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Accumulation of Strontium-90 into Human Fetal Teeth and Bone.* (32128)

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Previous studies have shown that the accumulation of strontium-90 in the bone of fetuses is a function of the mother's dietary intake of the nuclide and the discrimination factor against strontium-90 between her diet and her fetus(1). In order to determine the maximum amount of fallout strontium-90 in fetal teeth and bone and to obtain additional information relating the fetal nuclide incorporation to the mother's dietary nuclide intake, the concentration of strontium-90 in tooth buds and mandibular bone has been determined in human fetuses aborted in the St. Louis metropolitan area between 1961 and 1966. This time interval coincides with the most rapid increase in milk strontium-90 that peaked in late 1963 and early 1964 and its slow decline thereafter.

Materials and methods. Tooth buds and mandibular bone were separately obtained from fetuses during the last trimester of development; these were defleshed by boiling in distilled water. Comparable hard tissues from 1-5 fetuses were pooled for each analysis by methods previously reported in detail (1,2). The strontium-90 concentrations in milk for the St. Louis area were obtained through the courtesy of the St. Louis Health Commissioner's office. The fetal data and milk values are presented as arbitrary averages for the first and last 6 months of each year.

Results and discussion. The relative strontium-90 content between tooth buds and mandibular bone averaged 0.99 ± 0.18 (S.D.) for 62 fetal samples. These data show that the strontium-90 content of calcified tissues in the fetus is equally distributed. Strontium-90 values in fetal mandibular bone and bottled cow's milk (Fig. 1) show the rapid increase of nuclide to peak values between 1963-1964 with a subsequent decrease thereafter as is to be expected(3). However, it may be noted that the peak milk strontium-90 content occurs about 6 months earlier than that occurring in the fetuses. This lag period appears to be due to at least two factors that are difficult to evaluate by direct analysis. In the first instance, it needs to be recognized that fetal calcium (and strontium-90) is drawn from the mother's body mineral pool in addition to the mother's dietary mineral intake. Consequently the fetal calcium represents, in part, a contribution from the mother's calcium stores previously deposited before fetal calcification begins. In the second instance, part of the mother's dietary intake of calcium and strontium-90 includes dairy products (cheese, powdered or skim milk, etc.) and other foods that have an appreciable shelf life and are consumed at some time interval after processing. It is important to note that when the dietary intake of strontium-90 is constant or changing very slowly, the lag period would be absent. This situation appears to be occurring for the period after 1965.

We have previously shown that the prenatal contribution from the mother's diet to fetal bone may be defined as:

$$C_B = C_D^M D_M \qquad \text{(Eq. 1)}$$

where C_B is the fetal bone Sr-90/g Ca, C_D^M is the mother's dietary intake of Sr-90/g Ca and D_M is the discrimination factor against strontium-90 between the mother's dietary intake and her fetus. To solve the equation, values for D_M and C_D^M must be experimen-

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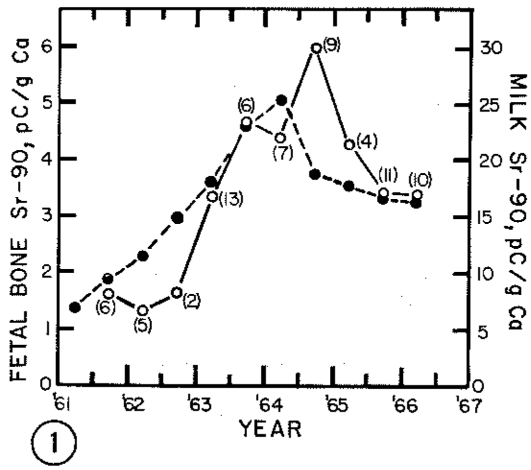

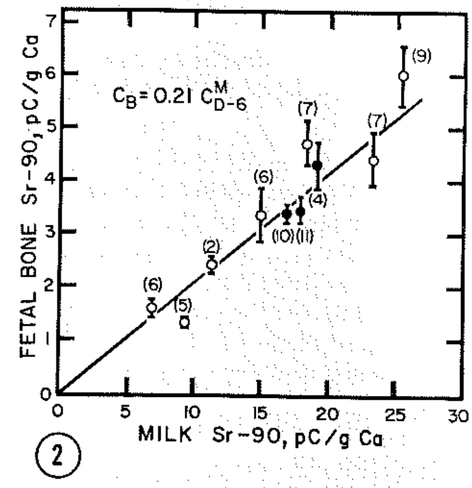

FIG. 1. Strontium-90 content of fetal mandibular bone (- ○ -) and commercial cow's milk (- - ● - -) *vs* year for number of fetal samples in parentheses.

