Rev Esp Med Nucl Imagen Mol. 2016;35(3):175–185

Original Article

Radiation dose produced by patients during radiopharmaceutical incorporation in nuclear medicine diagnostic procedures☆

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ARTICLE INFO

Article history:
Received 13 August 2015
Accepted 13 October 2015

Keywords:
Nuclear medicine
Radiation protection
Dose to members of the public
Diagnostic procedure
Radiopharmaceutical incorporation

ABSTRACT

Objectives: The aim of this study was to assess the dose received by members of the public due to close contact with patients undergoing nuclear medicine procedures during radiopharmaceutical incorporation, and comparing it with the emitted radiation dose when the test was complete, in order to establish recommendations.
Material and methods: A prospective study was conducted on 194 patients. $H^*(10)$ dose rates were measured at 0.1, 0.5, and 1.0 m after the radiopharmaceutical administration, before the image acquisition, and at the end of the nuclear medicine procedure. Effective dose for different close contact scenarios were calculated, according to 95th percentile value (bone scans) and the maximum value (remaining tests).
Results: During the radiopharmaceutical incorporation, a person who stays with another injected patient in the same waiting room may receive up to 0.59 mSv. If the patient had a medical appointment, or went to a restaurant or a coffee shop, members of the public could receive 23, 43, and 22 μSv, respectively. After finishing the procedure, these doses are reduced by a factor 3. In most of the studies, the use of private instead of public transport may reduce the dose by more than a factor 6.
Conclusion: It is recommended to increase the distance between the patients during the radiopharmaceutical incorporation and to distribute them according to the diagnostic procedure. Patients should be encouraged to use private instead of public transport. Depending on the number of nuclear medicine outpatients per year attended by a physician, it could be necessary to apply restrictions.

Dosis de radiación producida por los pacientes durante la incorporación del radiofármaco en las pruebas diagnósticas de medicina nuclear

Palabras clave:
Medicina nuclear
Protección radiológica
Dosis al público
Procedimiento diagnóstico
Incorporación del radiofármaco

RESUMEN

Objetivos: Evaluar la dosis que pueden recibir los miembros del público debido al contacto con pacientes de medicina nuclear durante la incorporación del radiofármaco y compararla con la dosis impartida una vez finalizado el estudio, con el fin de establecer recomendaciones.
Material y métodos: Se estudiaron 194 pacientes de forma prospectiva. Se midió la tasa de dosis $H^*(10)$ a 0,1; 0,5 y 1 m tras la administración del radiofármaco, antes de la imagen y finalizada la prueba diagnóstica. Se calcularon las dosis efectivas para diferentes circunstancias de contacto, mediante el percentil-95 (gammagrafías óseas) y el valor máximo (resto de los estudios).
Resultados: La dosis máxima que recibe el paciente por compartir sala de espera con otro paciente, durante la incorporación del radiofármaco, es 0,59 mSv. Si acudiese a una consulta médica, a un restaurante o a una cafetería las dosis a terceros alcanzarían los 23, 43 y 22 μSv. Estas dosis se reducen en un factor 3 cuando dicha actividad tiene lugar una vez finalizada la prueba. En la mayoría de los estudios, el uso del transporte privado, frente al público, reduce la dosis en un factor superior a 6.
Conclusiones: Durante la incorporación del radiofármaco se recomienda maximizar la distancia entre pacientes y hacer una distribución de los mismos en función del tipo de estudio. Debe fomentarse que los pacientes hagan uso del transporte privado frente al público. Dependiendo del número de pacientes de medicina nuclear por año que reciba un médico en su consulta, puede ser necesario aplicar restricciones.

☆ Please cite this article as: Morán V, Prieto E, García-García B, Barbés B, Ribelles MJ, Richter JÁ, et al. Dosis de radiación producida por los pacientes durante la incorporación del radiofármaco en las pruebas diagnósticas de medicina nuclear. Rev Esp Med Nucl Imagen Mol. 2016;35:175–185.
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2253-8089/

Introduction

Members of the public may sometimes be exposed to radiation from patients receiving a radiopharmaceutical. Therefore, several studies have evaluated the radiation dose to which the public is exposed due to contact with patients undergoing diagnostic studies involving conventional nuclear medicine procedures[1,2] as well as positron emission tomography (PET).[3,4] In addition, the possible radiological impact of high levels of radiation received during therapy have led to studies on the radiation dose received by third parties in contact with patients treated with radiopharmaceuticals.[5] National practical guidelines have been established with the aim of unifying the application of basic international recommendations for radiological discharge of patients treated with radiopharmaceuticals.[6] On the other hand, some studies have assessed the dose received by technical personnel during diagnostic procedures including PET.[7,8] Technical staff are not considered members of the public since these professionals are exposed to ionizing radiation. However, little information is available on the radiation dose produced by patients during the period of radiopharmaceutical incorporation.[9] Estimation of the dose and the recommendations derived thereof should be made based on worst-case scenarios, that is, those in which the dose rates are highest.

