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MEDICAL APPLICATION OF NEUTRON CAPTURE γ-RAY SPECTROSCOPY: MEASUREMENT OF CADMIUM AND NITROGEN IN LIVING HUMAN SUBJECTS

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A significant environmental-medical problem is the internal deposition of cadmium in man. Cadmium is absorbed by human beings via inhalation of poluted air or ingestion of contaminated food and water. Absorbed cadmium is concentrated in the liver and kidneys. The "Standard American Man" has been reported to contain approximately 30-50 mg of Cd in the whole body of which about one-half is in the kidneys and the liver together. The small quantity of cadmium found in the human newborn (<1μg) as contrasted with the accumulation with age lead to the hypothesis that certain chronic diseases could be the result of Cd toxicity. Cd has been suggested as a possible causative agent of hypertension, emphysema, renal disfunction and osteomalacia. In-vivo measure of the liver and kidney Cd provides a direct index of Cd exposure and can help in the determination of dose-effect relationships.

Nitrogen unlike cadmium is central to the structure of living matter. It is not only present in all amino-acids which form the structural and fundamental proteins of the body, but it is also present in such important biological molecules as for example the DNA of the cell nucleus. A simple knowledge of nitrogen balance or alternatively of changes in body nitrogen is important in medicine. A common observation in illness is loss of weight. But quantitation of weight loss is not sufficient to describe events. A knowledge of which tissues have lost weight and what elements have been lost (or gained) is also very important. If a particular diet produces weight gain, an increase in fat rather than more useful tissue may be occuring. Nitrogen is a constituent of

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tissue protein chiefly in the form of muscle, collagen and bone. Thus changes in body nitrogen content under various clinical conditions will reflect changes in body protein. This is of particular interest in such conditions as cancer, muscular dystrophy, malnutrition, liver and kidney disease and long term haemodialysis.

a) Kidney and Liver Cd. In-vivo measurement of small quantities of Cd is possible due to the high radiative neutron-capture cross-section of ^{113}Cd (12.3%, 20000 b). Under slow neutron capture in ^{113}Cd, the excited ^{114}Cd decays by prompt emission of cascade of gamma-rays of which the most intense is the 559 keV transition from the first excited state to the ground state. A schematic representation of the irradiation and detection facility is shown in Fig. 1. An 85 Curie ^{238}Pu-Be isotopic neutron source is housed in a collimator made of epoxy resin heavily doped with Li compounds. The collimator is designed to provide a rectangular neutron beam 13 x 20 cm at the level of the bed situated 50 cm above the source. The gamma ray detection system consists of two Ge(Li) detectors having a total active volume of 193 cc.

For a total kidney or liver dose of 670 mrem, the detection limits are 2.5 mg or 1.5 µg/g respectively. Table 1 shows the results of a study on normal subjects with smoking and non-smoking history. The study indicates higher cadmium levels in the group of smokers.

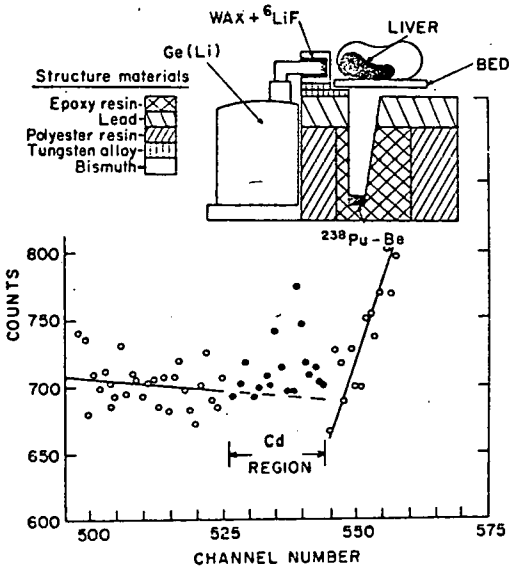

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Fig. 1

Cd facility and a representative spectrum for the left kidney of a normal 52 year-old male. The Cd peak represents 4.0 ± 2.5 mg Cd.

Table 1.

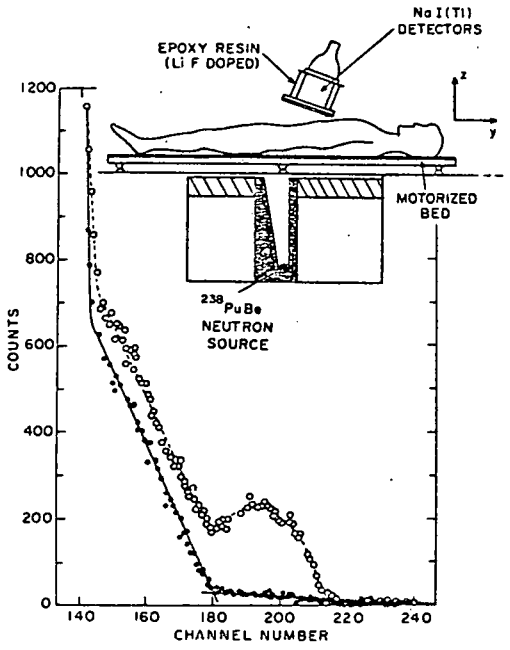
Subjects	N	Liver* (μg/g)	Kidney* (mg)	Renal Cd / Hepatic Cd
Smokers	12	4.1(1.6)	5.8(1.7)	10.6
Non-Smokers	8	2.3(1.6)	3.1(2.0)	11.3
P		0.05	0.02	N.S.

*Geometric mean (Standard Deviation)

b) Total Body Nitrogen. The method of measuring body N utilizes the $^{14}N(n,\gamma)\ ^{15}N$ reaction. The total energy available on slow neutron capture is 10.83 MeV and approximately 15% of the de-excitations take place directly to the ground state of ^{15}N. The irradiation facility (Fig. 2) is basically the same as that described in section (a) for measurement of Cd. The Cd collimator, however is replaced by a second collimator designed to provide a wide beam 13 x 60 cm at the level of the bed. During the irradiation the subject lies on a motorized bed which moves across the neutron beam. Two 15.2 x 15.2 cm NaI(Tl) detectors are located above the subject just outside the direct neutron beam. The precision or reproducibility of the measurements was performed using an Alderson phantom. For a standard 70 kg man having 2000 g of N, the accuracy of the measurement is ± 2% with an error of 1.3% for reproducibility, based on several measurements over a 6-month period. The total radiation dose for a bilateral irradiation is 45 mrem. Initial clinical studies will concentrate on sequential measurements of body N.

Fig. 2

N facility and spectra from an Alderson man-like phantom containing tissue equivalent liquid and N free liquid.



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