Triggering radiation alarm at security checks. Patients should be informed even after diagnostic nuclear medicine procedures

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Abstract

During the last few years an increasing number of nuclear medicine patients in various countries evoked a radiation alarm after therapeutic or diagnostic procedures, and even after passive exposure. A prospective calculation of activity retention in the patient's body is difficult due to extremely high variation of uptake and kinetics. Furthermore, different sensitivities and distances of the detectors make a prospective calculation even more difficult. In this article a number of cases are being reported, related problems are discussed and the surprisingly very limited literature reviewed. In order to minimize problems after eventually triggering alarms, we strongly recommend that each patient receives a certificate providing personal data, tracer, dose, half-life of the radionuclide, type and date of procedure applied as well as the nuclear medicine unit to contact for further information. Furthermore, a closer cooperation and exchange of information between the authorities and local nuclear medicine societies, would be welcome.

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Introduction

A fast increase in the numbers of diagnostic and therapeutic nuclear medicine procedures and more strict security measures in different countries have led to a so far underestimated problem: patients may trigger radiation alarms - mainly at airports - consequently causing problems for the authorities, the patients and for the institutions that have administered the radionuclide [1].

Description of cases

In this article we describe several such cases of patients who after nuclear medicine procedures triggered the alarm of special detecting equipment in airports or elsewhere. Special aim is to create awareness and offer useful information on that problem to physicians, their patients and to public controlling personnel. In the original reports dating back to 1986 the setting of radiation alarm on Pennsylvania avenue [2] and 1988 in a bank [3] has been described. It was reported in 1986, that two visitors on a public tour to the White House, four days after diagnostic scintigraphy with thallium-201(^{201}Tl) 92.5 MBq, induced the alarm [2]. Another patient triggered the alarm when he was going to his bank to look into his safety box; the patient continued to set up the alarm on consequent visits to his bank until the 9th day after a diagnostic myocardial investigation (^{201}Tl-dose not given in the paper) [3].

Based on an EU-agreement in 1993 [4] and as a consequence of the September 11th attacks, as well as of several other cases who attempted to smuggle radioactive material, security measures were tightened world-wide. It has been reported recently that two patients in Europe triggered the alarm at an airport [5, 6]. In both cases the respective Nuclear Medicine Societies were unaware of the installation of portable radiation detectors as well as of their extremely high sensitivity. In one case, a 55 years old pilot travelling as a crew member to Moscow triggered the alarm 4 days after a ^{201}Tl myocardial perfusion scan that gave him a standard dose of 80MBq of the radiopharmaceutical. The patient was detained but explained that he underwent myocardial perfusion scintigraphy and that the radioactive isotope may have triggered the alarm, so he was soon after released. However, it was at the same airport 4 days later when he again triggered the alarm. He was again detained, but very soon released and the airport security officers gave him a card to carry while travelling, a recommendation delivered long before in the United States. This card explained clearly his propensity for setting off alarms as a consequence of his ^{201}Tl scintigraphy [5]. The other case was a patient who 25 days after radioiodine (^{131}I) treatment with 148 MBq for toxic multinodular goitre, triggered the alarm at the Vienna-Schwechat airport after returning from Frankfurt, where he did not evoke an alarm. The reporting author phoned to the security staff at the airport to assist the patient. The staff mentioned that already two other patients had triggered the alarm before. The public and the nuclear medicine community in Austria did not become aware of the above described incidents at any time. Almost two decades after the original description of the problem [2, 3], in November 2006, six more people having been treated with 740 MBq of ^{131}I, triggered the alarm during the annual Christmas tree lighting in the New York Rockefeller Center [7].

Other cases on triggering alarms after diagnostic [2, 3, 8] or after therapeutic [6, 9-11] applications and even after passive incorporation of ^{131}I by a wife whose the husband has been treated with 185 MBq of ^{131}I 15 days before, have been reported [12]. In August 2006 a British citizen set off the sensors at the Orlando airport six weeks after receiving 400 MBq of radioiodine treatment. This case was published as "lesson of the week" in BMJ [10]. Another patient 24 days after receiving 1.1 GBq ^{131}I at Miami triggered the alarm [13]. After 38 days when radiation dosimetry was 30 μSv/h he did not trigger the allarm at the same airport [13].

