Measurements of Gaseous ^{85}Kr by the Catheter-type Semiconductor Detector

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It was pointed out in this meeting by our collaborator that catheter-type detectors are useful for the examination of local pulmonary functions. However, when examining the pulmonary function with the catheter-type semiconductor detector using gaseous β-activity such as ^{85}Kr, the results depend upon the geometry of the bronchus, i.e. diameter, length, the branch direction etc. This is due to the fact that the range of 670 keV β-particle—maximum energy of ^{85}Kr—is about 2 m in the air. In this report, a theoretical analysis of geometrical effects is performed and is also verified experimentally.

A cylinder is adopted as a model of the trachea and an endwindow-type detector is placed on the cylinder axis. Then, the counting rate I of β-activity is expressed generally as

$$I = \int_0^L \int_0^R \omega I_0 2\pi \, y \, dx \, dy$$

where ω is the solid angle of the elementary volume subtended by the detector, I_0 is the source density, R is the innerdiameter of the cylinder and L is the istance form the detector along the cylinder axis.

In the approximation, ω becomes $\pi a^2 \cos\theta/\gamma^2$, then Eq. (1) is calculated as $I = 2\pi a^2 I_0 R\left\{\left(1+\frac{L}{R}\right)-\sqrt{1+\left(\frac{L}{R}\right)^2}\right\}$ The function in the brace in Eq. (2) approaches 1 at $\frac{L}{R}=\infty$ and I becomes 0.9 of its saturation value at $\frac{L}{R}=5$. This means that counts are determined mainly by the sources in the limited volume near the detector.

As a result of experiments to determine whether the approximation used in the solution (Eq. (2)) is good or not, the following facts were confirmed. Counting rate I is proportional to the inner diameter of the cylinder instead of its cross-sectional area. Experimental curve I vs $\frac{L}{R}$ is very similar to Eq. (2) and the experimental value of I at $\frac{L}{R}=5$ is only 5% less than the theoretical value.

On the basis of the conclusions mentioned above, the catheter-type semiconductor detector with sheath was designed to be used in gaseous measurements. The sheath covers the detector and has a dimension of $\ell/\gamma \approx 5$, where γ is inner diameter of the sheath and ℓ is its length. The results obtained with this improved detector is independent of geometry of the bronchus. In conclusion, with this modified detector regional pulmonary function can be measured in each bronchial tree without influences of the size and length of bronchus.