≪特別講演≫

2. Whole-Body Counter in Medical Research

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During the past decade, the whole-body counter has evolved as a highly developed, practical system for measuring with accuracy and precision body burdens of internally-deposited gamma-emitting radionuclides. Numerous applications for this system have been made in the field of medical research and diagnosis. There are three basic counting systems based on differing detectors and geometries: the single crystal detector, the multicrystal detector and the liquid scintillation counter. Of these, the most widely used system employs a single fixed crystal (8″×4″) with "standard-chair" geometry, in a shield of 6″ of steel.

Whole-body counting systems require that a high signal-to-noise ratio be attained for the detection of low levels of in-vivo activity. This ratio depends on the performance of each of the components in the system: the detector, the electronics, the shielding and the patient-detector geometry. Each of these is discussed in some detail. The minimum detectable activity under standard counting conditions for a single NaI detector systems is approximately 1 mμc.

The advantages of whole-body counting are multiple: the speed of the operation; the accuracy and reproducibility of the measurements; the very low levels of isotopes necessary to make measurements over a long period of time, thus giving negligible radiation exposure to the patients; the ease with which measurements are made, thus involving no discomfort to the patient, since no samples or specimens need be taken; the ease with which the output data can be transferred to computers, thus permitting high speed recording and analysis of large quantities of data. Because the whole-body counter has high energy resolution, multiple tracer experiments may readily be conducted. A very important advantage of the whole-body counter is that each measurement is independent, whereas the method requiring the analysis of urine samples is susceptible to cumulative errors, a factor of particular importance in long-term studies.

The chief problem encountered in the application of these counters is the calibration problem resulting from the effect of patient-detector geometry on the counting efficiency. The efficiency varies as a function of localized concentration of radionuclides and changing distributions of the isotope. The calibration problem is most noticeable directly following oral administration of an isotope, before an equilibrium distribution is obtained. Thus, in general, it is less satisfactory to carry out short-term studies than it is to carry out long-term studies in which the early changes are less important, and retention can be normalized at some time following administration of the isotope. For the same reason, measurement of absolute values are more difficult than relative measurements of the percentage of retained values. These difficulties can be overcome to a large extent with the multiple-detector system. Recent developments of the more complicated multiple-detector systems make their application more feasible for routine studies, particularly short-term studies and those involving absolute measurements.

From the large number of studies carried out to date, a representative selection was made to illustrate the unique opportunities afforded by whole-body counting, its limiations and potentialities for future studies. The studies fall into two general groups: those in which absolute levels of radioactivity are measured, and those in which the relative percentage of administered activity is measured. In the first group are studies determining body burdens of radium, thorium, (Fig. 1) uranium and plutonium, and certain isotopes from radioactive fallout. In these applications, the

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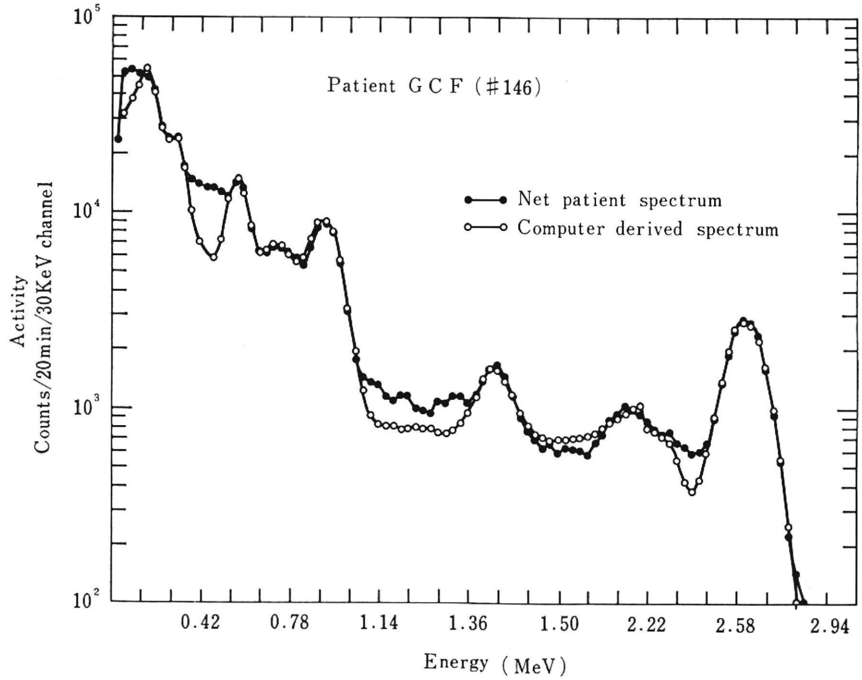

Fig. 1 Gamma spectrum of thorotrast patient compared with computer-derived spectrum.

