Tritium Metabolism in the Human Body

Tsuyoshi MASUDA, Kensaku MATSUSHITA, Yasuhiro TAKO, Shun'ichi HISAMATSU
Department of Radioecology

Abstract

In the radiation safety assessment for nuclear facilities including the first commercial spent nuclear fuel reprocessing plant in Rokkasho, Japan, the internal radiation dose of the public due to tritium has been estimated using the dose conversion factors based on the ICRP metabolic model of hydrogen in the human body. The ICRP metabolic model is very simple and is comprised of a free water tritium (FWT) compartment and an organically bound tritium (OBT) compartment having biological half-lives of 10 and 40 d, respectively.

Although the biological half-life of tritium water (HTO) in the human body was examined in several cases such as accidental intakes or experimental administrations, actual data on the metabolism of OBT are quite limited. The objective of this research program is to establish experimentally the metabolism of tritium including OBT in the human body for more realistic dose estimation. In the experiment, the stable isotope of hydrogen, deuterium (D), was used as a substitute for tritium.

In FY 2012, volunteers were administered with 4 g of D-labeled palmitic acid (1 g each in each of four daily lunches consumed); then their urine and breath samples were collected up to 16 weeks after the first administration, and analyzed with a mass spectrometer to get the isotopic ratios of D/H. All procedures of the experiment were approved by the IES Review Board for Human Subject Experiments, and written informed consents were obtained from all volunteers. The D isotopic ratios in the urine and breath samples increased after each administration, and then decreased. The urine data obtained were used to construct a compartment model of metabolism of D ingested as palmitic acid. The model had a compartment of free water D (FWD) and two compartments of organically bound D (OBD_1 and OBD_2), and those compartments were connected to each other in series. The transfer rate constants between those compartments and the excreting rate constant from the FWD compartment were determined by a least square fitting method using measured data. The excreting rate constant of D from the FWD compartment was 7.5×10^{-2} d^{-1} which was comparable with that of the ICRP metabolic model, 7.1×10^{-2} d^{-1}. Transfer from the OBD_1 to the OBD_2 compartment was rapid with a rate constant of 24 d^{-1}, while the degradation rate constant from the OBD_1 to the FWD compartment was 1.8 d^{-1}. The OBD_2 compartment had a long mean residence time of >100 d. Retention of D in each compartment calculated by the model showed that most of the administered D remained in the OBD_2 compartment at the end of the experimental period while the D concentrations that remained in the FWD and OBD_1 compartments were 2 and 4 orders of magnitude smaller than that in the OBD_2 compartment.

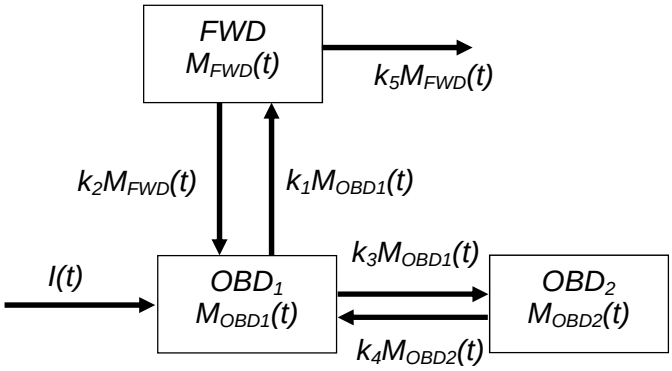

Table 1 Transfer rate constant of D in model

Transfer rate	(d^{-1})
k_1	1.8
k_2	2.6×10^{-5}
k_3	2.4×10^{1}
k_4	7.6×10^{-3}
k_5	7.5×10^{-2}

Fig. 1 Three-compartment model of metabolism of D ingested as palmitic acid

FWD, OBD_1, OBD_2: compartment names, $M_{FWD}(t)$, $M_{OBD1}(t)$, $M_{OBD2}(t)$: D amounts in each compartment (g). k_1 to k_5: transfer rates.