In March 2003 a bus on the route from New York to Atlantic City was stopped after triggering an alarm when passing a radiation detector in a tunnel. A passenger had received 370 MBq ^{131}I earlier that day [14]. The patient ignored the written instruction of the Nuclear Medicine Department not to use public transportation for at least two days.

The majority of the patients described above had received radioiodine. These cases are definitely by far underreported in scientific literature. Authorities don't inform nuclear medicine societies, patients don't contact their physicians, etc. In fact, nobody around the world keeps data on how often patients were stopped, at what intervals and for what isotopes.

We introduced a radiation protection certificate at the Institute for Nuclear Medicine, ISOTOPIX, in Vienna related to previous studies [6]. This certificate written in English beside patient's data, contains information on the tracer administered, the dose, the half-life of the radionuclide, the date and time and the type of investigation or of treatment as well as the contact information of the respective institute. This certificate is being handed out to all foreigners and all patients receiving radioisotopes for treatment. All other patients are asked whether they plan to cross the country's border within the given time limits (Table 1). If they intend to do so they get this certificate as well as all other patients who request it, even after they underwent diagnostic procedures.

Radiation dose rate measurement of another patient gave an amount of 30 μSv/h 38 days after the application of 1.1 GBq of ^{131}I [9]. Key problems are that the distance of measurement is not mentioned and the sensitivity of the (different) detectors is unknown. To us the sensitivity seems to be very high. Considering the decay after 38 days there still remains an activity of 42 MBq. Excretion, however, is not considered in that assumption. Gamma dose rate constant of ^{131}I is 0.066 μSv.m^2/(MBq.h), that means at 1 m distance 1 MBq from ^{131}I produces a dose rate of 0.066 μSv/h, therefore 42 MBq are producing a maximum of 2.8 μSv/h. To detect 30 μSv/h the detector should have been placed at a distance of much less than 33 cm most likely directly on the surface of the patient's body. According to our experience, in patients with a remaining activity of 185 MBq at 1m we find a dose rate of less than 11 μSv/h. Passive incorporation in our patient triggering an alarm revealed an effective dose of 0.85 mSv. Again the sensitivity of the detectors must have been extremely high and the distance very low, information that was not provided by the authorities.

Table 1. *Number of days up to which alarms may be triggered after administration of frequently used tracers* [4, 21] *when patients walk through sensitive portal detectors*

Radionuclide	Number of days
Fluoride-18	1
Technetium-99m	3
Iodine-123	3
Indium-111	14
Gallium-67	30
Thallium-201	30
Iodine-131	95

Two patients one female, aged 57 years, 13 days after receiving 185 MBq of ^{131}I treatment and a 47 year old male, 16 days after a diagnostic gallium-67 (^{67}Ga)-scintigraphy with 185 MBq, triggered the alarm. These patients already were able to show this certificate which was accepted by the authorities without any problem.

The proposed certificate should be used with caution.

Two patients, a female aged 54 years, 8 days after ^{131}I treatment with 185 MBq and another 64 years old male, 3 days after ^{201}Tl-myocardial scintigraphy (with 80 MBq) presented their certificate to the authorities of the airport although they did not trigger the alarm. This turned out not to be wise because thereafter they had been thoroughly investigated and examined. Actually, the first of these cases was allowed to continue her journey only after the authorities confirmed the content of the certificate through the patient's nuclear medicine unit by phone.

