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TRITIUM HAZARD VIA THE INGESTION PATHWAY*

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ABSTRACT

The classic methodology for estimating dose to man from environmental tritium ignores the fact that organically bound tritium in foodstuffs may be directly assimilated in the bound compartment of tissues without previous oxidation. We propose a four-compartment model that allows for the ability to input organically bound tritium in foodstuffs directly into the organic compartments of the model. We found that organically bound tritium in foodstuffs can increase the total body dose by a factor of 1.7 - 4.5 times the free body water dose alone, depending on the bound to loose ratio of tritium in the diet.

INTRODUCTION

Various models have been proposed to describe the kinetics of tritium in the human body. The most widely accepted of these is Bennett's three compartment model[1] which has been adated by the National Council on Radiation Protection (NCRP)[2]. The NCRP model assumes that all ingested tritium, whether organically bound or free, enters directly into the free body water compartment. On the basis of predictions made by this model, the NCRP indicates that organic binding of tritium in the body may be adequately accounted for by multiplying the free body water dose by a factor of 1.2.

Tritium models currently sanctioned by national or international radiation protection committees ignore the fact that organically bound tritium in foodstuffs may be directly assimilated in the bound compartments of body tissue without previous oxidation. We propose a four-compartment model[3,4] that has explicit representation for tritium bound in the organic constituents of food. Our model consists of a free body water compartment, two organic compartments, and a small rapidly metabolizing compartment. Model parameters (transfer rates and compartment masses) were selected so that the response to a pulse of tritiated water input directly into the water compartment would duplicate the tritium retention data reported by Snyder et al.,[5] and Sanders and Reinig[6]. The utility of this model lies in the ability to input organically bound tritium in foodstuffs directly into the organic compartments of the model. The purpose of this paper is to discuss the dosimetric implications of our four-compartment model and to present a preliminary validation using measurements of background levels of loose and bound tritium in Italian subjects and their diets.

DOSIMETRY

Our primary purpose in developing a compartmental model of hydrogen metabolism was to obtain better indications of the dosimetric consequences of human exposure to organically bound tritium. To answer this question, we input a single tritium pulse of 1μ Ci/kg into both Bennett's model and our four-compartment model. Using Bennett's model, cumulative total body dose in μ Ci days/kg after 2000 days is 20.33. As should be the case, this is approximately 1.2 times the dose from the free body water compartment alone (16.49 μ Ci days/kg). Our four-

compartment model, which allows for input of organically bound tritium directly into the compartments representing tissue solids, yields a cumulative dose after 2000 days of 29.5 μ Ci days/kg, a factor of 1.7 times the dose contributed by the free body water compartment.

In estimating body burdens, the ratio (R) of total bound to total loose tritium (including drinking water) ingested daily by an individual is an important quantity. Under equilibrium conditions, R for total ingested tritium is low (R=0.15) since the average human diet is composed of much more loose than bound hydrogen (and consequently tritium). However, R has been estimated to be as high as 8.9 for the diets of actual subjects? Figure 1 shows the ratio of total body dose to free body water dose after 2000 days (as predicted by the four-compartment model) as a function of ratio R. For a hypothetical diet in which the total intake of bound tritium is ten times larger than the total intake of loose tritium (R=10), cumulative total body dose after 2000 days would be a factor of 4.5 times higher than the dose to free body water alone.

VALIDATION OF FREE BODY WATER COMPARTMENT

Belloni et al.[7] summarized the findings of a study on background tritium content in the Italian diet and its transfer to man. Daily dietary intake and excretion of tritium were measured for seven health subjects. Bound to loose tritium ratios measured in individual food items of the Italian diet ranged from 2.3 for flour to 48.1 for meat. These measurements are contrary to the commonly held assumption that bound to loose ratios in food items under background conditions should

be one (2,7). Bogen et al.[8] have also measured bound to loose ratios in food items in a New York diet and found them to range fromm 1.2 through 5.6. The ratio (R) of dietary tritium in the seven Italian diets was found to range from 0.5 - 8.9.

Daily intake of loose tritium for each of the seven subjects was based on estimated tritium concentrations in surface water (400 pCi/L), while daily intake of bound tritium was obtained by multiplying total intake of loose tritium by the measured value of R for each subject. Model predictions were used to estimate the concentration of tritium in the body water compartment of each of the seven subjects. The concentration of tritium in urine is assumed to be similar to that of the body water. Table 1 lists the measured concentration in urine for each of the seven snbjects, and the values predicted by our four-compartment model and the NCRP model (2). It can be seen that predictions of both models are very close to the measured value of 1.59 pCi/g.

VALIDATION OF ORGANIC COMPARTMENTS

Recently, Belloni et al.[9] have presented a summmary of data on tritium content of the diet and human tissues from a sample of the Italian population. Using the daily intake of loose and bound tritium from the Italians as input into our four-compartment model, we predict the average body burdens of loose and bound tritium at equilibrium to be 57,000 pCi and 91,000 pCi, respectively. This compares with the Belloni et al.,[10] estimate of 62,000 pCi and 93,960 pCi, respectively. Our model predicts a tissue concentration of 1.54 pCi/g compared to a

measured value of 1.59 pCi/g.

The NCRP model as it is now structured (inputting both loose and bound tritium into the free body water compartment) will not reproduce the concentration of tritium in the bound compartments as reported in the Italian study (the NCRP model predicts tissue concentrations of 0.15 pCi/g, a factor of 10 too low). These data support our claim that by not explicitly accounting for organically bound tritium in food, the NCRP methodology can underestimate cumulative dose from tritium.

