STRONTIUM AND CALCIUM METABOLISM IN CHILDREN OF VARIOUS AGES

H. N. WELLMAN, B. KAHN, A. SALEM and P. J. ROBBINS

Nuclear Medicine Section, Radiological Health Research Activities, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio, Division of Radiological Health, Public Health Service, U.S. Department of Health, Education and Welfare (U.S.A.)

Abstract—As part of a study to determine the effect of age on ^{90}Sr retention by children, metabolic balance studies were performed with 3 children aged 6 years and 3 children aged 9 years. The children were selected as being normal on the basis of clinical history, physical examination, serum calcium, phosphorus, and alkaline phosphatase, routine laboratory tests and bone-age radiographs. The children were maintained in a metabolic ward for the 15-day balance period and were fed commercially available foods. A balanced diet, recommended by the National Research Council, provided normal intakes of all dietary components. The diet was consumed quantitatively during the balance period and for one month prior to the period. Diet, urine and feces were analyzed for calcium, phosphorus, stable strontium, and ^{90}Sr content.

The average daily intake of the 6-year-old children contained 1.34 g calcium, 1.36 phosphorus, 1.01 mg strontium, and 24 pCi ^{90}Sr; that of the 9-year-olds, 1.49 g calcium, 1.54 g phosphorus, 1.31 mg strontium, and 29 pCi ^{90}Sr.

There was a marked difference in the dietary components which contribute stable strontium and ^{90}Sr, with dairy products responsible for 70 per cent of ^{90}Sr, but only 40 per cent of stable strontium. Urine specific activities (pCi ^{90}Sr/mg Sr) in the children were approximately one-half that in the diet. In previously studied infants, for comparison, the ratio of urine specific activity to dietary specific activities was about 0.7. These specific activities would suggest either that ^{90}Sr was not as available from the diet as stable strontium, or that the skeleton was not yet in equilibrium with ^{90}Sr in comparison to stable strontium.

Mean observed ratios (O.R.) in infants have been found to be about 0.6. Mean O.R.s were 0.4 in 6-year-olds and 0.3 in 9-year-olds. This may indicate a trend downward toward the O.R. of 0.25 which has been found in most adult studies.

DISCUSSION

C. A. Adams (*U.K.*):

The solution in the form of the sum of three exponentials implies that the transfer between one compartment and the next is proportional to the amount of substance available in the first compartment. It is possible that other assumptions could give the same solution as an approximation. It would be of interest to know what assumptions were made.

A further question arises in connection with the dependence of the transfer rates on the amount of the available substance, if this amount is very greatly increased. Where blocking action is possible the implication is that the transfer rates can be reduced. It would be interesting to know if the authors have undertaken this analysis which I have carried out for a particular three compartment model. The solution is, however, dependent on the range of numerical values of some of the constants.

M. L. Shore:

The model investigated represents a steady state system which follows first order kinetics relative to the tracer substance or radionuclide. The amount of tracer moving out of a compartment is determined by the constant amount of unlabeled compound moving out of the compartment per unit time, and constitutes a constant percentage of the total amount of compartmental radionuclide per unit time. In the strictest sense the triexponential equations presented apply only to the steady state systems. More practically, however, they can be used in those instances where systems approximate the steady state. Where very gross deviations from steady state occur, non-steady state kinetic equations must be derived. These are considerably more complex and may present a formidable problem to the mathematician. In the experiments described above it is assumed that a negligible amount of compound is injected as the radioactive tracer. Thus no alterations occur in the normal steady state metabolic dynamics of the system.

G. Joyet (*Switzerland*):

1. Je voudrais souligner l'importance considérable que représente pour le diagnostic l'adoption d'un schéma de compartiments, à la condition toutefois, que celui-ci soit adéquat. L'établissement du schéma et son contrôle expérimental demandent un travail préliminaire considérable. Mais quand le schéma est bien établi, le nombre des mesures peut être considérablement réduit.

2. Il faut remarquer que la loi de proportionnalité du passage d'un compartiment à l'autre ne s'applique plus au cas de certains compartiments tissulaires comme la thyroïde pour l'iode et la masse osseuse pour les os.

