AN IMPROVED HIGH-LEVEL WHOLE-BODY COUNTER

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This whole-body counter is relatively inexpensive to build and provides quantitative whole-body retention values from 0.01 to 100 mCi. Two NaI(Tl) detectors suspended from the ceiling are positioned so that a point source anywhere on the bed gives a uniform counting response (±5%). Subjects are counted on a floor-level pad 1.9 meters under the detectors. The pad is hinged and can be fastened flat against the wall of the counting room when not in service. Optimum-window counting techniques provide a highly quantitative response regardless of the distribution of activity within the subject. A 1-min count of a person with more than 0.1 mCi results in an expected standard deviation of less than ±5%; 10 min are required for similar statistical results in the 0.01–0.1 mCi range.

The phrase "whole-body counter" usually conjures up visions of a massive steel-shielded room, large detectors, and elaborate electronic instrumentation—all very expensive and beyond the fiscal resources of many medical institutions. Such equipment is necessary when maximum sensitivity and minimum background are required for measuring levels only slightly above background. However, whole-body retention can be measured with less elaborate and less costly devices when the administered radioactivity is in the routine diagnostic and therapeutic range.

In the past, we have operated three whole-body counters with overlapping ranges of sensitivity: high-, diagnostic-, and low-level (*1–4*). With these counters we could measure therapeutic doses as high as 150 mCi from the time of administration until the remaining activity decreased to body background levels in the nanocurie region. Since the total span was 100,000,000:1, we designed each counter to have an operating range of about 1,000:1 with some overlap.

Recently we designed and constructed a new counter with an extended counting range to replace the high- and diagnostic-level counters. This counter can be used to obtain diagnostically useful whole-body retention data.

DESIGN AND DEVELOPMENT

Because our low-level whole-body counter (*3,4*) can measure up to 0.04 mCi, the new counter was designed to measure from 0.01 to more than 100 mCi, thus assuring some overlap. To provide the required counting sensitivity, we used two 5.1 × 5.1-cm (2 × 2-in.) NaI(Tl) crystals positioned 2.6 meters apart and 1.9 meters above the bed (Fig. 1). This geometry results in a uniform counting response (±5%) when a point source is moved along the length of the bed.

Both detector assemblies are attached by movable supports to a ceiling-suspended I-beam. The detectors have identical collimators with one lip flared at an angle of 40 deg so each detector has an unobstructed view of the entire subject. Initial experiments showed that the counter would require some means for reducing sensitivity to achieve a 10,000:1 activity span. This was accomplished by the use of lead attenuators that are tapered to maintain the uniform counting response. The end view of the shield (Fig. 1 inset) shows the position of the attenuator in the unattenuated counting configuration that is used when the subject contains less than 3 mCi. For higher activities the operator pushes the wedged attenuator under the detector. One of the detector assemblies as seen from the bed is shown in Fig. 2.

This counter was installed in a hallway leading into our low-level whole-body counting facility. During the few minutes of counting, the bed is lowered to the hall floor. When not in use, the bed is raised

