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THE ABSORPTION OF INGESTED TRITIUM WATER AND THE WATER DILUTION VOLUME OF MAN

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Work done by:
Ernest A. Pinson
Ernest C. Anderson
Virginia Lotz

Report written by:
Ernest A. Pinson

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ABSTRACT

Tritium activity in venous blood of humans increased linearly with time after the ingestion of HTO. This increase in activity began 2 to 9 min following ingestion and reached a maximum in about 40 to 45 min. The rate of appearance of tritium in the blood was essentially the same when the HTO was ingested in 100 ml of water or in 1000 ml of water. These studies suggested that water absorption from the gastrointestinal tract began 2 to 9 min after ingestion. They also suggested that the volume of water transferred from the gastrointestinal tract to the blood, by absorption or exchange was linear with time after ingestion and was proportional to the volume of water ingested within the range of 100 to 1000 ml. The time required for the complete absorption of 100 to 1000 ml of water from the gut was 40 to 45 min.

After reaching a maximum in about 45 min the activity in venous blood usually declined slowly until equilibrium was reached at about 2-1/2 hours. From the equilibrium activity measured at 2-1/2 hours it was possible to determine the dilution volume for HTO in the body. The body dilution volume ranged from 57.6 to 67.3 per cent of the body weight in five experiments on three men. The average of all determinations was 62.2 per cent.

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1. INTRODUCTION

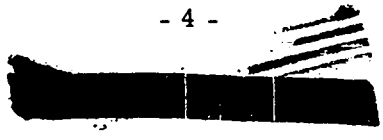
Experiments on the absorption of ingested HTO were undertaken for the primary purpose of determining the volume with which tritium water appears to be diluted in the human body and to provide additional information on the radiation hazard associated with its ingestion. These data may be used in subsequent experiments to determine the quantity of HTO absorbed through the skin and lungs by measuring the increase in activity in body fluids and multiplying by the dilution volume determined from the ingestion experiments. The results obtained for HTO absorption through the skin and lungs will be presented in a subsequent report. In addition to serving the primary purposes mentioned above, these experiments give interesting information regarding the rate of appearance of HTO activity in the blood and urine and the length of time required to establish essential equilibration of HTO in body fluids following its ingestion in various volumes of water.

2. METHODS

Volumes of water ranging from 100 to 1000 ml and containing measured amounts of tritium as HTO were ingested by male human subjects. The experiments were always started at about 9 a.m. The subjects were instructed not to eat or drink just prior to and during the experiment. The tritium water was warmed to 37°C before ingestion. Less than 15 sec was required to ingest the 100 and 200 ml volumes, and about 3 min was required to ingest the 1000 ml volume. Subjects were clothed and at normal room temperature of about 25°C throughout the experiment.

Samples of venous blood taken from the anticubital vein, and urine samples were collected just prior to the ingestion and at intervals for 2-1/2 to 5 hr following the ingestion. Water from the venous blood and from the urine samples was obtained by complete distillation in vacuo and was analyzed for tritium activity by the method previously described.[1] An aliquot of the ingested water was diluted and analyzed for HTO activity by the same method.

The nude body weights of the subjects were obtained at the end of the experiment and recorded to the nearest 0.1 kg.



3. RESULTS

Following ingestion of HTO water, the tritium activity in venous blood rose steeply for a period of 30 to 40 min. The rate of increase was linear with time during this period. A maximum activity in venous blood was reached in about 40 to 45 min, after which the activity usually declined slowly until essential equilibrium in all body fluids was attained in about 2 to 2-1/2 hr. Beyond 2-1/2 hr no further decline occurred as far as could be ascertained by the sensitivity of the analytical method employed (Figs. 1 and 2). Activity in the urine followed closely the activity in venous blood during the later part of the experiment, i.e., at times of 1 hr and longer after ingestion. Between 30 min and 1 hr after ingestion the activity measured in urine averaged about 3 to 5 per cent higher than that in the venous blood in all experiments.

Figure 2 shows the change in activity in venous blood with time for five experiments on three subjects in which the HTO activity was ingested in different volumes of water varying from 100 to 1000 ml. These data show that the initial slope of the curve and the time required to reach maximal activity was about the same whether the activity was ingested in 100 or 1000 ml of water. This observation suggests that the amount of water transferred from the gastrointestinal tract to the blood per unit time is proportional to the amount of water ingested and that the time required for complete absorption, or more precisely complete equilibration, of ingested water with the blood is about 40 to 45 min and is independent of the volume of water ingested in the range of 100 to 1000 ml.