A. Lafontaine (*Belgium*):

J'ai été particulièrement intéressé par l'excellente communication de M. Thompson. Je me permet de lui poser deux questions tout en étant convaincu que la réponse apparaitra dans le texte intégral.

1. Sous quelle forme le Ca et le Sr ont ils été administrés et par quelle voie?

2. A-t-il été tenu compte des ions P et Mg dans le régime?

R. C. Thompson:

The details concerning which Dr. Lafontaine questioned will appear in the published version. Sr^{90} and Ca^{45} were injected intraperitoneally as the chlorides at approximately physiological pH. Phosphorus was present in all diets at a level of 0.5%, therefore the Ca/P ratio varied between diets. Mg was present at a constant level in all diets.

H. N. Wellman (*U.S.A.*):

I was wondering about the second component in the Sr curves; I don't believe it will resolve itself in such a clear exponential if you followed them much longer. At least in the children and the adults we are following, this is the case, and this has been previously reported by Cohn, also, and he had made a curve specifically. Anyway, after that first exponential it seems to be a constantly changing curve to which one could relate a single exponential, as it could be seen in our children and in our dogs. The second point I would like to comment on, the Ca curves clearly have different exponentials than the Sr curves, which is very interesting. I would like also to comment that our Ca curves versus Sr curves, in patients in which we have done both Ca^{47} and Sr^{85} studies simultaneously, are similar. There seem to be three, sometimes four, clearly visible exponentials for the Ca curves vs.

the one early exponential in the Sr curve and they are constantly changing their curves thereafter.

R. B. Holtzman (*U.S.A.*):

Would Drs. Thompson and Wellman care to comment on the possibility of the power function fitting the data and the significance thereof? There is some evidence and a school of thought that the power function does have a significance similar to that of the exponential which represents a first order reaction kinetics. The power function represents n-th order kinetics. Other explanations of the significance of the power function are possible. [*Note added*: The power function is particularly useful in health physics in that if retention does fit this function it is easier from a measurement at a certain time to estimate the initial and subsequent dose rates. Unless a single exponential applies or the exacting details of the multiple exponential representation are known, retention estimates are more difficult than with a single power function.]

R. C. Thompson:

In response to the question concerning the use of "power function" vs. "exponential function" to describe data, I think it is important to keep in mind that the data represent neither a power function nor an exponential function, but, rather, a biological function. How we may choose to represent this biological function mathematically is purely a matter of expediency. For some purposes an exponential function may serve best; for other purposes a power function may be preferable. In this report I was not concerned with precise representation of the data, but rather with pointing out the marked differences between the observations on mature and growing animals, and this was more effectively accomplished by an exponential approach.

H. N. Wellman (*U.S.A.*):

I think I have to say much the same. I think that the power function is just a description of the curve; it really does not tell us anything biological. It is not a mathematical construction like the exponential which helps us in the kinetical analysis. It is just a mathematical description of the curve. I don't think it can help us.

R. C. Thompson:

What I want to say is that there are a few, perhaps, good ideas about what the power function does mean. It does have some significance which is close to that of the exponential, that is, an exponential represents a first order chemical kinetic reaction, while a power function represents one possibility of a changing order of a chemical kinetic reaction. All of this is rather a wild thing with respect to this particular system.

[*Note*: The discussion is interrupted by the Chairman, who invites the speakers to continue their discussion during the interval.]

H. N. Wellman (*U.S.A.*):

The abstract we presented represents the work on six children; we subsequently had data on nine more children and this is a continuing study and we will try to get at least ten children of various ages.

If anyone would like to look at detailed data, I have them with me.

R. J. Della Rosa (*U.S.A.*):

The work on beagles (University of California, Davis, California) following long term ingestion of Sr^{90} starting *in utero* suggests that at 3 years—following acquisition of body burden—both the power function model or a series of exponential functions can be used to describe the whole body (skeletal) retention of Sr^{90}. Continued follow-up in these animals (years) may shed further light on which of these two mathematical models can better describe the biology.