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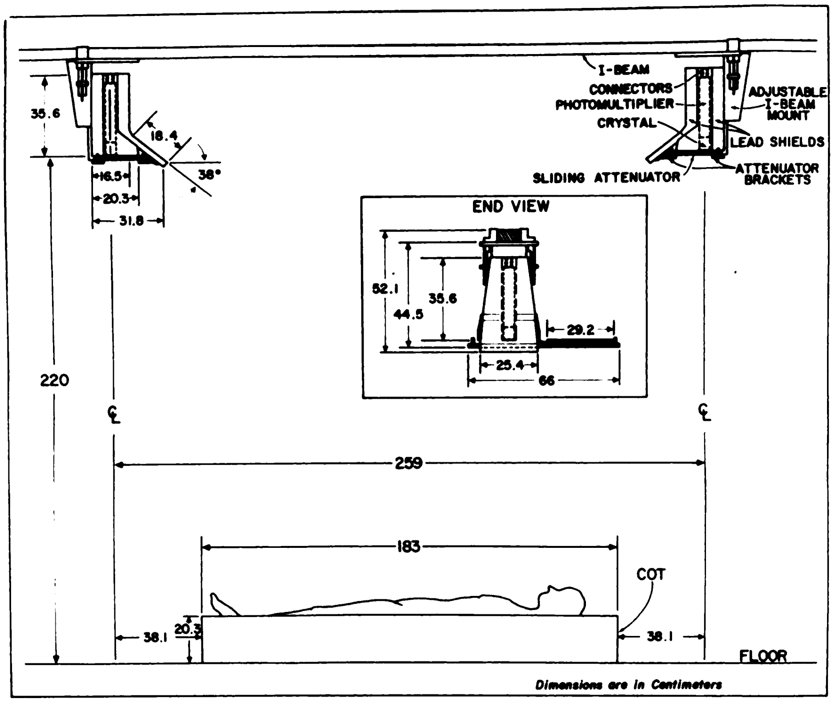

FIG. 1. Side view of counting geometry and end view of collimator shield. Detector assemblies are movable and are supported by fixed I-beam. Patient's cot is hinged to far wall and is raised and hooked up to clear area when counts are not in progress. End view shows lead attenuator plate in "sensitive" counter position. Plate is pushed under detector to reduce sensitivity for counting patient activities above 3 mCi.

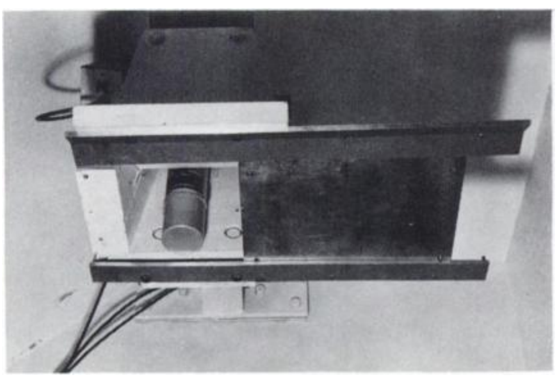

FIG. 2. Photograph of lower portion of detector shield. Attenuator plate is stored to right main housing. Detector-collimator's umbra field can view whole length of patient being counted.

on hinges and hooked up flat against a side wall to clear the passageway floor. Since there is a 2.18-meter vertical clearance between the floor and the bottom of each shield, the hallway is unobstructed when the counter is not in use. Nonambulatory patients are placed on a stretcher that sits directly on the floor on 13.5-cm legs.

Each detector is supplied high voltage through a voltage divider and well-regulated power supply. Signals from both detectors are passed through a single-charge preamplifier coupled to a spectrometer. Each detector can be energy-calibrated separately.

CALIBRATION

The variation in counting response along the bed which would be expected from inverse-square law effects and the actual response curves both with and without the attenuator plates in position are shown in Fig. 3. The response curves were obtained by counting a ^{131}I point source every 10 cm along the center line of the bed. The response varied less than $\pm 5\%$ and was well within our clinical requirements.

By counting a water-filled 8-liter polyethylene bottle into which increasing amounts of ^{131}I were thoroughly mixed, we measured the counting response of the system. When the bottle was positioned at the center of the bed, the system gave a linear response from 10 μCi to more than 100 mCi, Fig. 4.

OPERATION

This equipment is in routine clinical use for measuring whole-body retention of gamma-emitting radionuclides such as ^{131}I, ^{99m}Tc, ^{67}Ga, and ^{51}Cr. Immediately after the radionuclide is administered, the patient is counted supine and prone. A reference

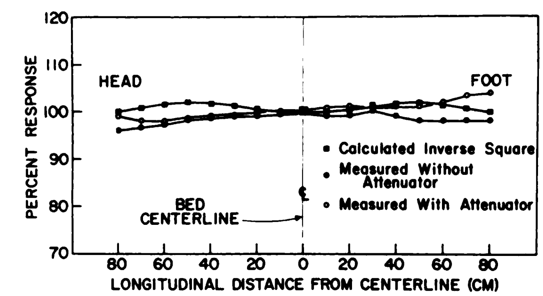

FIG. 3. Response curves of high-level whole-body counter showing curve of response to be expected from inverse-square calculations versus the two measured curves of detector response with and without lead attenuator plates in use. Counting response shows variation of less than $\pm 5\%$ down total patient's length.