CONCLUSION

Under conditions of exposure to tritiated water, organically bound tritium in the human body contributes little to cumulative dose. To account for this metabolic incorporation of loose tritium into human tissues, it is currently suggested that cumulative dose estimates be multiplied by a factor of 1.2. However, if exposure is through tritium bound in food, the cummulative dose from organically bound tritium in the body may be large, and must be considered separately. We found that organically bound tritium in foodstuffs can increase cumulative total body dose by a factor of 1.7 - 4.5 times the free body water dose alone, as the total intake of bound tritium to the total intake of loose tritium ranges from 0.15 (environmental equilibrium conditions) to 10.

Given the potential importance of tritium in both fission and fusion nuclear field cycles, we stress the need for further research on uptake of organically bound tritium. This research should emphasize both human metabolism and microdosimetry of organically bound tritium.

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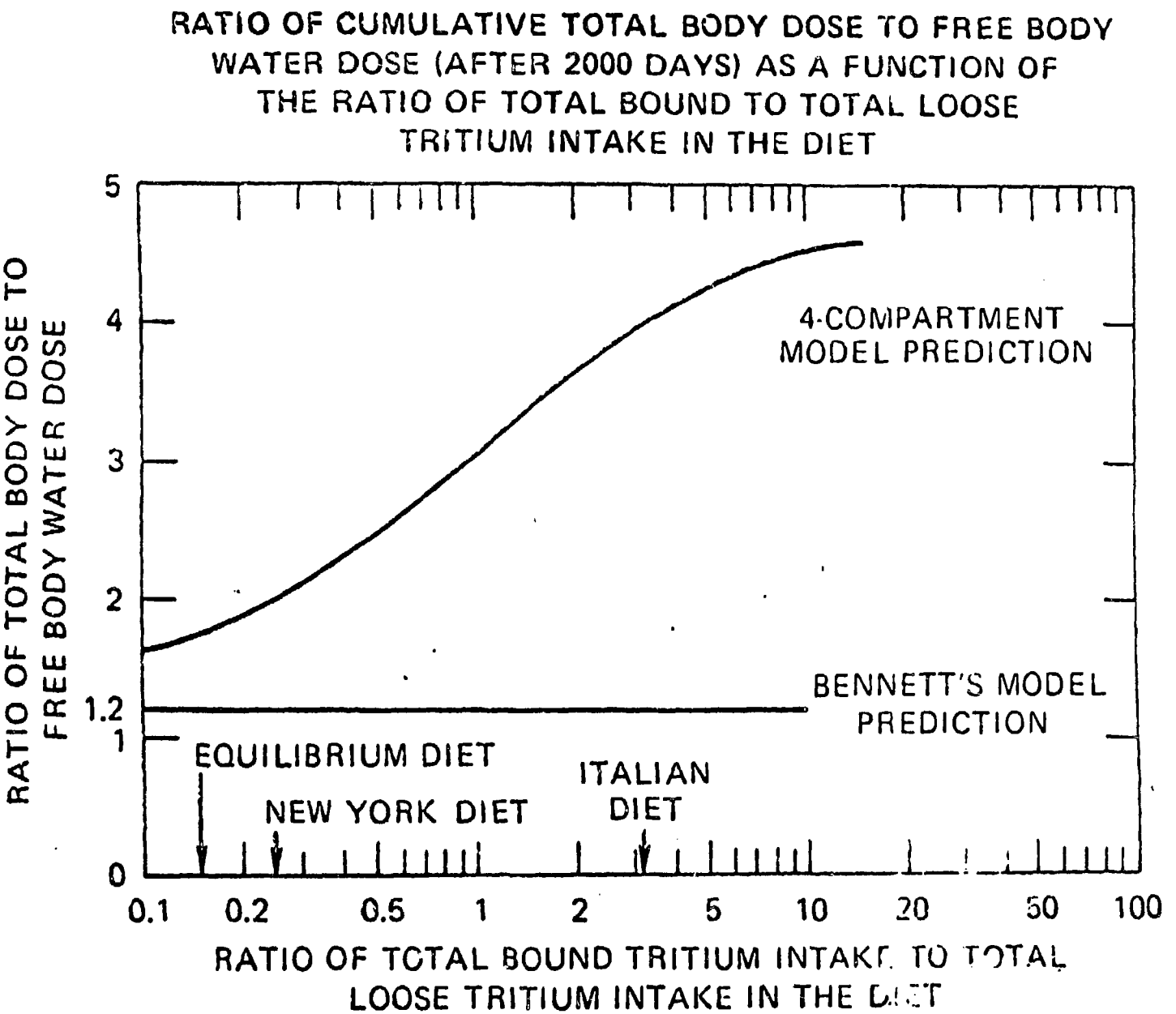

Table 1. Comparison of measured to predicted urine concentration for seven Italian subjects

Subject	Urine concentration (pCi/mL)		
	Measured values[a]	Four-Compartment model prediction[b]	NCRP Model prediction[c]
1	1.4	1.4	1.4
2	0.7	0.6	0.6
3	1.8	1.5	1.5
4	0.7	2.7	2.7
5	1.9	0.3	0.3
6	0.5	0.5	0.5
7	0.9	1.0	1

[a]From footnote 1.

[b]Based on computer runs using model in Ref. 3.

[c]Based on computer runs using model in Ref. 2.