FIG. 2. Strontium-90 content of fetal mandibular bone *vs* milk Sr-90 content. Vertical bars represent standard error of the mean for number of bone samples in parentheses. Open circles represent values obtained during increasing milk concentrations between 1961 and the peak year. Closed circles are values obtained for declining milk concentrations after the peak year.

tally determined. A factor of 0.13 for D_M appears to be satisfactory(1). Because it is difficult to determine directly the mother's total dietary intake of Sr-90/g Ca (C_D^M), the nuclide concentration of milk is used as an index of strontium-90 concentration in the diet. Milk values are available and are well characterized. Studies of composite diets for adult persons in the United States suggest that the average intake of strontium-90 (4), is 1.5 times the milk concentration. The value varies with food composition and may vary between 1-2. The 6-month lag period between the strontium-90 concentrations of bottle milk and fetal calcium suggests that the milk Sr-90/g Ca intake of the mother 6 months previously leads to a better correlation.

The data for 73 fetal samples of mandibular bone are plotted against the milk concentration existing 6 months previous to abortion (Fig. 2) and the line has been fitted through the origin by the method of least squares. The experimental points adequately fit the line for both increasing and decreasing strontium-90 concentrations of milk. From this line a value of 1.6 C_D^M is obtained which is in excellent agreement with that of Michelson *et al*(5) and the Federal Radiation Council(4). Equation 1 may be written as:

$$C_B = 1.6\ C_{D-6}^M\ D_M \qquad \text{(Eq. 2)}$$

where C_{D-6}^M is the mother's strontium-90 intake for the previous six month interval. With 0.13 for D_M, the final equation becomes:

$$C_B = 0.21\ C_{D-6}^M \qquad \text{(Eq. 3)}$$

The data presented in this report substantiate the discrimination factor of one-eighth between the mother's diet and her fetus. This value was previously found to be adequate by Rosenthal *et al*(1) in human mothers and by Comar(6) in animals but differs from the finding of Kulp(7) who observed that the concentration of strontium-90 in fetal bone averaged one-twelfth of that of the mother's diet.

The present value of 1.6 times the milk Sr-90/g Ca differs from the value of 1.2 previously based on limited data for fetuses aborted between 1961 and 1963(1). The difference of 25% between the two values is probably within experimental error. A value of 1.6 times the milk Sr-90/g Ca, determined for a larger number of samples over a longer period of time and for periods of increasing and decreasing milk strontium-90 levels, appears to be a more valid estimate. The present data show that the maximum values for fetal strontium-90 at peak fallout nuclide concentrations in milk, reached an average value of 6.03 pC Sr-90/g Ca. The linear relationship between milk strontium-90 and the deposition of the nuclide in fetal calcified tissue may be useful to estimate fetal concentrations of nuclide from milk values. Conversely, a knowledge of the fetal strontium-90 content may lead to an estimation of the mother's dietary strontium-90 when milk or diet data are not available.

Summary. The strontium-90 content of mandibular bone and tooth buds of 73 fetuses aborted in the St. Louis metropolitan area between 1961 and 1966 has been correlated with the mother's dietary intake of the nuclide. The data obtained during increasing and decreasing periods of fallout may be expressed by a linear equation, $C_B = K\, C^M_{D-6}$, where C_B is fetal bone Sr-90/g Ca, C^M_{D-6} is the mother's dietary strontium-90 intake for the first 6 months of pregnancy and K is a constant equal to 0.21. The equation is useful to calculate the amount of strontium-90 accumulating in fetal calcified tissues from known milk strontium-90 values or conversely, to obtain data concerning the mother's dietary strontium-90 intake when fetal strontium-90 values are known.

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