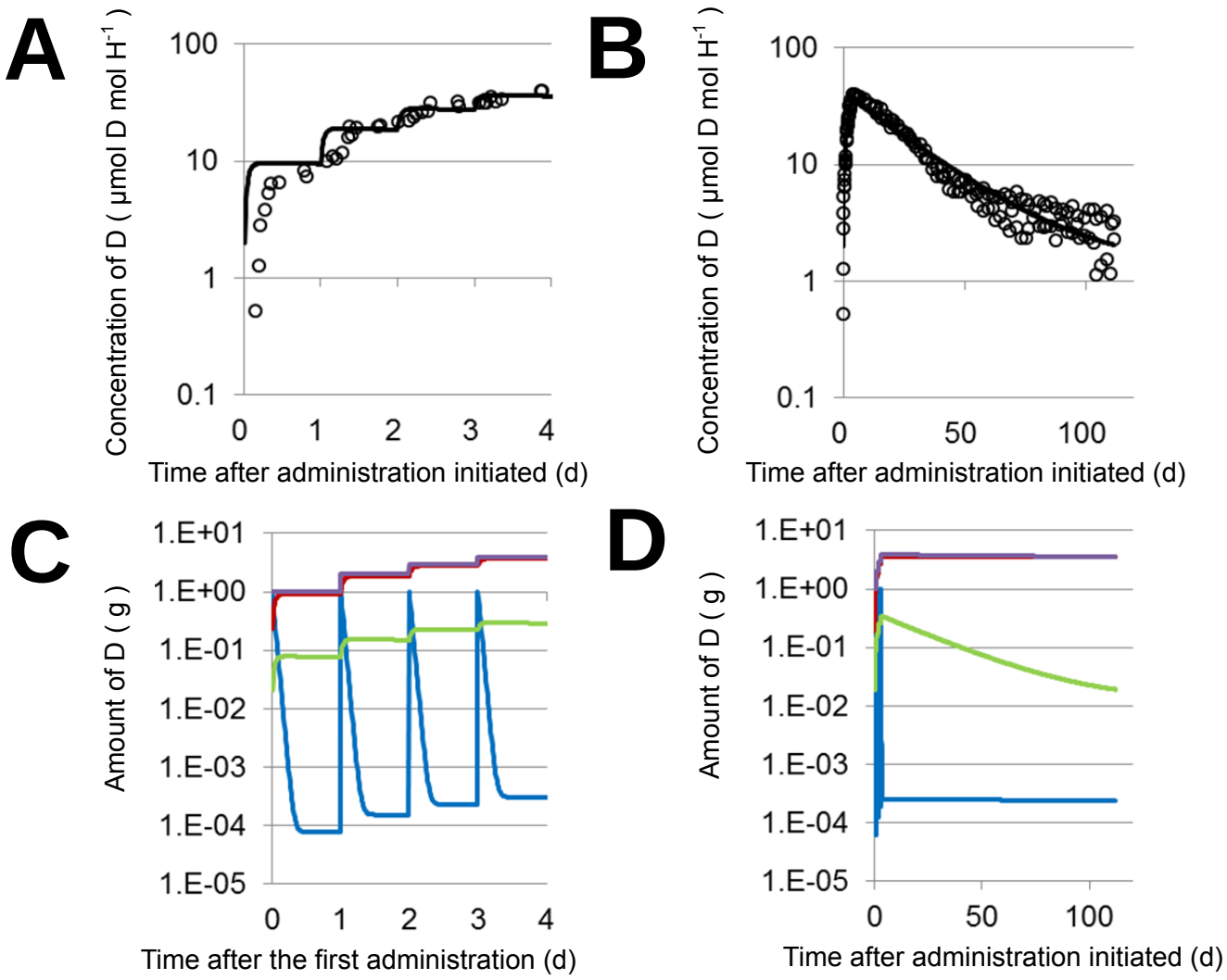

Fig. 2 Estimation of retained D in each compartment of the model

A, B: D concentration in water in urine after D-labeled palmitic acid administration. Solid line: estimated values by the model. C, D: Retained D amount $M_{FWD}(t)$, $M_{OBD1}(t)$, $M_{OBD2}(t)$ (g) in *FWD*, OBD_1, and OBD_2 respectively. Green Green line: $M_{FWD}(t)$, blue line: $M_{OBD1}(t)$, red line: $M_{OBD2}(t)$, purple line: total D retained. A, C: until 4 days after administration initiated. B, D: until 112 days after administration initiated.