Correction of Attenuation in Whole-Body Determination of Co-57 B_{12} Absorption: Concise Communication

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The use of Co-57-labeled B_{12} for whole-body measurement of B_{12} uptake in humans has the advantage over Co-58 of easy commercial availability and lower cumulative radiation to the liver, but the disadvantage of significant attenuation. Methods devised to correct for the attenuation have used inaccurate early 100% counts. A method is described here that uses a liver phantom, containing a dissolved Co-57 B_{12} capsule, in a water tank. The ratios of upper to lower detector counts is related to total counts; it varies at different depths in the tank, and with the overall tank depth that is selected to accord with measured body habitus. The ratio of detector counts in the final patient count is used to read off the appropriate 100% total count. With this technique there is a clear discrimination between normal patients and those with pernicious anemia.

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In a recent assessment (*1*) of the five methods to measure absorption of orally administered radioactive B_{12}, whole-body counting was said to be the best on the basis of theoretical considerations. It was further stated that although Co-57 delivers less cumulative radiation to the liver, Co-58 is the preferred tracer because of "inaccuracies associated with radiation attenuation in the body if Co-57 is used under suboptimal conditions of whole-body count." Several studies (*2–6*) have described the use of different methods to achieve optimal conditions with Co-57. These include the use of the low-energy (Compton) region of the spectrum (*2*), the use of counts at 30 min as 100% despite marked "random" variations (*4*), the use of scanning (*2–4*) or multiple static detectors (*5,6*), and the use of a regression of counts on body weight to calculate retention (*5*).

The present study was undertaken to investigate further the effects of attenuation of Co-57 by the body and to devise a method more precise than those previously described for the measurement by total-body counting of absorbed orally ingested B_{12} labeled with Co-57.

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METHODS

Both static and scanning measurements were made in a total-body iron room using two 8- by 4-in. NaI (Tl) crystals 35 cm above and 15 cm below a stationary bed. Both detectors simultaneously scanned the prone subject over a distance of 6 ft. Initially room background and natural body radioactivity was measured. A Co-57 B_{12} capsule was given orally with 50–100 ml of water. The capsule was counted statically, and the patient was counted at one or more of the following time intervals: 5–20 min, 2 hr, and 7–14 days. The 100% absorption count was determined by correcting the original capsule count for geometric variation as described below. The final count, representing the absorbed and retained Co-57, was determined between 6 and 22 days, and occasionally at several intervals when slow bowel excretion was suspended.

The 100% absorption value should but cannot be counted with the same geometry as that of the final count. The latter is measured from activity distributed largely in the liver (*7*), the former largely in the gut. To simulate liver-counting geometry for the 100% value, the radioactive capsule was placed in a "phantom liver" in water tanks of depths from 15 cm to 30 cm. These depths were chosen to match the thickness of the supine patient

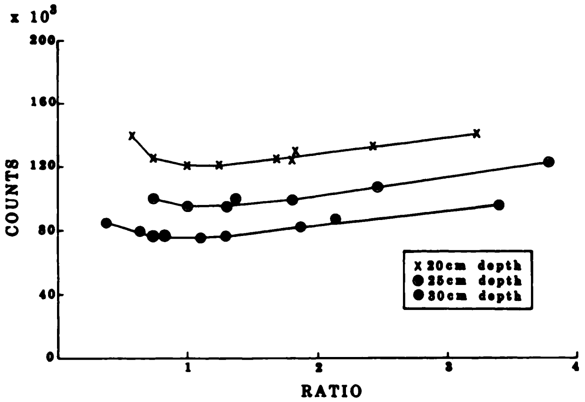

FIG. 1. Relationship between ratio of detectors and total counts of liver phantom (plastic bag) set at various levels in tanks of different depths. At patient's final count, the ratio between counts from detectors above compared with below patient is found, and from this ratio (x-axis) vertical line cuts curve representing patient's thickness—20, 25, or 30 cm. Height of this intersection is read on y-axis scale to obtain "100% count." As phantom liver approaches lower detector and ratio goes below 0.9, total counts rise again. Such ratios are not observed in patients.

as measured at the location of the liver, a value not necessarily correlated with overall weight. The Co-57 B_{12} capsule was dispersed in a 1000 ml plastic bag measuring 23 × 11 × 6 cm, which was then immersed in water. The different ratios of scanning counts between the upper and lower detectors with the bag at various depths were plotted against the total count (Fig. 1). The ratio of the counts from the two detectors in the final patient count intersects the phantom curve (in Fig. 1) appropriate to the thickness of the patient, and the 100% count is read off the y-axis.

RESULTS

In 27 patients the ratios of upper to lower detectors, as counted statically 10 min after the ingestion of Co-57 B_{12}, varied between 1 and 12 (average 5.5) (Table 1). The range at 2 hr was 1.0 to 10.7 (av. 3.7), and at 6–14 days, 0.9 to 2.8 (av. 1.5). In 22 patients the ratios counted by scanning geometry were from 1.2 to 11.5 (av. 4.1) at 2 hr, and 0.9 to 2.3 (av. 1.5) at 7–22 days.

The total counts varied a great deal between 10 min and 2 hr, increasing 53% (on average), and, in individual cases, over fourfold. The result was similar when the scanning mode was used. In 14 patients in whom the increase in counts between 10 min to 2 hr was large, averaging 92%, the increase occurred largely in the upper detector in six patients, in the lower detector in two, and in both detectors in six.

