Efficiency Calibration of Phantom Family for Use in Direct Bioassay of Radionuclide in the Body

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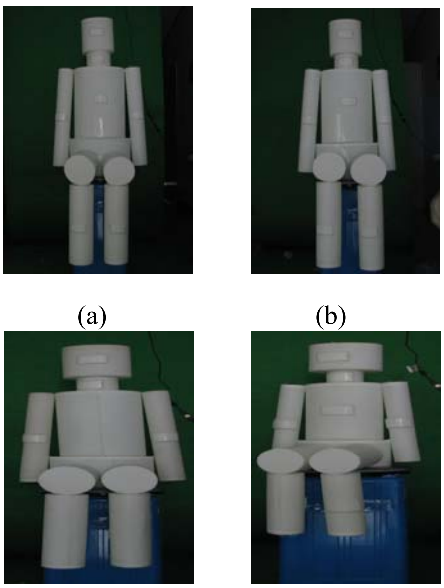
1. Introduction

A major source of uncertainties of in vivo bioassay using a whole body counter calibrated against a body phantom containing known radioactivities is variation of counting geometry caused by the differences in body size of the subject from that of the phantom. Phantoms such as the BOMAB phantom are based on the body size of the reference man and usually single phantom is used in usual calibration of the counter. This is because it is difficult to apply a set of phantoms having different sizes. In order to reduce the potential errors due to variation of counting geometry, use of a set of phantoms having different body-shapes have been attempted. The efficiency files are stored in the computer analyzing the measurement data and a suitable one is retrieved for the specific subject. Experimental or computational approach can be employed in generation of the efficiency files. Carlan et al.[1] demonstrated that Monte Carlo simulations can provide acceptable efficiencies by use of the IGOR phantom family[2]. The body size of the individual subject undergoing in vivo bioassay should be determined by an appropriate method.

2. Methods and Results

2.1 BOMAB Phantom Family



(a) (b)

(c)

(d)

Fig. 1. BOMAB phantom Family

All the experiments were measured through BOMAB phantom. Fig. 1(a) stands for a reference male; Fig.1(b) a reference female; Fig.1(c) a reference 10year old child; Fig.1(d) a reference 4year old child. The BOMAB phantom made of polyethylene is packed with 0.01M HCl and 7 water-soluble radionuclides. The used nuclides are Am-241, Co-57, Ce-139, Sn-113, Cs-137, Y-88, and Co-60, the efficiency of which can be obtained for 59.5keV, 122.1 keV, 165.9 keV, 391.7 keV, 661.7 keV, 898.0 keV, 1173.2 keV, 1332.5 keV, and 1836.1 keV.

Table I: Phantom size

	Male	Female	10yr	4yr
Head	4.3L	3.4L	3.4L	2.4L
Neck	1.5L	1.2L	0.76	0.4L
Torso	20.1L	16.0L	10.0L	5.1L
Pelvis	11.3L	9.0L	5.6L	2.8L
Arm	4.1L	3.3L	2.0L	1.0L
Thigh	7.5L	6.0L	3.8L	1.9
Calf	4.8L	3.8L	2.3L	1.2L
Total	70.1L	56.1L	35.9L	19.0L

Table I shows the volume of each part in BOMAB phantom. The values were rounded up from the second decimal place. A reference female has large volume of pelvis when compared with its total size, and the child has relatively large head when compared with the body. The specific activity of each part has the same value.

2.2 Measurement

Whole body counter used in the experiment was the chair type and designed to be movable. The counter is equipped with a HPGe coaxial detector(CANBERRA Model GC9021) of 90% relative efficiency. The detector was shielded with 5 cm thick lead and had an opening angle of collimator is 90°. The detector was positioned at 38 cm from the surface of the chair. The detector is connected to a computer equipped with an MCA data acquisition card.

2.3 Efficiency

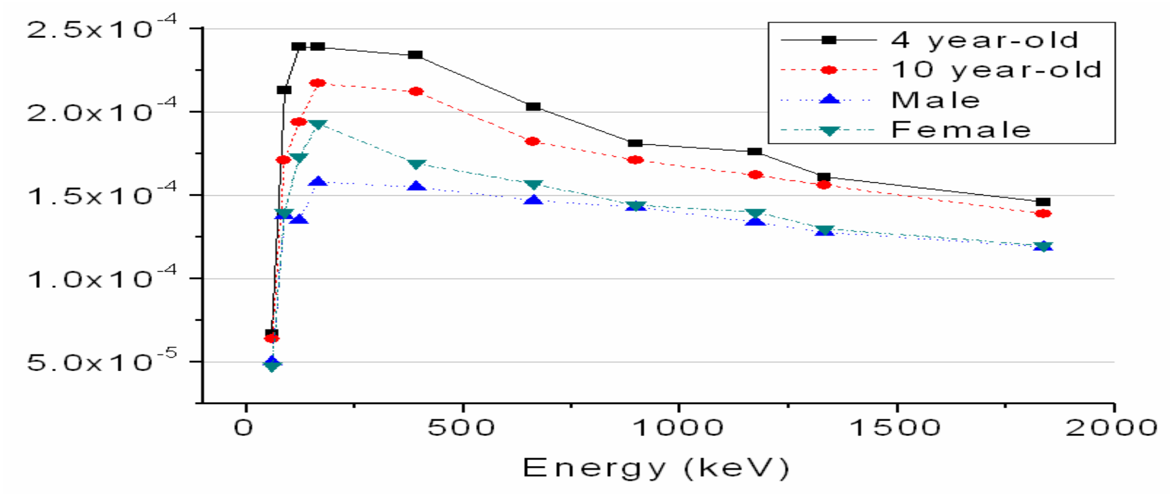


Fig. 2. Counting efficiency of BOMAB phantom family

Fig 2. shows the efficiency of each energy. Statistical error does not exceed 10% in 59.5keV, and 6% in other cases. The slopes vary according to their phantom sizes, and this phenomenon is caused by the fact that the measuring instrument is fixed and the phantom is placed on the chair. If the measuring instrument is fixed, the position of each part becomes different according to the shape of phantom and at this time the slope can change. If the size increases, the efficiency decreases; and if the size decreases, the efficiency increases. As the position of measuring instrument is not adjusted according to the phantom, if the size decreases, the distance from the detector tends to be greater. And it brings out the decrease of efficiency. But, as the size becomes smaller, the position of source comes to be closer to the measuring instrument and the self absorption gets smaller. And it results in the increase of efficiency. Especially, the existence of collimator makes the efficiency more sensitive to the positions of measuring instrument and source. As the distance between the phantom surface and the detector is constant[3], if the size becomes smaller, the efficiency gets increased a lot.

3. Conclusions

The efficiency curve of BOMAB phantom family shows that the intake amount can be misjudged by up to 170% according to the size of the object in case of internal exposure. Therefore, for the calibration of WHOLE BODY COUNTER, it seems necessary to make the experiment while retaining each size of BOMAB phantom.

To fix or to change the distance between the phantom and the detector in measurement has its own merit respectively.

When fixing it, as the count number in the detector becomes greater, the measuring time get shorter. Meanwhile, when changing it, the efficiency for each size becomes similar. Considering that the size of human body is hard to define, it can be a great merit. But this problem seems a choice problem. According to the size of phantom and the position of source, we can expect more diverse efficiency curves may be drawn. Therefore, in the future it is necessary to develop the technique to predict the situations that cannot be covered with the experiment and to calibrate them with the MCNP simulation.

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