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Full Length Research Paper

Determination of absorbed dose by using absolute activity measurements

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The determination of absorbed dose in an organ is of critical importance especially in medical therapy applications. In this study the total attenuation coefficient has been measured experimentally and absolute activity has been calculated using an application of a general method presented by Fleming. The absorbed dose for different distances from the source has been determined using absolute activity with using Perspex phantom. The true dose value given to the medium has been investigated and the results were discussed.

Key words: Absolute activity, absorbed dose, γ-rays, attenuation coefficient.

INTRODUCTION

One of the most important applications of nuclear physics has been in medicine, both for diagnostic and therapeutic purposes. The use of x- rays for producing images for medical diagnosis is well known, but x- rays are of limited value. They show distinct and detailed images of bones, but they are generally less useful in making images of soft tissue. Radioactive isotopes can be introduced into body in chemical forms that have an affinity for certain organs, such as bone or the thyroid gland. A sensitive detector (called a "γ-ray camera") can observe the radiations from the isotopes that are concentrated in the organ and can produce an image that shows how the activity is distributed in the patient. These detectors are capable of determining where each γ-ray photon originates in the patient (Krane, 1996).Ever since nuclear physics began to be applied in medicine studies have concentrated on protecting the patient from unnecessarily high doses of radiation.The development of gamma cameras that are capable of recording the complete image of a large area provided some advantages in these studies. It became possible to find more accurate and reliable results. One of the aims of nuclear medicine is to define the exact amount of the absorbed dose in the organ that is being investigated for diagnosis or treatment. In such studies (Midgley, 2006; Singh et al., 2008; Ferreira et al., 2010), it is very important to correct for regional counts due to varying radio-isotropic absorption in human tissues. These corrections can be made by obtaining the value of attenuation coefficient. However, in the case of a thick organ, the errors in such measurements would be large. In this study, the activity has been checked using a computer-controlled gamma camera. The attenuation coefficient has been measured. The absolute activity has been calculated and the absorbed dose has been determined using this value, and then the results have been compared with each other.

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MATERIALS AND METHODS

The intensity of γ-rays from a gamma source decreases with distance resulting in less interaction with matter in its way. The fractional loss in intensity in any thickness of material is: *dx*, is $dI/I = -\mu x$. Thus $I = I_0 \exp(-\mu x)$ in passing through a thickness *x*. *I* is the gamma intensity arriving at the detector; I_0 is the intensity at the beginning, μ is the total attenuation coefficient. The relation between beam intensity and the attenuation coefficient is valid for photoelectric, Compton and for photons of sufficient energy- pair production interactions (James, 2000).In particular, the measurements for the decrease in photon intensity in deep layers may cause errors. This situation can and does have a negative impact on the results of the quantitative studies. The equation of the corrected activity given by Fleming (1979) is:

$$A\ell = (R_A\, R_P)^{1/2} \Big/ \left[\frac{\sinh(\mu\ell/2)}{\mu\ell/2} \exp(-\mu L/2) \right] E \tag{1}$$

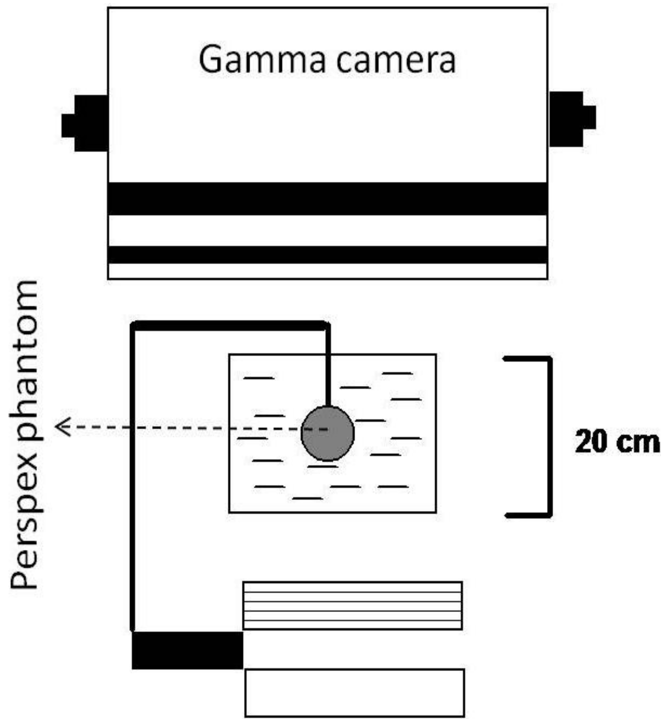

Figure 1. Experimental device used in the measurement of count rates.

Table 1. The measured data of the images from different distances.

Distance (cm)	**4**	**8**	**12**	**16**	**20**
Counts rate (count/ min)	2434780	1568460	946230	551120	324000

where R_A and R_P are the count rate measured from the anterior and posterior, respectively; L is the thickness of the body; ℓ is the thickness of the lesion. E and μ are measured and then the true activity can be obtained. The absorbed dose by the medium can be found by using the Equation 2:

$$E_{abs} = \Phi\left(\frac{\gamma}{cm^2 s}\right) \times E\left(\frac{MeV}{\gamma}\right) \times \frac{\mu}{\rho}\left(\frac{cm^2}{g}\right) \tag{2}$$

where, Φ is the photon flux and μ/ρ is the total mass attenuation coefficient (James, 2000).

