The Uptake and Distribution of Cadmium-115m in Calcium Deficient and Zinc Deficient Golden Hamsters

by DAVID W. MILLER, RICHARD J. VETTER, RONALD L. HULLINGER,* and STANLEY M. SHAW

Department of Bionucleonics & Department of Veterinary Anatomy Purdue University, West Lafayette, Ind. 47907*

Cadmium is a toxic, heavy metal capable of causing disfigurement and death when taken into the body in large quantities as was evidenced in the Itai-itai disease in Japan (YAMAGATA and SHIGEMATSU, 1970). Calcium deficiency has been shown to contribute to the development of the Itai-itai disease (YAMAGATA and SHIGEMATSU, 1970). Further, dietary zinc deficiency is important to study since zinc is chemically similar to cadmium and is competitively taken into the ionic pool of the organism. The object of this investigation was to study the effects of normal, calcium deficient and zinc deficient diets upon the uptake and distribution of cadmium-115m in the golden hamster.

EXPERIMENTAL

Three experimental groups composed of 5-week-old weanling golden hamsters[a] were randomly chosen from 8 litters of mixed sexes. Group I was administered a normal diet[b], group II was placed on a calcium deficient diet[c], and group III was provided a zinc deficient diet[c]. Each animal was supplied doubly distilled water ad libitum and was housed in a stainless steel cage.

Twice a week for 5 weeks each hamster received an intraperitoneal injection of cadmium-115m as cadmium chloride in physiological saline. The activity administered per injection was 1.1 uCi/kg body weight. The corresponding total cadmium administered per injection was 6.0 ug/kg body weight. The body weights of the hamsters ranged from 20-60 g during the study. Differential gamma-ray spectroscopy of the cadmium-115m showed no radionuclidic impurities.

After 10 injections, whole body counts were taken using a 25.4 X 28 cm NaI(Tl) crystal with a 10.2 X 20.3 cm well and a single channel analyzer. The counting system was calibrated at 2 keV per channel and set to count the Cd-115m gammas in an energy range from 0.4 to 1.4 MeV. The hamsters were then sacrificed by over-anesthesia and the cpm were determined for liver, kidneys, right femur and the remaining carcass. Radiographs were taken of

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[a] Lakeview Hamster Colony, Newfield, New Jersey, 08344.
[b] Allied Mills Incorporated, Chicago, Illinois.
[c] ICN Nutritional Biochemicals Corporation, Cleveland, Ohio, 44128.

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each hamster carcass to determine the extent of decalcification of the skeletons in each treatment group. The femur, liver and kidneys were sectioned and stained by hematoxylin and eosin stain, Masson's trichrome stain, and Movat's pentachrome stain (LUNA, 1968).

RESULTS AND DISCUSSION

During the course of the study, the average weight change was +27 g for the normal group, -4 g for the calcium deficient group and +20 g for the zinc deficient group. The growth-stunting effect of the calcium deficiency and cadmium toxicity was pronounced. By the 5th week, 3 individuals in the calcium deficient group manifested the calcium deficiency by fractures of the femur shaft. The number of hamsters in each treatment surviving the treatment period was altered due to "wet tail" deaths (HOFFMAN, et al., 1968). Microscopic examination of the histologically stained tissues revealed evidence of fatty deposits in some hepatocytes but it was not consistently found throughout a treatment group.

The mean and standard error for cadmium-115m count rate in each type of tissue are presented in Table 1. The one-way analysis of variance test computed for each of the five sets of data showed a significant difference in cadmium-115m content of the whole body ($P < .01$), kidneys ($P < .01$), and carcass ($P < .05$). The femur and liver showed no significant difference ($P < .05$) for the 3 diets. A Newman-Keuls sequential range test was conducted for each tissue (Table 2). The calcium deficient hamsters retained a significantly higher cadmium-115m count rate in the whole body and carcass than did the zinc deficient and normal hamsters. Cadmium retention in the kidneys of zinc deficient hamsters was found to be significantly lower than in kidneys from normal and calcium deficient animals.

Table 1
Summary of Treatment Means (cpm Cd-115m/g tissue)

Tissue	Normal Diet[a] Means ± Sx	Calcium Deficient[b] Diet Means ± Sx	Zinc Deficient[c] Diet Means ± Sx
Whole Body	1741 ± 123	2540 ± 71	1900 ± 66
Femur[d]	677 ± 61	614 ± 54	565 ± 67
Kidneys[d]	22,412 ± 1825	21,195 ± 705	15,058 ± 560
Liver	17,320 ± 1625	20,369 ± 484	19,111 ± 1113
Carcass	746 ± 85	972 ± 62	672 ± 25

[a] Average of 9 hamsters.
[b] Average of 5 hamsters.
[c] Average of 10 hamsters.
[d] Average net weight for femur and kidneys was 0.3 g and 0.8 g, respectively.

Table 2
Newman-Keuls Sequential Range Test for Treatment Means[a]

Tissue	Diets		
Whole-Body	Normal	-Zn	-Ca
Femur	-Zn	-Ca	Normal
Kidney	-Zn	-Ca	Normal
Liver	Normal	-Zn	-Ca
Carcass	-Zn	Normal	-Ca

[a] The diets are arranged in order of increasing magnitude of the mean Cd-115m count rate for each tissue from left to right. Those underlined are not significantly different from each other ($P < .05$).

The increase in tissue cadmium agrees with the results reported by LARSSON and PISCATOR (1971), who postulated that cadmium follows metabolic pathways analogous to that of calcium in rats. They reported that reduced calcium intake increased the absorption of cadmium, a finding which was supported by the results of this study. However, they did not report the effects of a calcium deficient diet on the cadmium content of bone. If cadmium is absorbed analogous to calcium in soft tissue, an increase in cadmium content would also be expected in bone during calcium deficiency and exposure to cadmium. The results of this study clearly show no increase in cadmium content of bone during a severe calcium deficiency. SUZUKI et al. (1972) showed that bones of pregnant mice retained less cadmium than those of non-pregnant mice. While a calcium deficiency or period of high calcium demand may increase toxic effects of cadmium exposure and decrease calcium content of bones, these conditions apparently do not result in increased cadmium content of bone.

Hamsters provided with a zinc deficient diet retained less cadmium in the kidneys. A trend was noted toward increased retention of cadmium by the whole body and liver of these animals which may explain the relative decrease by the kidneys. Cadmium may have replaced zinc in the liver and other sites where zinc would normally be found, thus resulting in less cadmium being available for transport to the kidneys. In addition, a reduction in zinc intake may have resulted in decreased metallothionien production, thus reducing transport of zinc and cadmium to the kidneys. Examination of the replacement of zinc by cadmium in the liver and pancreas and investigation of zinc deficiency effects on metallothionien levels may help explain the decrease in kidney cadmium seen in this investigation.

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