966;198:499–504.
9. Simonen O, Laitinen O. Does fluoridation of drinking-water prevent bone fragility and osteoporosis? *Lancet.* 1985;2:432–434.
10. Arnala I, Alhava EM, Kivivuori R, Kauranen P. Hip fracture incidence not affected by fluoridation. Osteofluorosis studied in Finland. *Acta Orthop Scand.* 1986; 57:344–348.
11. Arnala I. Fluoridation and hip fractures. *Med J Aust.* 1987;146:451.
12. Jacobsen SJ, Goldberg J, Miles TP, Brody JA, Stiers W, Rimm AA. Regional variation in the incidence of hip fracture: US white women aged 65 years and older. *JAMA.* 1990;264:500–502.
13. Sowers MFR, Wallace RB, Lemke JH. The relationship of bone mass and fracture history to fluoride and calcium intake: a study of three communities. *Am J Clin Nutr.* 1986;44:889–898.
14. Sowers MFR, Clark MK, Jannausch ML, Wallace RB. A prospective study of bone mineral content and fracture in communities with differential fluoride exposure. *Am J Epidemiol.* 1991;133:649–660.
15. Cooper C, Wickham CAC, Barker DJR, Jacobsen SJ. Water fluoridation and hip fracture. *JAMA.* 1991;266:513–514.
16. Danielson C, Lyon JL, Egger M, Goodenough GK. Hip fractures and fluoridation in Utah's elderly population. *JAMA.* 1992; 268:746–748.
17. Jacobsen SJ, Goldberg J, Cooper C, Lockwood SA. The association between water fluoridation and hip fracture among White women and men aged 65 years and older: a national ecologic study. *Ann Epidemiol.* 1992;2:617–626.
18. Melton LJ, Ilstrup DM, Riggs BL, Beckenbaugh RD. Fifty-year trend in hip fracture incidence. *Clin Orthop.* 1982;162:144–149.
19. Melton LJ III, O'Fallon WM, Riggs BL. Secular trends in the incidence of hip fractures. *Calcif Tissue Int.* 1987;41:57–64.
20. Kurland LT, Molgaard CA. The patient record in epidemiology. *Sci Am.* 1981;245: 54–63.
21. *Fluoridation Census 1985, Communities Using Fluoridated Water Adjusted and Natural.* Atlanta, Ga: Centers for Disease Control; 1988.
22. Bergstralh EJ, Offord KP, Chu C-P, Beard CM, O'Fallon WM, Melton LJ III. *Calculating Incidence, Prevalence and Mortality Rates for Olmsted County, Minnesota Residents: An Update.* Rochester, Minn: Section of Biostatistics, Mayo Clinic; April 1992. Technical Report Series No. 49.
23. Melton LJ. Fluoride in the prevention of osteoporosis and fractures. *J Bone Miner Res.* 1990;5(suppl 1):S163–S167.
24. Riggs BL, Hodgson SF, O'Fallon WM, et al. Effect of fluoride treatment on the fracture rate in postmenopausal women with osteoporosis. *N Engl J Med.* 1990;322:802–809.
25. Jacobsen SJ, Goldberg J, Miles TP, Brody JA, Stiers W, Rimm AA. Hip fracture incidence among the old and very old: a population-based study of 745,435 cases. *Am J Public Health.* 1990;80:871–873.