The experimental data has been obtained by using the apparatus shown in Figure 1. 2.2 mCi Tc-99^m was injected into the Perspex phantom mass, which was immersed in water to obtain the density of the tissue. The gamma camera and dose calibrator used in this work are General Electric 4ACT Starcam and Radcal Corporation Model 4050. All the quality controls carried out on these systems are for the elimination of systematic errors. To calculate the absolute activity from Equation 1, it is necessary to measure the gamma camera/collimator system efficiency, E, and the total attenuation coefficient, μ. The experimental data for the images have been obtained at various distances. μ and E have been calculated by using the variations in the count rate obtained by storing the images on the computer. Linear attenuation coefficient, μ, has been determined from the gradient of the graph of the count rate against thickness. Efficiency, E, was found by extrapolation of the same graph to find the count rate at zero thickness.

RESULTS AND DISCUSSION

The data measured using the experimental apparatus shown in Figure 1 have been given in Table 1. Total attenuation coefficient (μ) has been determined from the gradient of the graph of the count rate against thickness (Figure 2). The energy of the γ-rays from *Tc-99^m* is 0.143 MeV. The attenuation coefficient of these γ-rays for water is 0.15 cm^2/g in the XCOM programmed tables (Berger and Hubble, 1999).The result for total attenuation coefficient has been found 0.13 cm^2/g in this work. To obtain the absolute activity, it is also necessary to determine gamma/collimator system efficiency (E).The count at zero thickness has been found by extrapolation of the graph in Figure 2. E value has been found to be 15.25. To calculate the absolute activity from Equation 1, it is necessary to measure R_A and R_P. They have been measured as 2382300 and 2319960 kcounts /min,

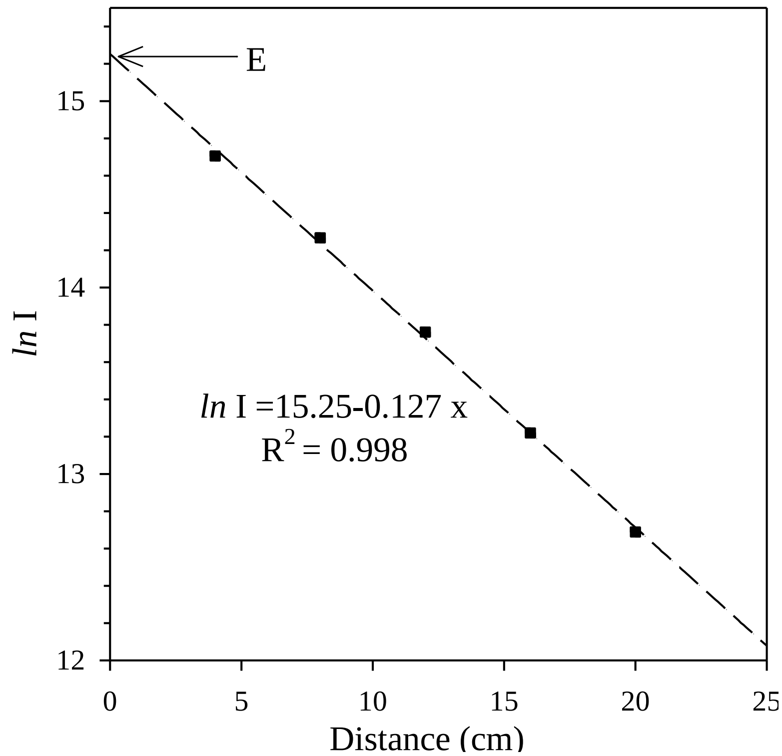

Figure 2. The thickness-intensity plot to obtain the mass attenuation coefficient and efficiency.

Table 2. The results of absorbed dose by the medium for different distance from source.

Activity (mCi)	**Attenuation coefficient (cm^2/g)**	**Absorbed dose (10^{-5}×Gy/s)**				
		4cm	**8cm**	**12cm**	**16cm**	**20cm**
Known activity 2.2	0.15[a]	0.14	0.035	0.015	0.0087	0.0056
Measured activity 2.02	0.13	0.11	0.028	0.0123	0.0069	0.0044
8.13%	13 %	20 %	20 %	18 %	21 %	20 %

[a] was obtained from XCOM program.

respectively. It has been found that the activity is 2.02 *m*Ci for L= 27.5 cm and l = 3.5 cm. This means that the mean error in assessing activity was 8.18%. This result is similar to the Fleming's result, which was obtained by using the same methodology (Fleming, 1979). According to Fleming, the mean error is 3.2% representing the best accuracy expected from this technique.

Although in practice, there may have been additional errors, which would account for the different result. If the additional errors are taken into account, it may be accepted that the results are in agreement. 5 to 10% absolute measurement errors are acceptable (Fleming, 1979). The main reason for the difference in the errors is the total thickness. The thickness must also be determined. The absorbed radiation doses by the phantom mass were calculated using both activities for each distance. For example: photon flux, $\Phi = 2.2 \times 3.7 \times 10^7 / (4\pi \times 16) = 405055.73$ decay/cm^2s; photon energy flux $\Phi_{en} = \Phi \times$ Energy = 8688.44 MeV/g s and dose, $E_{abs} = \Phi_{en} \times \mu/\rho = 0.14 \times 10^{-5}$ Gy/s. The results for absorbed doses over distance were shown in Table 2.

As shown in Table 2, while the activity value obtained by using experimental data is different from 8.13%, the absorbed dose values are ~20%. It can be concluded that the change in the absorbed radiation energy by the medium is dependent importantly on the mass attenuation coefficient and the absolute activity. Hence the radiation dose given to the patient must be corrected carefully.

In the radiation therapy applications, the most important quantities are the total attenuation coefficient to plan of the doses received by tissue. The methods should be developed to determine the correct doses absorbed by the patient tissue.

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