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Journal of Radiation Research and Applied Sciences

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Estimation of kidney and bladder radionuclide activity for patients undergoing bone scan

Luc T. Bambara [a], *Augustine K. Kyere* [a], *Francis Hasford* [a,b,*], *Edem K. Sosu* [a,b], *Isaac K. Wilson* [c]

[a] *School of Nuclear and Allied Sciences, University of Ghana, P.O. Box AE1, Accra, Ghana*

[b] *Radiological and Medical Sciences Research Institute, Ghana Atomic Energy Commission, P.O. Box LG 80, Accra, Ghana*

[c] *National Centre for Radiotherapy and Nuclear Medicine, Korle-Bu Teaching Hospital, P.O. Box KB 369, Accra, Ghana*

ARTICLE INFO

Article history:
Received 6 February 2015
Received in revised form
10 April 2015
Accepted 28 April 2015
Available online 14 May 2015

Keywords:
Counts of activity
Quantitative assessment
Primary bone tumour
Scintigraphy
Radionuclide

ABSTRACT

Radionuclide activities in the kidney and bladder have been estimated experimentally from practical data 3 h after injection of Tc-99m MDP, using conjugate view methodology. The study involved sixty-five patient images from the database of a nuclear medicine department in Ghana. Time−activity curve was stimulated with MatLab computer program using biokinetic model published in MIRD Report 13. The model was used to determine theoretical activities in kidney and bladder, which were compared with the experimental data. Estimated radionuclide activities for the kidney and bladder were both minimal in the experimental case comparative to the theoretical. The fraction of injected activity in kidney and bladder were less than 1% of injected activity, and hence kidney and bladder could be seen to receive very low doses during bone scans.

1. Introduction

Nuclear medicine is a medical specialty using radioisotopes as tracers to diagnose diseases or for therapy. These tracers are usually attached to chemical compounds that are attracted to organs of interest such as bones or thyroid gland. After administration into the body, tracers emit characteristic radiations. Special electronic instruments, such as scintillation detector or a gamma camera, displays the recorded emissions as images. The images yield information about the anatomy or the functional state of the organ being imaged.

In clinical applications of nuclear medicine, the amount of administered activity is low such that its corresponding absorbed dose to imaged and non-imaged tissues are typically very low and thus stochastic effect are outweighed by the diagnostic benefit of the imaging process (Bolch & Fahey, 2013). The role of internal dosimetry in diagnostic nuclear medicine is thus to provide the basis for stochastic risk quantification. Once this risk is quantified, it may be used to

* *Corresponding author*. Medical Radiation Physics Centre, Radiological and Medical Sciences Research Institute, Ghana Atomic Energy Commission, P.O. Box LG 80 Legon, Accra, Ghana.
E-mail addresses: haspee@yahoo.co.uk, haspee@gmail.com (F. Hasford).
Peer review under responsibility of The Egyptian Society of Radiation Sciences and Applications.
http://dx.doi.org/10.1016/j.jrras.2015.04.005

optimize the amount of administered activity in order to maximize image quality while minimizing patient risk. This optimization is considered, and always evaluated for any imaging procedure (IAEA, 2011).

Accurate dosimetry of diagnostic procedures is important for making judgments on the diagnostic benefits to the patient compared to the associated radiation risks. Dosimetry of diagnostic radiopharmaceuticals is therefore primarily concerned with the dosimetry of a total population or group (Hickson, 2011). Image quantification in nuclear medicine is used, among other options, to estimate activity in human subjects for the calculation of radiation dose in individuals undergoing radionuclide therapy and to study pharmacokinetics for approval of new radiopharmaceuticals (Pereira, Stabin, Lima, Guimarães, & Forrester, 2010; Sgouros et al., 2003).

The objective of this study is to determine the amount of radionuclide activity in kidney and bladder of patients 3 h after injection of technetium-99m (Tc-99m) in nuclear medicine, using conjugate view approach.

2. Methodology

Single photon emission computed tomography (SPECT) system (Siemens, Germany) was used for performing bone scans on patients as employed in studies by Yigbedeck et al. (2014) and Hasford et al. (2015). The system was equipped with low energy all purpose collimator and whole-body images acquired 3 h post-injection of Tc-99m methylene diphosphonate (MDP). Quantitative analyses were performed on acquired images by drawing regions of interest (ROIs) in the system's e.soft software application, and tabulating counts of radionuclide activity in the bladder and kidneys.