When the curves are extrapolated to the abscissa (Fig. 2), it appears that tritium activity in the venous blood does not begin to increase until 2 to 9 min after ingestion of the HTO water. It may be that this is the length of time required for the water to move from the stomach to the intestinal tract.

It was observed by others[2] that when 450 ml of water containing 45 ml of deuterium oxide was ingested, deuterium water began to appear in venous blood 7 min after ingestion, and absorption or equilibration of the D_2O was completed in 40 min.

In Table I are shown the data from which the dilution volume for HTO in the body of each subject was calculated. Since no change in HTO activity in venous blood and urine could be detected beyond 2-1/2 hr (within the limits of the analytical methods used) the activity measured at 2-1/2 hr was assumed to be the equilibrium value. The calculated dilution volume given in the table was derived by dividing the activity (in microcuries) of HTO ingested by the equilibrium activity in the body fluids. The body dilution volume was calculated by subtracting the water volume ingested from the calculated dilution volume.

In the last column of Table I it may be noted that the percentage of body weight appearing as a dilution volume for HTO ranged from 57.6 to 67.3 per cent, with an average of 62.2 per cent. Schloerb, et al.[3] found an average value of 61.8 per cent on 17 normal male subjects, using deuterium oxide as a tracer. These figures probably include body water plus rapidly exchangeable hydrogen atoms in organic constituents. It has been estimated that the rapidly exchangeable hydrogen atoms in organic constituents may account for a dilution effect equivalent to 1 to 2 per cent of the body weight if considered as water.[4]

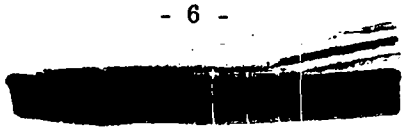
One subject had a weight loss of 7.9 kg between the first experiment and two subsequent experiments shown in Table I. For this weight loss there was a loss of only 1.6 liters (average) in calculated body dilution volume. If the weight loss is presumed to be due to loss of fat and the water contained therein, it becomes possible to calculate the percentage water in the fat lost as follows: $\frac{1.6}{7.9} = 20.3$ per cent. Fat obtained from this subject by biopsy was found to contain 19.8 per cent water.

4. SUMMARY

When human subjects ingested water containing HTO, the tritium activity in their venous blood increased linearly with time. This increase in activity began 2 to 9 min following ingestion and reached a maximum in about 40 to 45 min. The rate of uptake in the blood was essentially the same when the HTO was ingested in 100 or 1000 ml of water. It was concluded that water absorption through the gastrointestinal tract began 2 to 9 min after ingestion; and that the volume of water transferred from the gastrointestinal tract to the blood by absorption and exchange was linear with time and was proportional to the volume of water ingested within the range of 100 to 1000 ml. The time required for the absorption or transfer of 100 to 1000 ml of water from the gut to the blood was 40 to 45 min.

After about 45 min the activity in venous blood usually declined slowly until about 2-1/2 hr after ingestion, following which no further change was measurable with the analytical methods employed. The activity measured at 2-1/2 hr was taken as an equilibrium value, and calculations were made of the dilution volume for HTO in the body. The body dilution volume for HTO ranged from 57.6 to 67.3 per cent in five experiments on three men, with an average of 62.2 per cent.

The change in tritium activity in urine with time following ingestion of HTO water roughly paralleled the change in activity in venous blood.



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3. P. R. Schloerb, B. J. Friis-Hansen, I. S. Edelman, A. K. Solomon and F. D. Moore, J. Clin. Invest. 29: 1296 (1950).
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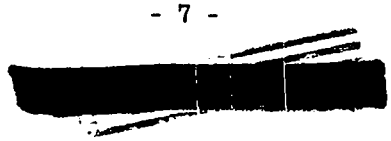

