

ORIGINAL ARTICLE

Impact of positron emissions from injected patients on *in vitro* test results

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Abstract

Aims This work is intended to establish the effect of ambulatory patients undergoing positron emission tomography (PET) imaging on a sensitive gamma counter that is located within the nuclear medicine department and used for *in-vitro* tests in the department.

Methods The effect on gamma counts recorded by a stationary ^{68}Ge positron source and of a PET patient (100 minutes post injection of 550 MBq ^{18}F-2-deoxy-D-glucose) walking past the Perkin Elmer WIZARD^2 2470 gamma counter's shielded laboratory was measured. Further tests using uniform ^{68}Ge sources both inside and outside the gamma counter laboratory were performed with a ^{99m}Tc glomerular filtration rate gamma counting protocol.

Results The stationary ^{68}Ge sources could be detected by the gamma counter during both a GFR counting protocol and an open-energy window protocol at all distances tested, both inside and outside of the shielded laboratory. A single PET patient walking past the laboratory had a negligible effect on an open counting window.

Conclusions The potential effects of PET patients on the WIZARD^2 gamma counter can be mitigated by ensuring these patients are encouraged to exit the department after their scan without lingering outside the shielded laboratory in the Nuclear Medicine department.

Key words: *gamma counter, positron emission tomography, shielding, F-18*

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Introduction

Integrated Positron Emission Tomography and Computed Tomography (PET-CT) imaging has significantly increased in popularity over the last few years. The benefits of the functional information provided by PET coupled with the anatomical information available from CT, have proven to be highly complementary. In the Queen Alexandra Hospital, ^{18}F-2-deoxy-D-glucose (FDG, half life = 109.8 minutes) is the main PET radiopharmaceutical used. The PET suite in the Hospital is embedded in the main Nuclear Medicine department (Figure 1) and the only patient access to this suite involves patients traversing the main clinical Nuclear Medicine area, directly past the sample analysis laboratory (henceforth called the laboratory). This laboratory contains sensitive

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equipment that could be affected by 'stray' radioactive sources in the department. Whilst the department has always had a continuous flux of patients who have received radioactive injections of a similar level of activity, they are usually with radioisotopes which have significantly lower energy gamma emissions, such as ^{99m}Tc (E = 141 keV), and therefore, such sources have a significantly lower penetrating power through the shielding provided by the walls and doors in the department.

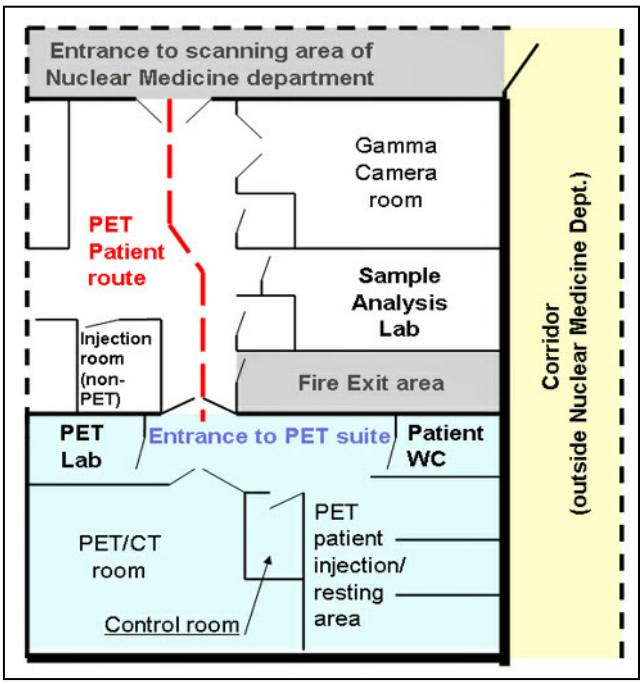

Figure 1 *Plan of the Nuclear Medicine Department*

The Perkin Elmer WIZARD^2 gamma counter is thought to be particularly susceptible to stray positron annihilation emissions given its high sensitivity. This counter does however incorporate its own internal lead shielding in order to minimize the effects of stray radiation on its measurements. The WIZARD^2 is mainly required to measure the radioactivity of blood samples from patients undergoing a glomerular filtration rate (GFR) test, and to measure wipe tests from sealed sources as required. The counting of GFR samples using a ^{99m}Tc energy window routinely occurs when PET patients may be returning through the nuclear medicine department.

