THE GAMMA CAMERA AS AN EMERGENCY WHOLE-BODY COUNTER FOR CONTAMINATED PERSONS

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INTRODUCTION

In case of a severe accident with release of large amounts of radionuclides into the environment there will be a great need for equipment to measure contaminated persons. Gamma cameras with large scintillation detectors are available at many hospitals. It would be of great importance if these could be used for measurements of gamma-emitting nuclides as Cs-137, Cs-134 and I-131 in the acute situation as well as in the control work which will be needed for a long period of time. The aim of this work is was to investigate the possibility of using gamma cameras in accident situations and to provide suggestions of measurement procedures. Simplicity was in this context judged to be essential.

MATERIALS AND METHODS

Two gamma cameras have been used. Camera A is an older camera with a 400 mm diameter 9 mm thick NaI(Tl) detector with the possibility to easily connect an external multi channel analyzer (MCA). Energy ranges can thereby be set even for energies above that of Cs-137 (662 keV). With the addition of an extra counterbalance the camera could be handled freely with and without a collimator. Camera B was more modern with a 400 mm diameter 6 mm thick detector and limited possibilities of setting energy ranges. No extra counterbalance could be used so the camera had to remain fixed when used without a collimator.

All calibrations were made with phantoms constructed from various numbers of 300 ml freezing sachets filled with known water solutions of Cs-137, Cs-134, I-131 and potassium. Tap water was used for background meaurements. The sachets were arranged in the form of rectangular boxes of various sizes, as well as three body-shaped phantoms simulating a four year old child (14 kg) as well as two adults of different sizes (60 kg and 90 kg).

At measurements the phantom was placed on a bed with a flat surface. The distance phantom surface - detector was 5 cm, 20 cm, and 35 cm respectively. At measurements with the body shaped phantoms the camera head was placed in two fixed positions one centered over the throat (thyroid) and one over the center of the body. At measurments with the box phantoms the camera head was fixed over the geometrical center of the phantoms.

Camera A was used with High Energy General Purpose (HEGP) collimator, Low Energy General Purpose (LEGP) collimator and without a collimator. The energy ranges investigated were 50 - 450 keV, 450 - 550 keV, 550 keV - 750 keV. Camera B was only used without a collimator and the investigated energy ranges were 50 - 450 keV and 450 - 511keV, the maximum possible energy to be pulse height analyzed for that camera.

Minimum detectable activities (MDAs) were calculated as three standard deviations of the background counts for 1 minute measuring time. In sensitivity values, cps/Bq, cps refer to the net counts from the present nuclide when background counts, from measurement with background fantom in the same energy interval, is subtracted. All MDA values, in Bq, and all sensitivity values, in cps/Bq, refer to total activity in the phantoms.

RESULTS

The highest sensitivity is achieved in the large low energy range, 50 - 450 keV, with camera A without collimator. In all three energy ranges the sensitivity decreases with increasing distance phantom surface - detector. The sensitivity for the Cs-137 phantom at constant distance phantom surface - detector decreases with increasing length, width and thickness of the phantom. The background increases with increasing distance phantom surface - detector and decreases with increasing length, width and thickness of the phantom. The variations of sensitivity and background with phantom size is larg at 5 cm distance phantom surface - detector. At 35 cm distance the variations are much smaller and for "adult" sizes of phantoms, especially in the low energy range, almost constant. MDA values for adult phantoms are in the low energy range 400 Bq (5 cm distance) to 1000 Bq (35 cm distance). The MDA values in highest energy range, covering the Cs-137 full energy peak, are 1,3 - 1,8 times higher than in the lowest energy range. In the intermediate energy range the MDAs are higher by a factor of 3 - 4 than in the low energy range.

With LEGP collimator variations of sensitivity and background with distance phantom surface - detector, and with phantom size, are similar but more pronounced than without collimator. The level of the background values are lower, but the sensitivity values are also lower, which gives higher MDA values by a factor of 3 - 4. Values of MDA with use of the HEGP collimator are approximately 10 times higher than without collimator.

MDA values of I-131 in thyroid at measurement over the phantom throat at 5 - 35 cm distance are in the low energy interval 100 Bq - 450 Bq without collimator, 800 Bq - 2500 Bq with LEGP collimator, and 12000 Bq - 17000 Bq with HEGP collimator.

All calibration measurements of potassium show that K-40 is not detectable (refering to three standard deviations of the background counts).

The sensitivity for camera B is in the low energy interval about 20 - 40% lower for both I-131 and Cs-134,137. In the intermediate energy range 450 keV - 511 keV, compared to 450keV - 550 keV for Camera A, the sensitivity is reduced by a factor 2 to 5.

