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Internal Dose Assessment in Patients Treated with I-131 using Whole Body Counter

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Abstract: ***The current paper concerned on internal dose assessment of I-131 for some individuals in diagnostic and screening geometry respectively using whole body counter. It consists of scanning high purity germanium detector assembly with the lead shadow. Calibration of single high purity germanium detector for a wide range of energies for organ compartments such as thyroid, lung, upper and lower gastrointestinal tract have been investigated using transfer phantom in fixed diagnostic and screening positions respectively. The committed dose equivalents of I-131 in thyroid of some individuals were ranged from 10.80 ± 0.76 to 60.60 ± 0.52 µSv in screening position.***

Keywords: Dose assessment, I-131, Diagnostic, Screening, Transfer phantom

1. Introduction

There are four main processes for intake of radio nuclides into a human body, ingestion via gastro intestinal Tract, injection via intravenous, absorption via skin and inhalation via respiratory tract system. The inhalation is considering the main route for intake of radioiodine by individuals in many processes. It includes internal exposure of radioiodine as results of activities of nuclear medicine practice, iodine production laboratories, and possibility of release of I-131 in the environment. For assessing the internal dose of radioiodine in some individuals, principal interest has been in I^{131}. We have been concerned primarily with the concentration of this radioiodine in the thyroid gland. The measurement of radioiodine needs special instruments like whole body counter.

The first whole body counter in Egypt was consists of NaI (Tl) crystal (20 cm diameter x 10 cm thick). It has been used for various studies: the measurements of total body potassium (1, 4). The measurement of Iodine content for some NRC workers after an incident, 1997(1) A few years ago, however, another two whole body counters were installed. Fast scan whole body counter uses two large NaI (TI) detectors (7.6 cm x 7.6 cm x 40.6 cm) configured in a linear array on a common vertical axis. It has been used for assessment of ^{40}K in the human body using fastscan technique (5.) Accuscan II whole body counter installed in NRC at 1999 uses single high purity germanium detector. The calibration of whole-body counter is very important for measurement of radioactivity. The current work is concise on internal dose assessment of I-131 in diagnostic geometry, phantom in rear wall position, to record all the signals with minimum dead time and in screening geometry, phantom close to the detector, to check if person contaminated or not.

2. Materials and Methods

The Accuscan II Whole Body Counter at AEA

The standard ACCUSCAN-II System includes a shield and scanning detector mechanism was presented as shown in Fig.1. A 25% coaxial germanium detector and cryostat assembly, a digital spectrum analyzer, as well as canbera's ABACOS whole body counting and Genie spectroscopy software packages. The ACCUSCAN-II uses a shadow shield to shield against elevated ambient background. The system's shadow shield is composed of two major assemblies, a low background steel personnel enclosure and a scanning tower assembly with a lead detector shield assembly. The personnel shield or enclosure provides shielding from the back and sides of the person and the lead detector shadow shield shields the detectors from the front.

The personnel shield is fabricated with a full 10 cm (4 in.) of low background steel. This low background steel is manufactured with a special cobalt free process. This process guarantees steel free of the ^{60}Co contamination normally found in steel, an important consideration in monitoring personnel for fission product contamination. The shield assembly also includes plastic liners designed to make decontamination fast and easy.

The ACCUSCAN II includes a scanning detector assembly with the lead shadow. The lead detector shield is attached to scanning mechanism, which is operated through the systems controller. The ACCUSCAN II 's detector shield provides 5 cm (2 in.) lead around the detector and includes a copper liner to reduce the effect of lead X-rays

Figure 1: Photograph of shield and scanning detector of the Accuscan II

System Operation

The subject enters the ACCUSCAN II shield assembly and stands against the back wall. There are molded positioning devices on the back wall that make it natural for the subject to stand in the correct location. The operator starts the count using the ABACOS software included with the system. The software starts the data collection and brings up a subject demographics screen. The operator fills in a brief demographics screen about the count (subject name, ID number, reason for count, etc.). The rest is completely automatic. There are two operating modes, local and scan modes. The gamma acquisition software displays the spectral data during the acquisition in local mode. It stops the count when the pre-programmed count time has elapsed; it stores the data, analyzes the spectral data and reports the results. ABACOS software uses in scan mode. Once the reporting phase of the count is completed ABACOS automatically resets the system for the next count. Count times are normally in the 5-20-minute range for a single detector system.