Discussion

In Italy, information on the administration of radioactive material to a patient is included in the final report of the scintigraphic examination or of the therapeutic procedure. However, this requires that the patient/passenger travels carrying the report and presents all his/her medical personal data to the Customs. It is certainly better that patients receive a certif-

Table 2. *Basics for assessment of retention (examples); modified from* [8]

Radionuclide	Physical half-life (h)	Pharmacon	Fraction f (%)	Biolog. half-life (h)	Effective half-life (h)	Elimination constant λ (h^{-1})
$^{131}I^{a)}$	192.5	NaI	f_1: 95 f_2: 5	6.0 1920	5.82 175	λ_1: 0.12 λ_2: 0.004
$^{131}I^{b)}$	192.5	NaI	f_1: 40 f_2: 60	6.0 1920	5.82 175	λ_1: 0.12 λ_2: 0.004
^{153}Sm	46.7	EDTMP	f_1: 46 f_2: 54	2.8 ∞	2.6 46.7	λ_1: 0.267 λ_2: 0.015

a) thyroid cancer patient after thyroidectomy , b) patient with benign thyroid disease, f_1: fraction of the compartment "blood"; f_2: fraction of the compartment "target organ", λ: elimination constant (= ln 2)

icate with data on radioactivity, the type of radiopharmaceutical administered and the kind of examination performed. At the Institute of Nuclear Medicine in Perugia a similar informational procedure certificate has been recently introduced.

Several problems still remain: The extremely high sensitivity of the various detecting devices [15], such as pagers, portable or fixed detectors, can not differentiate between therapeutically or diagnostically used radiopharmaceuticals and smuggling, which would certainly be detected even at much higher dose ranges. This problem has been recognised by the manufacturers of the detector systems, considering that it may be more accurate to use gamma spectroscopy with a special software allowing to distinguish between radionuclides usually used in medicine and potentially hazardous radioactive material. However, as reported earlier [12], smugglers again may overcome this approach by adding radioactive substances commonly used in medicine, to mask the spectrum of forbidden radioactivity. Definitely, the use of gamma spectroscopic systems and higher alert level settings, might highly improve the actual detection ability between true and false positive alarms.

There is apparently a focus onto gamma energy, most likely because it is the easiest to be detected. On the other hand, the extremely high sensitivity of detectors does not make any sense and does not offer advantage against criminal acts. It would be much more difficult to assess the "bremsstrahlung" of beta-emitters like ^{90}Y or ^{32}P. Beta-radiation would be even more difficult to detect. Such specific devices would be extremely expensive and more prone to any damage.

It could be suggested as optimal, to lower the sensitivity of detectors and to be able to calculate in advance the time between application of the radioactive material and the time it potentially enters a check point. However, this will not be practical for several reasons. For example: Samarium-153 (^{153}Sm-ethylene diamine tetramethylene phosphonic acid - ^{153}Sm-EDTMP) administered for bone pain palliation, has been reported to be retained in the human body 24 h after its administration in an extremely wide range between 29%-89%. Investigations have shown that some preparations of ^{153}Sm are contaminated [16] with various europium isotopes (^{152}Eu, ^{154}Eu and ^{156}Eu), two of them ^{152}Eu and ^{154}Eu, having extremely long half lives of 13.33 and 8.8 years, respectively. Impurities with ^{152}Eu and ^{154}Eu contribute to about 1.0% - 1.5% to the effective dose after treatment with 1.11 GBq of ^{153}Sm-EDTMP. For example, in cases of repeated administration of ^{153}Sm according to the Vienna protocol [17], the long-lived europium isotopes may contribute up to 20% of the total effective dose, lasting almost for the rest of the patient's life (Table 2) [6]. It is a pity that calculations for the medical use of radioisotopes concerning uptake (range and mean-value) calculated versus measured, are not available and thus, values of effective doses are difficult to calculate exactly or even approximately.

The effective dose is derived from external as well as internal radiation exposure. A calculation in relatives from patients receiving ^{131}I shows that after very close contact, they might receive up to 10% of the patient's dose. This might explain that only one such case of passive incorporation [12] as a consequence of her husband's treatment has been reported to trigger an alarm. They may detect doses as low as 37 KBq in a particular person [8] passing through the portal detector.

In 2008 more than 10,000 portable radiation detectors are in use in the United States. Surprisingly, very little related information is available in Europe.

Authorities using radiation detectors, patients and particularly nuclear medicine physicians should draw more attention to this problem and as postulated already several times many years ago [6, 14, 18] inform every patient properly.

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