Experiment report on sensitivity of a gamma camera with and without scattering medium

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Aim - Measure the sensitivity of two collimators at 140keV using a phantom, both in the presence and absence of attenuating material.

Introduction

The extrinsic counting efficiency (sensitivity) of a gamma cameras is an essential parameter for quality control (QC) (Rodrigues & Galiano, 2007). Sensitivity is defined by Prekeges (2012) as the efficiency of the gamma camera to use all of the photons available within a certain period of time. Extrinsic sensitivity can be used to measure overall performance of a gamma camera, in units of counts per second per Mega Becquerel (cps/MBq) derived from the total number of counts within the photo peak window (Santos, Sarmento et al. 2008). Sensitivity values vary depending on crystal thickness and therefore type of collimators used (Prekeges, 2012).

Method

The gamma camera used was a Siemens Ecam. A planar, **10cm square Perspex sensitivity phantom** was injected with 67.03 MBq of Technetium-99m as per department protocol for monthly QC measurements on extrinsic sensitivity.

* Detector heads at 180 degrees.

* The **low energy all purpose (LEAP) collimator** was attached to gamma camera head 1. The phantom was placed squarely in the middle of the detector ensuring the air bubble was in the corner of the phantom.

* Following Siemens QC procedures, camera head 2 was moved to **10centimetres** above camera head 1, measured by a ruler. The ruler could create a systematic error therefore it was checked against a known standard. It could also create a random variation due to the precision of the instrument or operator. This variation could be eliminated by repeating the reading more than 5 times but for the purpose of this experiment with one operator and one ruler, this area of precision was not deemed an issue.

* Total number of counts were recorded over a period of **400 seconds**.

* The attenuating medium '**Superflab**' was placed directly on top of the phantom and another 400 seconds of acquisition was started and total counts recorded.

* The LEAP collimator was substituted by a **low energy high resolution (LEHR) collimator** and the same parameters of data acquisition were repeated, with and without attenuating medium.

Justification of experimental parameters

Count rate Less than than 20,000 counts per second (kcps) to prevent dead time (Prekeges, 2012). **10 kcps** was considered a good compromise between radiation dose and acquisition time.

Radioactivity Technetium-99m was the chosen radionuclide as the aim was to measure the sensitivity at 140keV with a 20% window, and this is most widely used in clinical practice. 10kcps were acquired on a low energy all purpose (LEAP) collimator with a previous measured sensitivity of ~140cps/MBq. The required activity was;

$$10,000 \div 140 = 71.4 MBq \text{ (intended)}$$

70.7MBq – residue of 3.04 = **67.03MBq** @ 14:58hours **(actual)**

Number of counts This experiment aimed to achieve a high precision of 0.1% in the number of counts. To achieve this the number of counts were calculated as follows;

$$\sigma = \sqrt{N}$$

$$2\sigma = 2\sqrt{N} \text{ (for 95\% confidence)}$$

$$2\sqrt{N} = 0.1\%$$

$$N = (2 \div 0.001)^2$$

$$N = 4000,000$$

Data acquisition period LEAP collimator sensitivity is expected to be ~140cps/MBq and 4million counts were needed to get an error of 0.1% therefore the desired acquisition time is;

$$\frac{4000,000}{(140 \times 67.03)} = 426 \text{ seconds}$$

426 seconds was rounded down to **400 seconds** in order to follow departmental QC protocol.

Attenuating medium The chosen attenuating medium was Superflab plastic bolus material, provided in a 1x30x30 centimetre sheet. It is a flexible and tissue equivalent material which conforms to the contour of the phantom and maintains uniformity of thickness (Banaee et al., 2013).

Error Analysis

Factors that affect the experimental precision include the counting statistics and precision of the calibrator. The number of counts was determined to keep the counting statistics to a precision of ~0.1%. The precision of the calibrator is tested on a annual basis and is shown to be ~0.25%. Factors that affect the experimental accuracy include the radionuclide decay during the acquisition time and the accuracy calibration of the radionuclide calibrator. To reduce the error of the decay correction, the mid time point of acquisition, rather than the start time was used. The accuracy of the calibrator is shown to be within 3% of the national primary standard. The uncertainties were combined and the overall error on the sensitivity measurement was shown to be dictated by the accuracy of the calibrator.