Calibration Procedures

High purity germanium detector was calibrated via two steps; energy calibration for a detector and efficiency calibration for a whole-body counting system. The energy calibration for the detector was carried out using mixed sources of Eu-152, Eu-154 and Eu-155. The electronic system for the detector was adjusted to have a scale of 0.5 keV/channel. After the energy calibration, an efficiency calibration in rear wall position was performed using a multi-nuclide mixed solid matrix dissolved in liquid scintillation vial. This standard radionuclide source was prepared using an aliquot of 0.02717 grams measured gravimetrically from a master radionuclide solution source which was calibrated using a germanium gamma spectrometer system. The mixed radionuclide source was attached to rear wall position. The activities of radio-nuclides of the master radionuclide solution source were shown in table1.

Table 1: The activities in Liquid vial source and their standard uncertainties

Isotopes	Gamma–Ray Energy (keV)	Activity KBq	Total uncertainty %
Cd-109	88	130.87	4.8
Co-57	122	2.96	4.2
Ce-139	166	4.70	4.2
Hg-203	279	8.95	4.6
Sn-113	392	7.36	4.8
Cs-137	662	3.59	4.4
Y-88	898	13.10	4.2
Co-60	1173	6.33	4.8
Co-60	1332	6.33	4.3
Y-88	1836	13.10	4.2

Density of solid matrix 1.15 g/cc.

The mixed radio nuclides of known activities were immersed in locations of transfer phantom organs such as thyroid, chest, upper and lower gastro-intestinal tract. Canberra 2257A Transfer phantom used in calibration was presented as shown in Fig.2. It consists of two basic components: a "torso" section, and a "neck" section. The torso section is constructed from flat sheets of cast acrylic material (e.g. Lexan or Plxiglass), with the front sheet thickness chosen to provide the proper amount of absorber between the calibration source and WBC system detector (s). Three interior source cavities provide lung-equivalent, G.I. region-equivalent configurations. The neck section is a cast acrylic cylinder with a thyroid-equivalent source cavity, with dimensions specified in ANSI N44.3. The configuration provides the ANSI approved reference thyroid counting geometry.

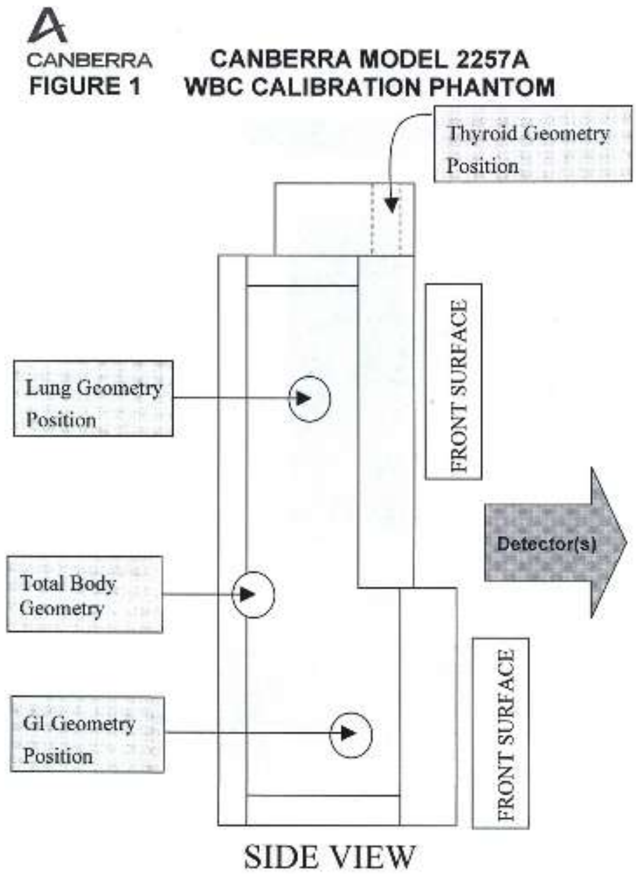

Figure 2: Canberra Model 2257A Whole Body Counter Calibration Phantom

The counting efficiency E was estimated using the equation (1).

$$E = C/AI \quad (1)$$

Where C is the full energy peak counting rate estimating from the summed spectrum, A is the activity in the phantom and I is the gamma –ray emission probability. Minimum Detectable Activity (MDA) values for the Ge detector system were calculated under the following conditions: (1) the counting time of 1200 sec and (2) background counts corresponding to a counting time were used for N.

3. Results and Discussions

Gamma Ray Spectra

Linearity between channel number and energy (keV) obtained for multi-nuclide sources in real wall position free in air is shown in Fig.3. The counting time was 1200 sec for high purity germanium spectrometer. The energy increased linearly with channel number of multichannel analyzers. The correlation between energy to channel number was 0.45 keV/ch.