Whole-body bone scintigrams of 65 patients acquired with the SPECT system were randomly selected for this study. Computed tomography (CT) scans of 36 of the sampled patients were obtained and used in estimating average thicknesses of the organs of interest and their associated body section. RadiAnt DICOM viewer software was used in measuring the thicknesses in the anterior – posterior direction. Table A1 in Appendix A presents data on sampled patients' age, gender and administered activity.

Mean counts of activity in the kidney and bladder were estimated using conjugate view methodology (Hasford et al., 2015; Yigbedeck et al., 2014). Anterior and posterior counts of activity were obtained from the scintigrams and geometric mean count estimated using equation (1).

$$GMC = \sqrt{C_A \times C_P} \quad (1)$$

Counts of activity were converted into radionuclide activity (mCi) using Equation (2) (Pereira et al., 2010).

$$A = \sqrt{\frac{C_A \times C_P}{e^{-\mu_e t}}} \times \frac{f}{C} \quad (2)$$

where, A is organ activity (mCi); C_A and C_P are the anterior and posterior background corrected counts respectively; t is body thickness across organ of interest (anterior–posterior); μ_e is effective linear attenuation coefficient of Tc-99m in soft tissue; C is system calibration factor in counts per unit activity, expressed as $\{source\ counts/known\ activity\}$; f represents correction for the source region attenuation coefficient (μ_e) and source organ thickness (t) and is expressed as $\{(\mu_e x/2)/\sinh(\mu_e x/2)\}$ (Jönsson, 2007; Shahbazi-Gahrouei, Cheki, & Moslehi, 2012; Siegel et al., 1999; Stabin, 2008).

Biokinetic model in MIRD Report 13 (Weber et al., 1989) was used to simulate transfer of Tc-99m in the body with MatLab program. The transfer of Tc-99m activity in blood, bone, kidney and bladder was simulated by Equation (3)–(6).

$$\frac{dq_{Bd}}{dt} = -(k_R + K_{21} + k_{31})q_{Bd} + k_{12}q_{B0} \quad (3)$$

$$\frac{dq_{B0}}{dt} = -(k_R + K_{12})q_{B0} + k_{21}q_{Bd}. \quad (4)$$

$$\frac{dq_{Kid}}{dt} = -(k_R + K_{43})q_{Kid} + k_{31}q_{Bd} \quad (5)$$

$$\frac{dq_{Ub}}{dt} = -k_R q_{UB} + K_{43}q_{Kid} \quad (6)$$

Table 1 presents transfer rate constants k_{12}, k_{21}, k_{31} and k_{43} specified in MIRD Report 13. Physical decay constant $k_R = 0.115\ h^{-1}$.

The resultant MatLab algorithm for the transfer of Tc-99m activity in blood, bone, kidney and bladder is presented in Appendix B:

3. Results and discussion

3.1. *Organ and body thickness*

Estimated average thicknesses of kidney and bladder, and their associated body sections for the 36 patients are summarized in Table 2. The average thickness estimates for left and right kidneys vary insignificantly by 4.2%. The measurements of 4.92 cm and 5.14 cm for the left and right kidneys are respectively consistent with study by Larsson et al. (2012). For 36 patients, the group estimated the thicknesses of left and right kidneys to be 5.39 cm and 5.69 cm respectively. The estimated average thicknesses in this study were used to calculate attenuation coefficient of Tc-99m by conjugate view approach.

3.1.1. *Radionuclide activity in kidney and bladder*

Average estimates for the radionuclide activity in the kidneys and bladder 3 h after injection of Tc-99m MDP, and their respective fractions of injected activity for the 65 patients are presented in Table 3. Radionuclide activity in the kidneys (0.041 ± 0.013 mCi) is much lesser than in the bladder

Table 1 – Transfer rate constants.

Radiopharmaceutical	Tc-99m MDP
k_{12}	0.063 ± 0.010
k_{21}	0.295 ± 0.025
k_{31}	0.305 ± 0.012
k_{43}	3.25 ± 0.37