Table 1. Sensitivity, background and MDA values (1 min. measuring time) for camera A at 35 cm height above adult phantom Whole-body Cs-137 measured over the center of the phantom; I-131 in thyroid measured above thyroid. Comparison with standard measurements at the whole-body counter (WBC) in Göteborg (one - two 12,5 x 10 cm NaI(Tl) detectors).

Energy range (keV)	Collimator	Sensitivity, Cs-137 [cps/Bq]	Sensitivity I-131 in thyroid [cps/Bq]	Background countrate [cps]	MDA Cs-137 (Bq)	MDA I-131 (Bq)
50 - 450	No	2.1E-02	4.7E-02	3200	1000	450
450 - 550		8.5E-04	2.0E-04	80	4100	17000
550 - 750		2.2E-03	4.7E-04	110	1800	8500
50 - 450	LEGP	2.4E-03	3.4E-03	460	3500	2500
450 - 550		2.3E-04	8.4E-05	35	10000	27000
550 - 750		6.4E-04	1.6E-04	65	4900	20000
50 - 450	HEGP	1.5E-04	4.1E-04	330	24000	17000
550 - 750		8.0E-05	5.4E-04	40	16000	4500
WBC Göteborg (1,2)		1.2E-03	2.2E-02	0.5 (Cs-137) 0.4 (I-131)	230	3

DISCUSSION

The most important parameter is the background. For the normal standard gamma camera, the background constitutes the major part of the pulses in the camera, without or with a contaminated person. This makes a stable and known background extremely important. A "normal" change in background - due to changes in the general background or due to a person passing close to the camera making a shield for a part of the background or due to contaminated persons or items in the neighbourhood of the camera or due to a different body shape of the measured person or another distance person to camera head than taken into account - can alter the measured value with thousands of Bq. Lead shields around the camera will decrease the background and its variations. Moreover a lead shield under the camera head reduces the photon field from below, including scattered photons, and hence reduces the background (3).

A realistic goal is to keep the background within six SD of the mean (i.e. double MDA values). This requires stable background conditions and a background calibration measurement performed in the present outdoor contamination situation. If the background is kept within these limits an activity measurement at the MDA level means that the activity in the body is somewhere between 0 Bq and an activity corresponding to two MDAs. Hence the accuracy of activity measurements increases with increasing activity in the body. However the MDA values are in most cases low when considering the doses achieved from internal contamination. For a person of 70 kg a constant body burden of 160 kBq Cs-137 gives a yearly effective dose of 5 mSv. For a child of 10 kg the corresponding figure is 24 kBq (4). An intake of 120 kBq I-131 giving 35 kBq at maximum in thyroid gives a thyroid dose of 50 mSv (5).

Suggested measurement procedure

To maximize the sensitivity of the gamma camera, a camera with a thick chrystal and without collimator is to prefer. The most sensitive energy interval is in all situations for all nuclides 50 - 450 keV or larger. To minimize the changes in background with various body sizes, a not to short, but fixed, distance body surface - chrystal should be used e.g. 30 - 40 cm. Since the background without phantom/person varies with distance of the camera head above the floor, the most stable condition is a fixed camera head above a flat bed possible to change in height. A gamma camera without a collimator is difficult to handle so a convenient height may be difficult to achieve without special arrangements. The person making the measurement should be placed at a fixed place at least a few meters away from the camera. No other persons should be allowed in the closest area.

For calibration it is most simple to use simple box phantoms made of larger plastic containers. The size of the phantom should be approximately, length 150 cm - 170 cm, width 30 cm - 40 cm, and height 15 cm - 20 cm. For adults one phantom for background and one for each radionuclide is sufficient. The background phantom could be filled with water or, rather, a mixture of water and 1,5 g - 2 g potassium/kg phantom. For children one or more phantoms sizes may be needed. For calibration of I-131 in thyroid a small container (appr. 20 ml) with I-131 placed under a few cm of water will be sufficient. It is necessary to make often repeated background measurements without a phantom to correct the background values measured with water phantom for changes in the background photon field.

CONCLUSIONS

The gamma camera can be a good and important tool for assessing the internal contamination of gamma-emmitting nuclides in an accident situation. The background is a large source of uncertainty and must be kept low, if possible, and known and stable at all times. To avoid variations in background and sensitivty with body size, which severely influence the accuracy of the measurements, the camera should be used without a collimator, a large low energy interval should be chosen and the distance persons surface - detector should be at least 30 cm. Measurements can then be performed with simple calibration procedures. In the case of low contamination levels near the theoretical MDA values, use of collimator, short distances measured persons surface - detector, or simultaneous measurements of e.g. I-131 and Cs-137,134, somewhat more extensive calibrations are necessary.

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