Counting Efficiency

Counting efficiency of high purity germanium detector has investigated in rear wall, position without phantom as shown in fig.4. The efficiency is too high at low energy due to high detector self absorption and the efficiency decreases as energy increases due to part of the energy transmitted, another part absorbed, and another part scattered. The counting efficiencies has investigated in two geometries, rear wall, diagnostic position and screening position as shown in fig.5.

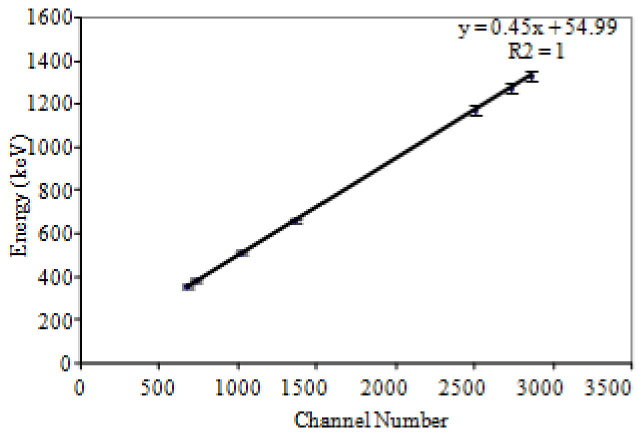

Figure 3: Linearity of Accuscan II HPGe Whole Body Counter

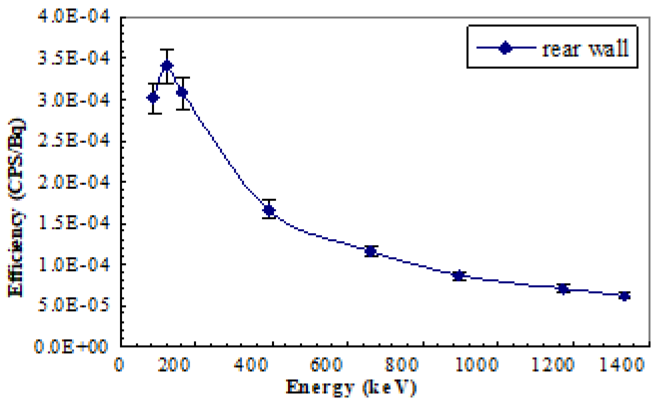

Figure 4: Efficiency of Accuscan II HPGe in rear wall position using Aliquote

Mixed standard source

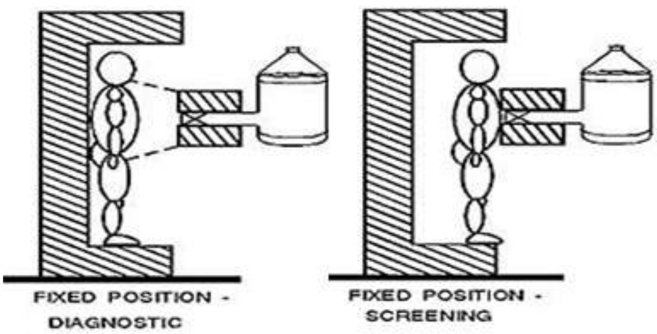

Figure 5: Diagnostic and Screening geometries

Counting efficiencies for organ compartments such as thyroid, chest, upper and lower gastrointestinal tract have been investigated using transfer phantom in fixed diagnostic, source to detector distance is 7 cm and screening. Source to detector distance is 20.2 cm positions respectively as shown in figures 6and 7. The counting efficiency differs for each organ due to different in source to detector distance and attenuation coefficient for each organ tissue equivalent. The organ efficiency depends on amount of energy transmitted from Plxiglass materials. Whereas plexiglass thickness for thyroid gland is 0.5 cm, lung is 8.5 cm, upper gastrointestinal tract is 14 cm and lower gastrointestinal tract is 4.7 cm from body surface. Organ counting efficiencies for compartments such as thyroid, chest, upper and lower gastrointestinal tract in screening position is higher than that in diagnostic position by approximately factor of three.