It was clear that such marked variations would lead to some significant inaccuracies were those early counts to be used as the 100% absorption count. The phantom counts, as plotted in Fig. 1, followed curves that varied according to the depths of the tanks. When the phantom counts and ratios were used, the calculated final percent absorption was sometimes little different from that using the 2-hr count as the 100%, but in many instances the difference was large.

Although 7 days has been accepted as an appropriate interval before the final count (*2,3,5*), one patient in this study has a normal absorption of 70% at day 16, but on day 27 it was 7.8%. It is obvious that one must be sure that the patient has had adequate bowel clearance before the final count; this patient had a history of infrequent bowel movements.

The method described was used in the study of 28 hospitalized patients (Table 2). In 12 patients with clinical and hematological evidence of pernicious anemia, the total body B_{12} absorption was low, 1% to 8% (av. 4%), compared with that in 16 normal patients, 33% to 85% (av. 57%). These B_{12} absorptions are not significantly different from those reported in normals (37% to 88%) and in pernicious anemia patients (0% to 10%) when Co-58 was used with whole-body counting (*8*), or when a double-tracer whole-body technique was used (*9*).

DISCUSSION

The use of whole-body counting to determine the absorption of B_{12} has clear advantages over other available procedures, particularly the Schilling test with its often inaccurate and inconvenient urine collection. The use of Co-57 as the B_{12} label would be favored be-

TABLE 1. VARIATION IN DETECTOR RATIOS AND TOTAL COUNTS WITH TIME

Patients	Time	Upper/lower ratio		Total counts		Range of % change 5 min–2 hr
		Range	Average	Range	Average	
27 Static	10 min	1.0–12.0	5.5	3560–24709	13806	
	2 hr	1.0–10.7	3.7	14528–36781	21174	−5, +362
	6–14 days	0.9–2.8	1.5			
6–12 Scan	5 min	0.8–12.3	4.9	5081–22824	16022	
	2 hr	1.2–11.5	4.1	6639–22518	15605	−27, +213
	7–22 days	0.9–2.3	1.5			

TABLE 2. TOTAL-BODY B_{12} ABSORPTION IN NORMAL PATIENTS AND THOSE WITH PERNICIOUS ANEMIA

Patients	DX	Serum B_{12} (pg/ml)		Gastrin (pg/ml)		B_{12} absorption (%)	
		Range	(Av)	Range	(Av)	Range	(Av)
12	Pern. anemia	20–115	(63)	>1000		1–8	(4)
16	Normal	205–899	(329)	29–235	(104)	33–85	(57)

cause of a relatively low absorbed radiation dose were it not that its low energy results in more attenuation. There have been several suggested resolutions of this problem. Evidence was presented by Naversten et al. (*2*), that the use of the Compton energy range in counting Co-57 reduced the degree of attenuation. He calculated the final percent retention using the count 10–30 min after ingestion of labeled B_{12} as the initial value, despite the fact that an early count, determined in the Compton range, might differ by as much as 29% from one at 2½ hr. Boddy (*4*) believed that the attenuation problem was resolved by using a single crystal with a scanning bed and counting the patient supine and prone. He tabulated, in only four patients, a difference of as much as 16.7% between 30-min and 6-hr counts, yet concluded that 30 min was a satisfactory time interval at which to measure 100% retention. Finally and more recently, using multiple static detectors and despite finding a variation of up to 29% between the 1- and 6-hr counts, Tait and Hesp (*5*), based the 100% value on the 1-hr count, and drew a regression line of the ratio for the 1-hr Co-57 count rate from each patient to the count rate from the corresponding capsule against body weights. It was said that values derived from this line could be used as the 100% value and the final B_{12} uptake calculated from a 7-day patient count.

These past studies raise two questions subsumed under the general attenuation problem: should one use an early count of the patient to represent 100% absorption and, if not, how may one best duplicate 7-day geometry in calculating the 100% value. The present study further documents the large variation noted in early counts and emphasizes the obvious inaccuracies in using them as representing the 100% value. Neither scanning with an upper and lower detector, nor static prone/supine counting, nor limiting the count to scattered lower energies, eliminates these variations. The problem of the various and varying distributions and attenuations can only be resolved accurately by correcting a base or capsule count with a phantom representation of the later geometry. The latter can be made more specific by assessing pertinent body habitus. Thickness of the abdomen in the counting position seems theoretically more relevant than weight. A water tank of depth similar to that of abdominal thickness, with activity concentrated largely in a simulated liver, will then come close to the natural late distribution of Co-57. It should be reemphasized that the considerable difference in geometry between that for the 100% count, where the dissolved B_{12} capsule is located somewhere in the mobile gastrointestinal tract, and that for the final count, where the absorbed B_{12} is concentrated in the relatively fixed liver (*7*), has not been adequately considered in studies on B_{12} absorption.

The use of whole-body counting in determining Co-57 B_{12} absorption has major advantages to both patient and laboratory. It is easy in that it requires only one follow-up visit, no rigid schedule or collections, and treatment may be started before or after. It is accurate in that it clearly differentiates normals from patients with pernicious anemia.

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