Typically, a PET patient will be injected with up to 550 MBq of F-18. They will remain in the PET suite for approximately 90-100 minutes to allow for uptake and imaging before leaving the nuclear medicine department. At this stage, which is approximately 1 half-life after the injection, the remaining activity in their bodies will usually be between 250 and 350 MBq. Also, given the patient body absorption factor of 0.36 for 511 keV photons [1], the apparent activity of the patient is ~200 MBq. The patients are instructed to leave the department directly, therefore in principle they should walk straight past the laboratory without lingering.

The impact of PET patients on the results from the WIZARD^2 was measured on the gamma counter in using unshielded sources inside the laboratory and a patient and stationary unshielded source outside of it.

A ~20 MBq unshielded positron-emitting source was placed at various distances from the Perkin Elmer WIZARD^2 2470 whilst it acquired data. The source(s) was unshielded to minimise backscatter. Three radioactive positron sources were used for this experiment: two identical 10.5 MBq ^{68}Ge sealed line sources, and one 22.3 MBq sealed cylindrical uniform ^{68}Ge source. The activity used was relatively low for reasons of radiation protection, but was sufficiently high to establish whether effects would be seen on the counter. Two different acquisition protocols were run on the gamma counter: 1) the standard GFR protocol which involves a 10 minute acquisition centred on a ^{99m}Tc energy window (120-160 keV) and includes a decay correction, and 2) a 60-minute acquisition with an open-energy window, which does not include decay correction which is used for conducting wipe tests on the counter. The latter of these would also establish the worst effect that a positron source or PET patient could have on the

Table 1 *Comparison Details of WIZARD² experiments. The Tc-99m window is shown as 140 keV ± 20%. The open energy window accepts all measurable incident photons. Note that the experiments with ID 11 and ID 12 were repeated 3 times to get a good estimate of the background radiation present*

ID	PET source(s) used	Total Activity (MBq)	Duration of counting (minutes)	Accepted energy window	Distance from WIZARD² (m)
1	2 x line	21.0	10	140 keV ± 20 %	0.1
2	2 x line	21.0	10	140 keV ± 20 %	1
3	2 x line	21.0	10	140 keV ± 20 %	2
4	2 x line	21.0	10	140 keV ± 20 %	3
5	2 x line	21.0	10	140 keV ± 20 %	4
6	2 x line	21.0	60	Open	0.1
7	2 x line	21.0	60	Open	1
8	2 x line	21.0	60	Open	2
9	2 x line	21.0	60	Open	3
10	2 x line	21.0	60	Open	4
11	Background	0	10	140 keV ± 20 %	N/A
12	Background	0	60	Open	N/A
13	Uniform cylinder	22.6	10	140 keV ± 20 %	7m including shielded door

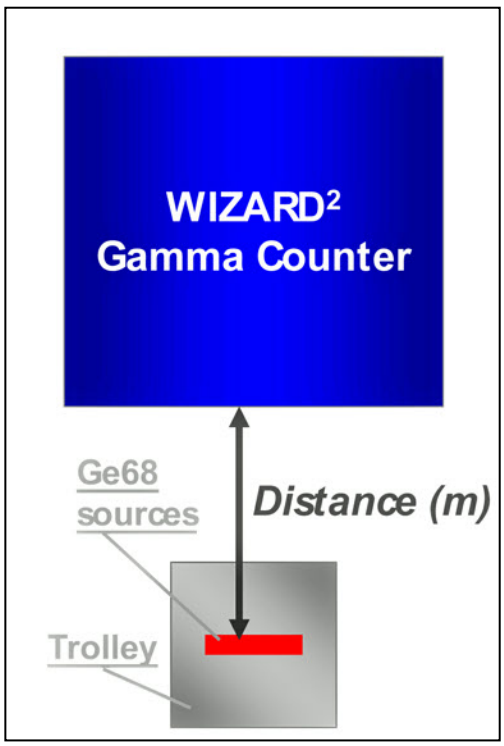

Figure 2 *The experimental setup to test the sensitivity of the WIZARD² to an external source of 511 keV photons*

counter for any other protocols that are likely to be performed.

Good radiation protection practice was employed throughout. Doses rates were calculated and required that the laboratory be designated a controlled area for the duration of the experiments where the sources were inside the lab [3]. The experiment with the cylindrical source outside of the laboratory was done when there were no patients, staff or members of the public present in the department to avoid the possibility of their receiving an unnecessary radiation dose. The set of measurements shown in Table 1 were taken.

