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SOME CRITERIA FOR EVALUATION OF PERFORMANCE OF WHOLE BODY COUNTING SYSTEMS

A. Nagaratnam, M.M. Gupta, S.C. Mehta, G.C. Bhola, B.S. Rawat and K.K. Kapoor

Institute of Nuclear Medicine & Allied Sciences, Delhi-110007, INDIA

1. INTRODUCTION

Criteria for a whole body counter are high sensitivity and independence of detector response with respect to both source location and body build. One of the methods of assessment is to evaluate the following two parameters (1): (i) the average response $\bar{R}$ as a point source is moved over a length of about 170 cm (height of adult), and (ii) the non-uniformity factor $f_1 = (R_{max} - R_{min})/\bar{R}$, where R_{max} and R_{min} are the maximum and minimum responses when the activity is concentrated at a point within the length of the source. The intervening medium is usually taken as air. The objective is to maximise $\bar{R}$ consistent with a specified degree of non-uniformity of response (say, f_1 less than 20%). In place of f_1, one could also use f_2, the coefficient of variation of the individual responses R (standard deviation of R's divided by $\bar{R}$).

2. MATERIALS AND METHODS

Three modifications have been introduced in the present study. The first consists in replacing $\bar{R}$, the average sensitivity, by a weighted average sensitivity $\bar{R}_w$, for the following reason. Whether it be clinical applications (e.g. body potassium, iron and vitamin B_{12} retention) or monitoring for internal contamination (critical organs mainly GI tract, bone, total body, kidneys, liver, lung) the majority of radionuclides have either a more or less uniform whole body distribution or are concentrated in organs located in the central regions of the body. In the case of whole body distribution, about 80% of the body mass is situated in the trunk, abdomen and thighs. Hence in all these situations, the central regions contain the bulk of the activity. (An exception is radioiodine in thyroid).

To take this factor into account, each segment of the line source representing the body has been weighted by a factor proportional to the mass of the body in that segment. The weighted average $\bar{R}_w$ is likely to be a better parameter than $\bar{R}$.

Three cases have been considered, viz. 170, 150 and 100 cm of line source length, L, corresponding respectively to adult, adolescent and 3-year old child. Table 1 depicts the lengths and percentage masses of the six segments, based on the well-known Bush phantom for the adult and modified from the adolescent and child phantom data of Hayes and Brucer (2). The masses of the arms are added to those of the thorax and abdomen.

The next modification is to calculate a weighted non-uniformity factor f_{1w} or f_{2w} for the same reasons given earlier. The third modification is to consider the line source as sandwiched at the centre of a tissue equivalent medium of appropriate thickness 2t (20, 16 and 12 cm for adult, adolescent and child respectively), to take into account effects of tissue absorption and body build.

The subject was taken to lie flat on a stretcher bed and computations were made for a single detector (to understand the pattern of variation) and 4-detector setup (the geometry used in our Institute), using IBM-360 computer for a variety of situations. Values of $\bar{R}$, f_1, f_2 as well as the corresponding weighted parameters were calculated for a range of source-detector distances D_h (15-50 cm), 6 values of gamma ray energies (50-800 keV and also including no attenuation) and various detector configurations. Exponential attenuation was assumed (corresponding to photopeak counting).

3. RESULTS

3.1. Single-detector

Fig 1 depicts $\bar{R}$ and $\bar{R}_w$ for the case of no attenuation for the adult for a source-detector distance of 25 cm as the detector is moved laterally from the head to the foot. It is seen that as against the obvious symmetric response for $\bar{R}$, $\bar{R}_w$ has a maximum when the detector is about 15 cm to the head side of the centre, in agreement with the observations of Miller (3) for a patient administered ^{42}K. Further, the maximum value of $\bar{R}_w$ is about 35% higher than that of maximum $\bar{R}$. This reduces to about 22% for a height of 45 cm, where one approaches more closely the arc geometry. The f_{1w} values are found to be much lower (about one-third) than the corresponding f_1 values. As u increases, f values also increase.

3.2. Four-detectors

The detectors were taken in two pairs, the members of each pair being situated symmetrically with respect to the centre of the line source.