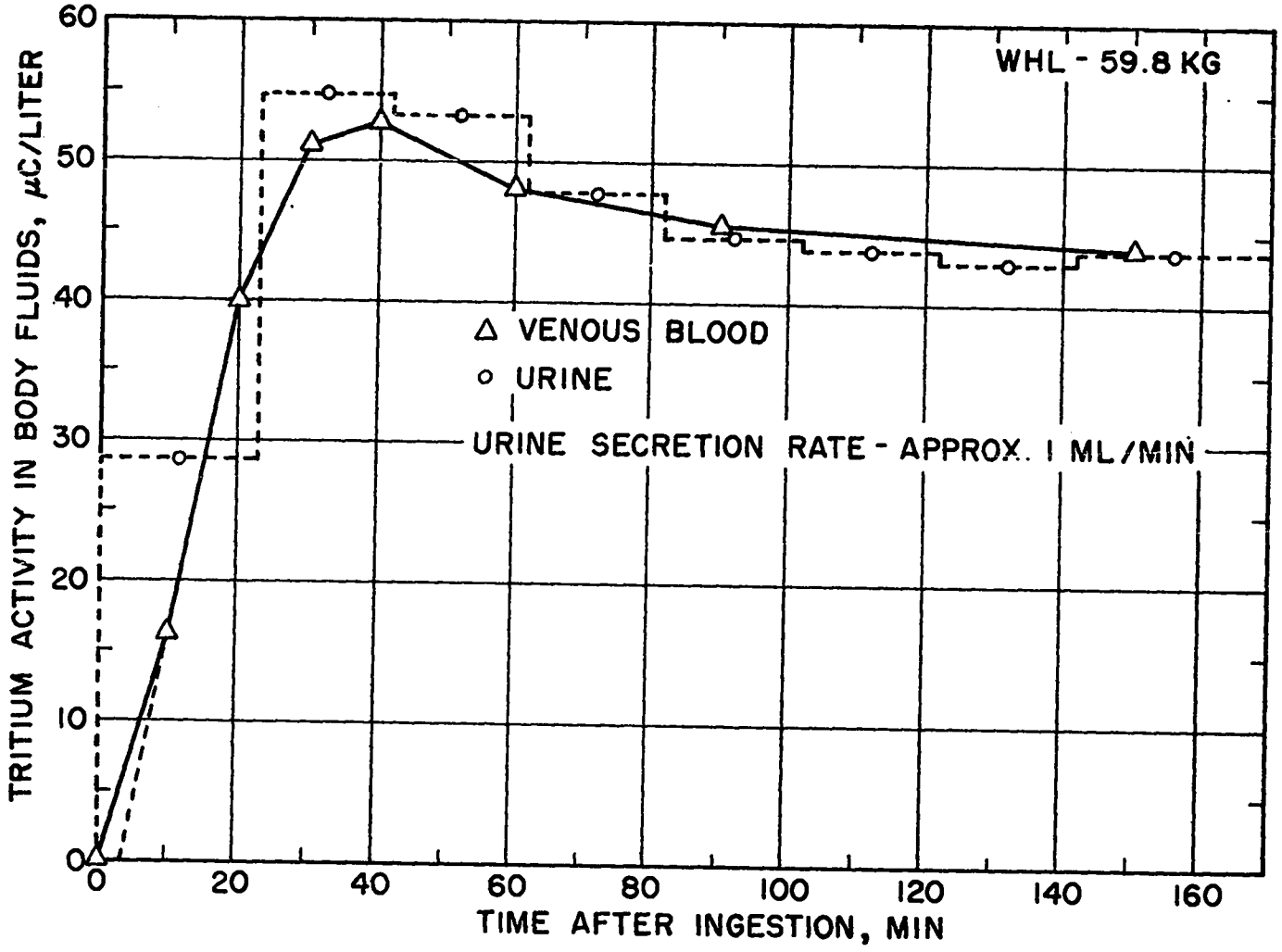

Fig. 1. Tritium activity in venous blood and in urine versus time after ingestion of 1640 μc of HTO in 100 ml of water.