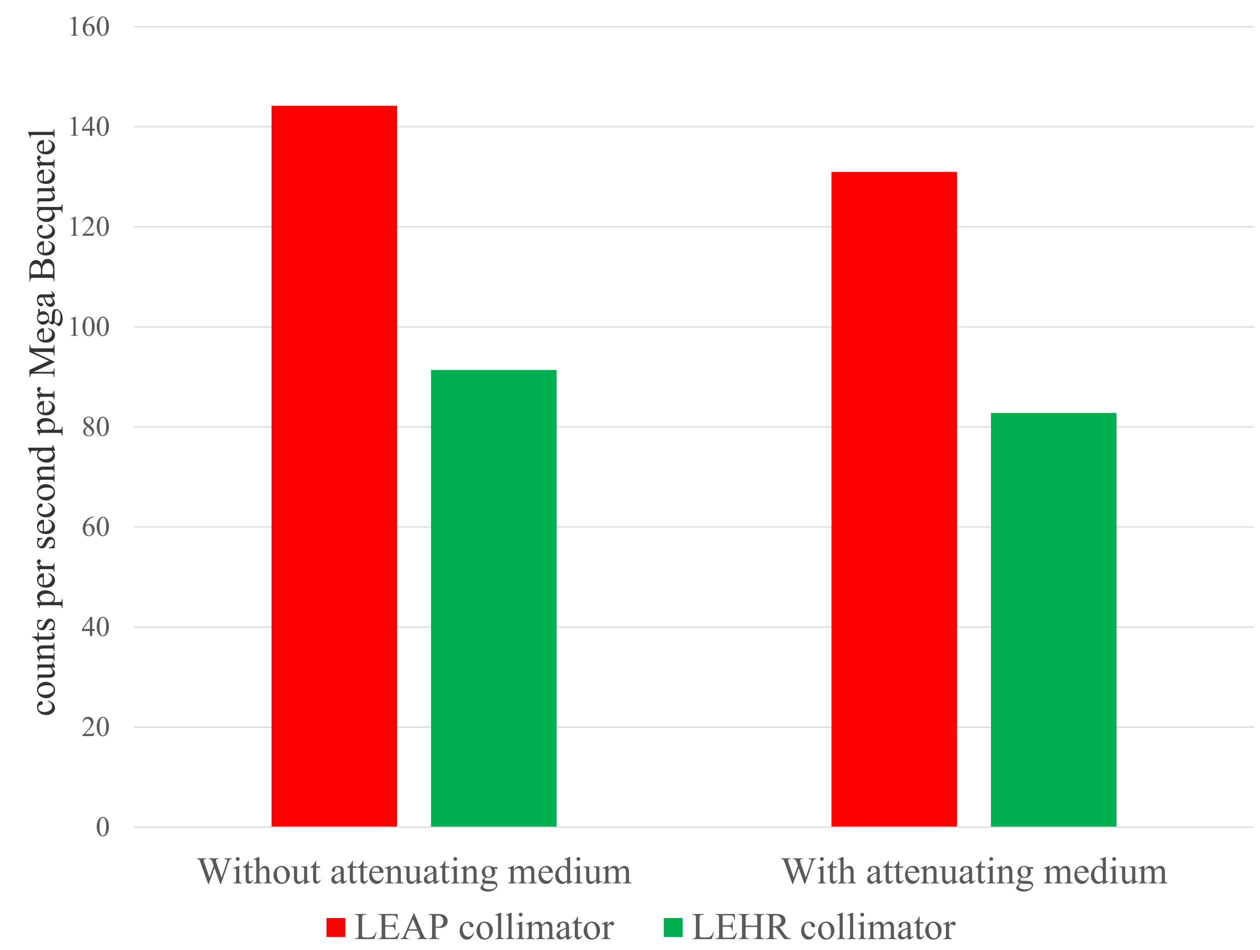
$$\text{Sensitivity} = \frac{\text{Total counts}}{\text{Time} \times \text{Activity}} = \frac{0.1\%}{0\times 3\%} = \sqrt{(0.001)^2 + (0.03)^2} = 3\%$$

$$\text{Overall Experimental Error} = 3\%$$

Results

A bar chart and table showing the sensitivity results of 2 collimators at 140keV with and without the addition of attenuating medium

Collimator	Attenuating medium	Total Counts	Duration in seconds	Activity	Counts per second	Counts per second/per MegaBecquerel
LEAP	none	3614940	400	62.66MBq@ 15.33hours	9037.4	144.2
LEHR	none	2203140	400	60.27MBq@ 15.53hours	5507.8	91.4
LEAP	Superflab	3243924	400	61.46MBq@ 15.43hours	8109.8	131
LEHR	Superflab	1977643	400	59.71MBq@ 16.03hours	4944.1	82.8



Analysis of results

The results show that when using a LEAP collimator the 1cm thick **Superflab** attenuates 9% (131/144x100=91%) of the 140keV radiation compared to 9.4% with the LEHR collimator. The Sensitivity @ 10 cm of a LEAP collimator is documented by Siemens to be 148.5cps/MBq, 3% difference from the experiment result. A lower sensitivity of 90.9cps/MBq is documented for a LEHR collimator, <1% difference from this experiment. An overall 63% difference between collimators correlates to the manufacturers values of 61% difference between the LEAP and LEHR collimators in cps/MBq. Whilst both collimators have holes of an equal length of 24.05mm the diameter of the holes in a LEHR are smaller (1.11mm) compared to the larger holes in a LEAP (1.45mm). This explains why the LEAP is more sensitive as there is a larger circumference for the gamma rays to travel through therefore a greater number of rays can reach the sodium iodide crystal (Siemens, 2016).

Discussion and conclusion

The LEAP collimators have a higher sensitivity compared to the LEHR collimators. These results support the clinical practice of giving larger radiation doses to larger patients (Uppot et al., 2007) as this shows 1cm of tissue equivalent material attenuates 9% of the diagnostic radiation.

Further research could be done with different distances from the phantom and different thicknesses of attenuating medium to see what effect this has.

References

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