By normalising $\bar{R}$ with respect to a standard value $\bar{R}_{max}$, it has been possible to make broad generalisations for each type of detector positioning regarding average detector response which are reasonably independent of D_h, µ, L or t. The standard $\bar{R}_{max}$ is taken as the value of the response (for given D_h, µ, L, t) when all four detectors are over the centre of the line source (Geometry A in figure 2). It is also found that $\bar{R}_{max}(\mu)$ for any µ may be found from the corresponding $\bar{R}_{max}(o)$ for air, using the expression $\bar{R}_{max}(\mu) = \bar{R}_{max}(o) \exp(-\mu t_{eff})$, where t_{eff} is nearly independent of µ and varies slowly with D_h. For example, teff for adult (t = 10 cm) is about 12.8 cm. With regard to f_1 and f_2 such quantitative generalisations are not possible. Of course f is better for large D_h, small u or L.

Considering $\bar{R}$ and f together, geometries A, B giving high sensitivity have poor f characteristics. Even for C, f is on the high side; only f varies here slowly with D_h and does not rise precipitously at low D_h. Geometry D with a sensitivity of 76% is extremely satisfactory from the point of view of f. The optimum positioning would therefore be around this geometrical configuration, with slight modifications improving the performance with respect to either or both $\bar{R}$ and f (such as pushing the end crystals 5-10 cm towards the centre or lowering D_h for the end detectors about 5 cm with respect to the central one).

One may generalise that whenever there is a substantial difference between $\bar{R}$ and $\bar{R}_w$ such a configuration will have poor f values. For configuration D, there is very little variation between $\bar{R}$ and $\bar{R}_w$ irrespective of D_h, L or u.

Body Region	Adult		Adolescent		Child	
	Length cm	% of total mass	Length cm	% of total mass	Length cm	% of total mass
Head	20	8.0	15	9.4	15	17.9
Neck	10	2.6	10	1.0	5	1.1
Thorax	40	41.8	35	40.9	25	39.8
Abdomen	20	26.0	20	22.5	15	23 .4
Thighs	40	13.5	30	15.2	15	8 .4
Legs	40	8.2	40	10.9	25	9.3
	170	100	150	100	100	100

TABLE 1 Lengths and Masses of Different Compartments for Adult, Adolescent and Child Phantom

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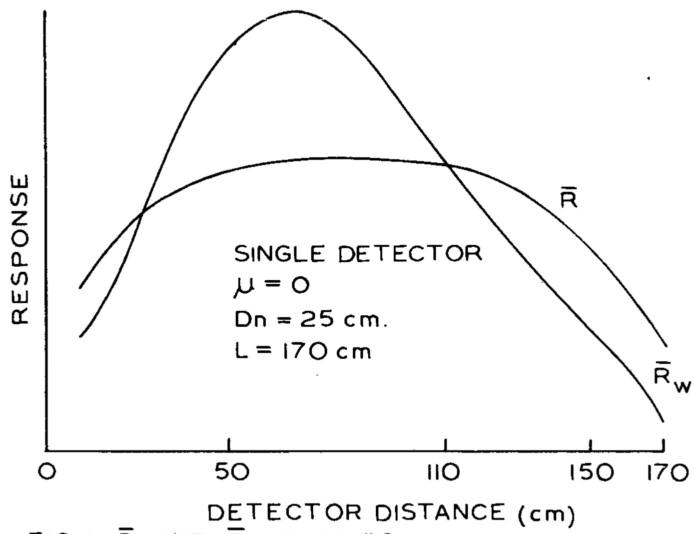

FIG. 1 $\bar{R}$ AND $\bar{R}_W$ VALUES

DETECTOR CONFIGURATION	$\frac{\bar{R}}{\bar{R}_{max}}$ (%)	Range of f_1 values (%) as Dn varies from 15-50 cm (L = 170 cm., $\mu = 0$)
A: •••• at L/2, Dn; O, L/2, L	100	400-130
B: •• at L/4, •• at 3L/4; O, L/4, 3L/4, L	93.7 ± 1.8	200-50
C: • at L/8, 3L/8, 5L/8, 7L/8; O, L/8, 3L/8, 5L/8, 7L/8, L	90.1 ± 3.6	110-50
D: • at O, L/3, 2L/3, L; O, L/3, 2L/3, L	76.4 ± 2.5	90-20

FIG. 2 $\bar{R}$ & f VALUES FOR VARIOUS DETECTOR CONFIGURATIONS