The line sources were positioned horizontally on a metal trolley at the required distance from and parallel to the front face of the WIZARD², as shown in Figure 2. They were at approximately the same height as the counter's base. Note that distances were measured horizontally from the front face of the counter.

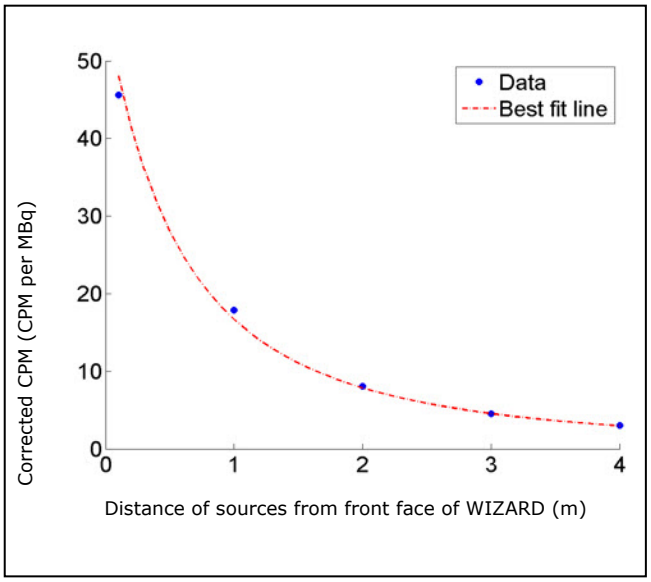

Figure 3 *Background-corrected CPM using line Ge-68 sources with a Tc-99m window as a function of distance*

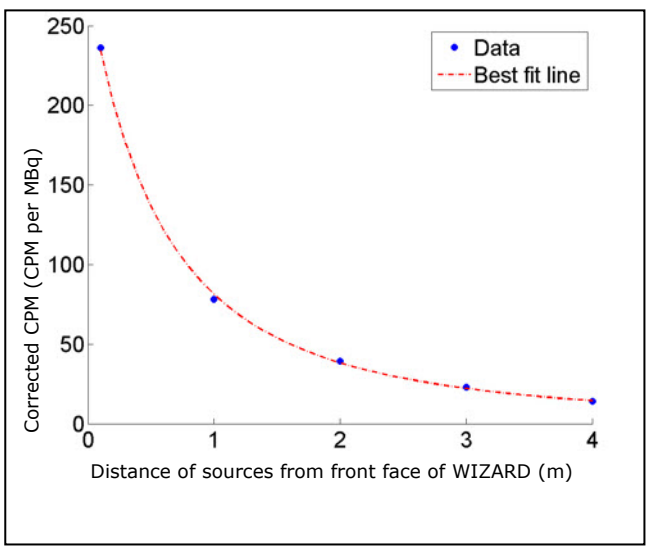

Figure 4 *Background-corrected CPM using Ge-68 sources with an open window as a function of distance*

The uniform cylindrical ^{68}Ge source (activity = 22.3 MBq) was measured during a GFR counting protocol, at a distance 7 m from the gamma counter and outside of the shielded laboratory door, in a position that it would be possible for a PET patient to be in the Nuclear Medicine department.

The positron emitting sources were stationary and in front of the detector for the whole of the counting time. The excess number of counts per minute per MBq (CPM MBq^{-1}) over the background CPM MBq^{-1} measured using the lines sources are shown in Figures 3 and 4.

Results & Discussion

As is seen, from all distances measured between 0.1 m and 4 m, there was a noticeable additional CPM using both a GFR counting protocol and an open energy window counting protocol on the WIZARD^2. The approximate fit to the lines plotted follow

Equation 1 $$y = \frac{A}{(x + x_0)^2}$$

where A is a constant for a given protocol and source combination and x_0 is a constant for the WIZARD^2 which here has been found empirically to be ~1.19. It was found that the average ratio between the CPM in the 2 protocols open energy window: GFR window with distance is 4.9(±0.3):1.

The background total counts and CPM taken for a 60-min open-energy window acquisition are shown in Table 2. The measurements reveal similar CPM for each test: the uncorrected CPM measured with the patient walking directly past the laboratory is actually lower than the background measurements. Therefore, a single PET patient walking straight past the Laboratory without stopping during either GFR counting or open-energy window counting will have a negligible effect on the results.

However, as shown in Table 3, the uniform cylindrical positron source (and therefore a patient) outside of the laboratory for a prolonged period during a GFR counting protocol produces a measurable effect.