Nuclear medicine departments have rooms in which the patients remain from the time the radiopharmaceutical is administered until the imaging study is performed.[10,11] This so-called waiting room for patients who have been administered the radiopharmaceutical is designed according to the ALARA principle which establishes that the dose should be as low as reasonably possible. While the patient is in this room other patients will be exposed to radiation but not members of the public not related to nuclear medicine procedures. When the diagnostic procedure is completed and the patient leaves the nuclear medicine department there continues to be a risk of radiation exposure, and yet there are no norms for radiological protection. Taking this into account it would be of interest to know the radiation dose received by patients on being in the waiting room and compare the dose received by members of the public if the patients do not remain in the waiting room during incorporation of the radiopharmaceutical and the dose the public receives when the contact is made upon the patient having completed the diagnostic test.

The aim of this study was to evaluate the radiation dose members of the public can receive from contact with nuclear medicine patients during the radiopharmaceutical incorporation and compare this dose with that produced by patients after having completed the diagnostic study in order to establish recommendations taking into account that current legislation requires that the public should not receive doses greater than 1 mSv over one year.[12]

Material and methods

Patients and diagnostic procedures

We prospectively studied 194 patients attending the Department of Nuclear Medicine for any of the following diagnostic procedures: bone scintigraphy ($N = 145$), parathyroid scintigraphy ($N = 4$), ventilation study/pulmonary perfusion ($N = 6$), glomerular filtration ($N = 3$), scintigraphy of the salivary glands ($N = 2$), thyroid scintigraphy with ^{99m}Tc ($N = 10$), myocardial perfusion study ($N = 2$), sentinel lymph node detection ($N = 12$), scan with ^{67}Ga ($N = 2$), somatostatin receptor scintigraphy with ^{111}In ($N = 2$), isotopic lymphography ($N = 5$) and leukocytes labeled with ^{99m}Tc ($N = 3$). The following data of each patient were collected: gender, age, body mass and height as well as the radioactivity of the radiopharmaceutical and the time of administration.

Measurement of the dose rate

A MiniTRACE ɣ Geiger-Müller detector (Genitron Instruments, Frankfurt, Germany) was used to determine the dose rate measuring the ambient dose equivalent $H^*(10)$. Since the equipment is calibrated with a source of ^{137}Cs, the calibration factor for ^{99m}Tc was determined using the gamma constant to measure the ambient dose equivalent.[13] Thirty measurements of a point source of 750 MBq of ^{99m}Tc in air were made. The measurements showed a statistical variability of 3%, and the calibration factor was 1.28.

On the other hand, to characterize the angle response of the measuring equipment a series of 30 measurements were made varying the angle position between the detector and the source (0°, ±30°, ±45°, ±60° and ±90°). The results obtained showed that the maximum difference of the dose rate measured with respect to the central position (0°) was less than 10%. This factor was not taken into account because the distribution of radioactivity of the patient and thus, the incidence of the photon angle in the detector was unknown.

In general the dose rate of each patient was measured after administration of the radiopharmaceutical prior to the imaging study (pre-miction) and when the patient left the Nuclear Medicine Department. The dose rate was measured at the level of the sternon and in an orthostatic position at 0.1, 0.5 and 1 m of distance.[2,5,8,14] Likewise, background radiation was also measured and the time of each measurement was registered. Lastly, the dose rate was calculated by unit of radioactivity administered.

Based on the acquisition protocol of the diagnostic test and the time of incorporation of the radiopharmaceutical, different sets of measurement were performed. Fig. 1 shows the time sequence of the different measures for each study together with the time of incorporation of the radiopharmaceutical and the time of image processing. The values presented are those used in our department which have been adapted from the Serena Puig and Campos Villarino protocols.[15]

On the other hand, we estimated the time of incorporation of the radiopharmaceutical (time from the time of administration of the radiopharmaceutical to the beginning of the imaging study) and the total time the patient remained in the Nuclear Medicine Department. This total time included the incorporation of the radiopharmaceutical, the time the patient was in the washroom and the dressing room, correct positioning in the equipment, image acquisition and the waiting time until the physician decided that no further studies were needed and the patient could leave.

Estimation of the effective dose

We calculated the radiation dose to which determined subjects such as a relative, or social contact or co-worker might be exposed on contact with a patient undergoing a nuclear medicine diagnostic test. We determined the dose produced from the measured dose rates and the time of permanence, considering only radioactive decay without taking into account the biological elimination of the radiopharmaceutical.

To do this we first obtained the ambient dose equivalent using the law of radioactive decay:

$$D = \int_{t_1}^{t_2} \dot{D}_0 \cdot e^{\frac{-\ln 2 \cdot t}{T}} \cdot dt = \frac{T}{\ln 2} \cdot \dot{D}_0 \cdot e^{\frac{-\ln 2 \cdot t_1}{T}} \left[1 - e^{\frac{-\ln 2 \cdot (t_2 - t_1)}{T}}\right]$$

where t_1 and t_2 are, respectively, the times at which the contact begins and finishes, T is the period of semidecay of the radiopharmaceutical, and $\dot{D}_0$ is the dose rate measured at the corresponding time point.

Finally, the magnitude of the ambient dose equivalent was converted into the effective dose from the coefficients shown in table