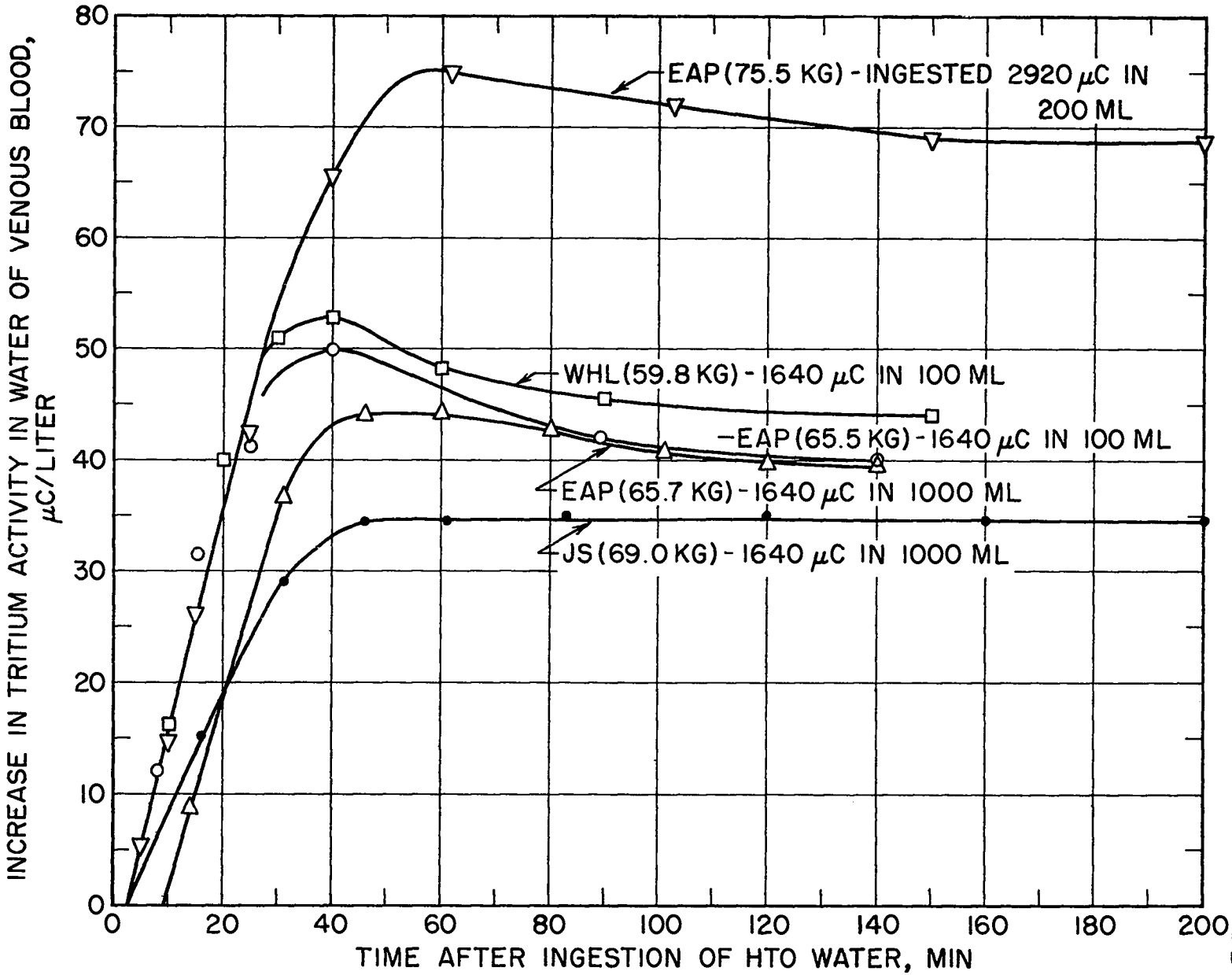

Fig. 2. Effect of volume of water ingested and time after ingestion on tritium activity in venous blood.

Table I

DILUTION OF INGESTED TRITIUM WATER IN THE BODY OF MAN

Subject	Body Weight, kg	HTO Ingested, μc	Volume Ingested, ml	Equilibrium Activity in Body Fluids,[a] μc/liter	Calculated Dilution Volume, liters	Body Dilution Volume, liters	Body Dilution Volume, per cent body wt
EAP	73.5	2920	200	68.7	42.5	42.3	57.6
EAP	65.5	1640	100	40.1	40.9	40.8	62.3
EAP	65.7	1640	1000	39.5	41.6	40.6	61.8
WHL	59.8	1640	100	44.0	37.3	37.2	62.2
JS	69.0	1640	1000	34.6	47.4	46.4	67.3

[a]The equilibrium value used is that activity prevailing in the water of venous blood 2-1/2 hr after ingestion.

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