Table 2 *Background measurements and uncorrected measurements using an open window when a PET patient walks past the laboratory*

	Total Counts	Counts per minute
Background 1	5002.25	83.37
Background 2	5041.13	84.02
Background 3	4959.81	82.66
With patient walking past	4882.25	81.37

Table 3 *Background measurements and uncorrected measurement when the uniform Positron emitting source was outside the laboratory door at a distance of 7m from the counter of total counts and counts per minute for a GFR counting protocol*

	Total Counts	Counts per minute
Background 1	86.27	8.71
Background 2	82.70	8.52
Background 3	70.48	7.40
Background 4	85.22	8.61
With uniform source outside Laboratory door	172.55	17.45

Table 4 *Possible effect of PET patient on real patient GFR results [5]*

Patient number	Original absolute GFR (ml min^{-1})	Max calculated absolute GFR given PET patient (ml min^{-1})	Min calculated absolute GFR given PET patient (ml min^{-1})
1	94.6	94.7	93.7
2	62.3	62.4	61.9
3	48.9	51.4	39.1
4	85.7	85.8	85.1
5	50.5	50.7	49.6

In this position, the CPM measured over the average background for the acquisition was 9.1 CPM for the 22.3 MBq source, corresponding to an excess 0.4 CPM MBq^{-1}. Given a PET patient standing outside the Sample Analysis Lab before leaving the Nuclear Medicine department who still displays an apparent activity of ~ 200 MBq (i.e. given they have voided reducing their activity by 0.15 [1, 2], there will be patient shielding [1], and some of the original injection isotope will have decayed), one may record an extra 80 CPM on a 10 minute GFR counting protocol. This is equivalent to an extra 800 counts, which could be sufficient to significantly change a GFR result.

To demonstrate the possible effect, a number of patient GFR results are considered in Table 4. These GFR tests are done following a modified version of the technique described by the British Nuclear Medicine Society Guidelines [5] adopting a Brochner and Mortensen correction [4], and taking 2 blood samples at 2 h and 4 h post an injection of approximately 10 MBq of ^{99m}Tc-DTPA. The

counts measured by the gamma counter in the plasma from these samples are background corrected and are used in conjunction with the measured activity in the ^{99m}Tc standard to calculate a patient's GFR result.

Here, the extra 80 CPM are added either to the measurement of the ^{99m}Tc standard, or one of the two blood samples that are measured during a GFR test and the minimum and maximum absolute GFR values given. It was assumed that adding these extra counts to the background measurements would be noticed as the results were checked and therefore would trigger the results to be recounted, whereas the difference in the other samples being counted are unlikely to be noticed.

Whilst the table shows that many of these GFR calculation results are changed very little (typically by less than 2%), the results for patient 3 could be changed by up to 20% (i.e. the original absolute GFR value was 48.9 ml min^{-1}, whereas the minimum calculated absolute GFR given the extra positron counts is 39.1 ml.min^{-1}). This could alter a clinical decision made on behalf of that patient. As this was just a selection of real patient data, it is possible that other patients could suffer from even greater errors in their results given this magnitude of error in the counts measured by the gamma counter for their results.

Conclusion

At all of the distances between the stationary ^{68}Ge sources (containing 21 MBq activity) and the WIZARD^2 gamma counter that were measured (0.1-4 m inside the Sample Analysis Lab and 7 m through the Sample Analysis Lab door), there was a noticeable impact on the counts recorded in both the GFR counting protocol and the open-window counting protocol. As would be expected, the extra counts recorded due to these positron sources reduced with distance. However, even at a distance of 7 m from the gamma counter and through the shielded door of the Laboratory, the 22.3 MBq uniform cylindrical source had a measurable impact on results. Given a patient leaving the nuclear medicine department may have an apparent activity of ~ 200 MBq, if such a patient were to be stand outside of the Sample Analysis Lab for a significant amount of time whilst one of these counting protocols were being run, the WIZARD^2 would be likely to measure an effect. In terms of a GFR test, this could impact on a patient's results. That said, a single PET patient leaving the department reasonably quickly after their scan would have a negligible impact on the counting results. Therefore, the effects on the gamma counter as a consequence of the extra PET patients can be mitigated by encouraging these patients to leave the department directly when they are finished in the PET-CT area of the department. This should be encouraged as a matter of course to minimise the dose that staff and other patients receive as a consequence of these patients.

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