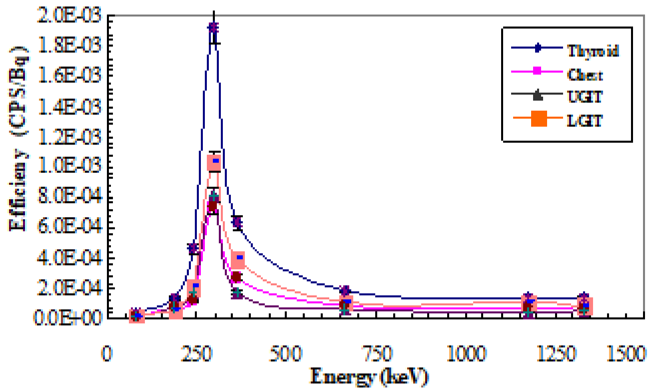

Figure 6: Organ Compartment Efficiencies of Accuscan II Whole Body Counter using Transfer Phantom in Diagnostic Position Geometry.

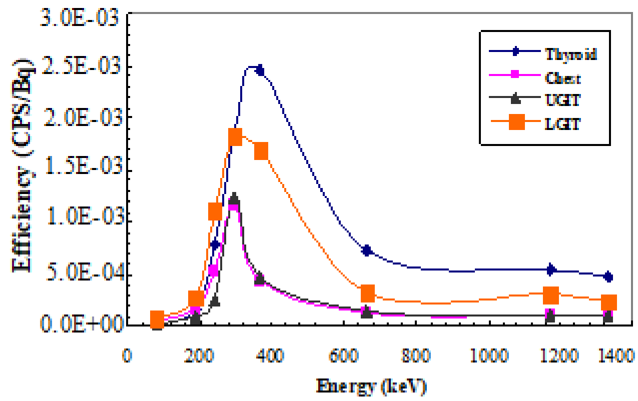

Figure 7: Organ Compartment Efficiencies of Accuscan II Whole Body Counter using Transfer Phantom in Screening Position Geometry

Due to different in Egyptian body sizes so that the thyroid detector distance will change and the counting efficiency of thyroid gland will change too as shown in Fig.8. The committed dose equivalents (CDE) for some individuals contaminated with radioiodine have been measured in diagnostic and screening geometry using organ dose equivalent conversion factor of 2.92E-7 Sv/Bq (James Martin , 2006)[7] as shown in table.2.

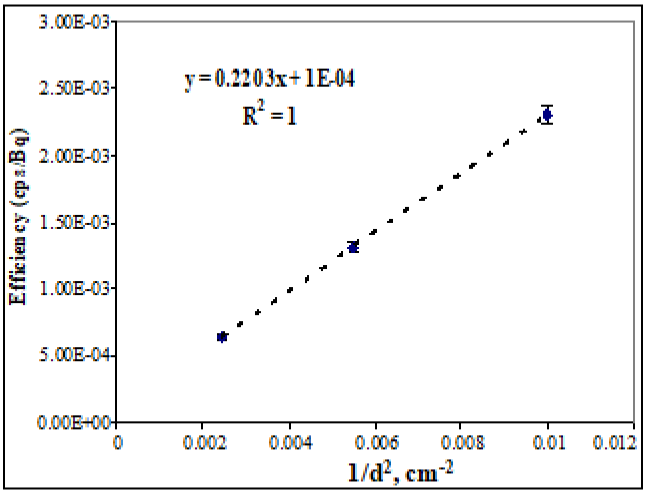

Figure 8: Relationship between Source Detector Distance, SDD and counting efficiency

The committed dose equivalents of I-131 measured in thyroid of some individuals were ranged from 10.80 ± 0.76 to 60.60 ± 0.52 μSv in screening position Iodine deposited in the transfer compartment is removed with biological half life of 0.25 days. The thyroid gland takes 30%, and 70% is excreted [(8)]. Since the I-131 has a short effective half of 7.6 day, so after approximately of three months from the intake date all the radioiodine will clear out of a human body. So, the follow up of internal contamination by whole body counter is necessary to protect the individuals from unwanted dose as advised by (Piruzan *et al* 2006)[9] .

Table 2: The committed dose equivalents of I-131 in thyroid of some individuals in screening Geometry

Subject Code	Screening Geometry
	Committed Dose Equivalents (μSv)
001	10.80 ± 0.76
002	22.03 ± 0.41
003	22.10 ± 0.33
004	44.04 ± 0.48
005	55.60 ± 0.52
006	53.90 ± 0.54
007	26.04 ± 0.39
008	60.60 ± 0.52
009	35.60 ± 0.49

4. Conclusion

The screening geometry was used to check the individuals contaminated or not. It was used to measure the contaminated persons with I-131. The committed dose equivalents of I-131 were measured in thyroid of some individuals and ranged from 10.80 ± 0.76 to 60.60 ± 0.52 μSv in screening geometry. The counting efficiencies for compartments such as thyroid, chest, upper and lower gastrointestinal tract in screening position was higher than that in diagnostic position by approximately factor of three.

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