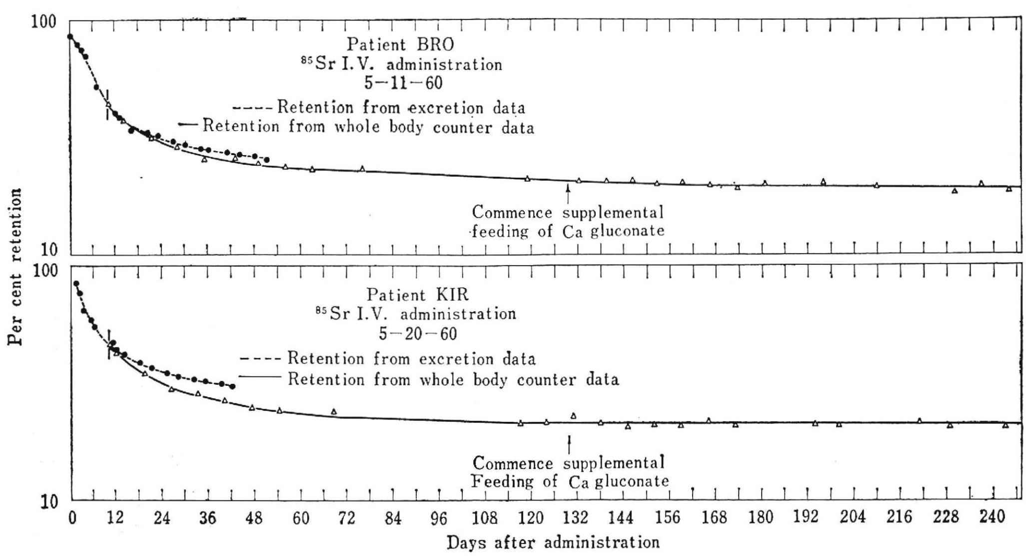

Fig. 2 The long-term retention of intravenously administered ^{85}Sr. ●=retention from excretion data. △, ○=retention from whole-body counting data.

whole-body counter is used either for diagnosis of radioactive poisoning, or for monitoring populations whose body burdens have been increased somewhat by exposure to a more radioactive environment. In addition, the counter has been used to monitor patients exposed to thermal neutrons accidentally or in the course of neutron capture therapy.

In the majority of clinical applications, in which the metabolism of the patient is studied by the introduction of very low levels of radioactive materials, either radioactive elements or labeled compounds, only the relative percentage of the abministered dose is measured. Some of the studies detailed were: 1) protein metabolism in cancer patients, 2) vitamin B_{12} absorption and turnover,3) thyroid metabolism, 4) iron metabolism, 5) electrolyte studies with Na and K, 6) turnover studies of trace metals in particular disease entities, 7) long-term turnover of fission products and other radionuclides, and 8) kinetics of skeletal metabolism (Fig. 2).

As the whole-body counter has been developed, there has been a parallel development in the use of automatic systems for recording and analyzing the greatly increased outflow of data. The most current and sophisticated equipment available for recording data as well as high speed digital computers for analyzing the spectral data are now employed in conjunction with whole-body counting systems. This combination of whole-body counters with high speed computers has greatly enhanced the speed and reliability with which in-vivo studies of tracers can be carried out.

Since many of the studies performed with medical whole-body counters involve ill or nonambulatory patients, it is essential that the counter be located in or near a hospital or clinic to facilitate the handling of patients. The integration of new medical whole-body counting facilities with existing clinical facilities can best be done with reference to the experience obtained in the already-existing installations.

Question: Kunio Okuda (Kurume Univ. Sch. Med.)

How accurate is the quantitation of B_{12} absorption? How do you calibrate the count relative to the dosage ? Don't you have to wait till the unabsorbed portion of B_{12} is eliminated befor the actual measurement ?

Answer: S. H. Cohn

VB_{12} studies can be accurately performed with levels of tracer as low as 0. 1μc. The patient serves as his own control. His retained activity at 0. 5 hr. is taken as the 100% dose and the seven day retained activity is then expressed as a percent of the original. This method is quite accurate and reproducible. At seven days the amount in the GI tract is of course insignificant.

Question: Takeshi Iinuma (Inst. of Radiologic. Sci.)

Have all the measurement been done in "Standard-chair Method "

Answer: S. H. Cohn

There is an inerant error caused by the standard chair counting geometry. The counting efficiency changes with the movement of the isotope in the body. To minimize this error the detector can be moved one meter away from the patient. This error in counting geometry is only significant at early times after administration of the tracer. It is not important in long-term metabolic studies.

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