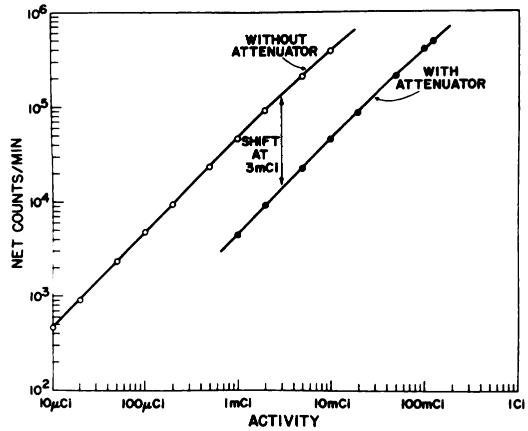

FIG. 4. Counting rates versus activity calibration for improved whole-body counter. Increasing activities of ^{131}I were counted in 8-liter, water-filled, polyethylene bottle. Insertion of attenuators cuts sensitivity for 364-keV gamma rays by factor of 9.3:1.

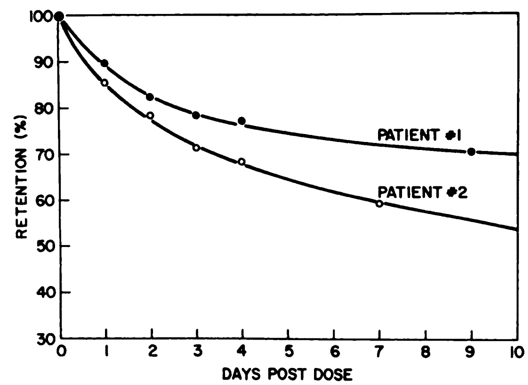

FIG. 5. Retention studies done on two patients following administration of radionuclide.

source prepared from the stock solution that was used for the patient is counted each time the patient is counted. This approach makes the patient his own 100% standard. Each subsequent count of patient and reference course is compared with the initial counts to calculate the fraction of activity retained by the patient. The equation for this calculation is:

$$\text{Fraction retained}_{(t)} = \frac{\text{Patient count}_{(t)}}{\text{Patient count}_{(t=0)}} \times \frac{\text{Reference source count}_{(t=0)}}{\text{Reference source count}_{(t)}}$$

where the subscripts simply indicate when the counts were made. The use of the reference source minimizes the effects of instrument variation and corrects for radioactive decay. The results of two typical whole-body retention studies are shown in Fig. 5.

Because the distribution of most radionuclides changes with time, quantitative measurements of the patient's retention will usually be in error if the photopeak counting method is used. By using the optimum-window counting technique, we reduce the effect of changes in distribution (*5–7*). This technique requires counting an energy band which may or may not include portions of the primary energy peak. The energy band used depends on the radionuclide and the geometry of the counter.

A 1-min count of a person containing more than 0.1 mCi results in an expected standard deviation of less than ±5% for most radionuclides even when the lead attenuators are used. A 10-min count is required for a ±5% standard deviation when measuring 0.01–0.1 mCi.

SUMMARY

This extended range whole-body counter is relatively inexpensive and easy to construct and it has adequate sensitivity and uniformity of response to perform retention studies after administration of most diagnostic and therapeutic doses. The use of the optimum-window technique minimizes errors caused by radionuclide redistribution in the patient. During the normal 10-min count, the patient lies on a comfortable bed.

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