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Effective Dose Assessment in Myocardial Perfusion Scan involving 99m Tc-Based Radiopharmaceutical – A Review

Muhammad Hamza [a], Dr. Muhammad Nadeem Badani [b], Dr. Muhammad Shahid [c]

[a, b] *Department of Basic Sciences and Humanities, UET Taxila, Pakistan*

[c] *Pakistan Nuclear Regulatory Authority, PNRA Islamabad, Pakistan*

ABSTRACT:

Internal dosimetry is an important field of medical physics that deals with the estimation and calculation of radiation dose received by living organisms including humans due to the radiation source present inside organism body for example radiation dose due to nuclear medicine scans or imaging. One such widely used procedure is myocardial perfusion scan/imaging also known as nuclear medicine cardiac scan which is mainly used to detect coronary artery disease (COD). In this paper, radiation dose received by patients who undergoes myocardial perfusion scan, selected randomly both males and females, is calculated using whole-body planar gamma camera images with conjugate view method. International Commission on Radiological Protection (ICRP) published radiation effective dose values from all currently used radiopharmaceuticals which are the reference in this research for internal dose assessment [1]. The results confirm that the radiation effective dose received by patients at Polyclinic Hospital during nuclear medicine cardiac scan involving radiopharmaceutical technetium-99m-MIBI is in the limits provided by ICRP. OLINDA V-1.1 and IDAC-DOSE 2.1 is used for internal dose assessment calculations.

1. INTRODUCTION:

1.1 Background:

The development of radiation science and its applications in the medical profession are major influences on the history of medical physics and dosimetry. Wilhelm Conrad Roentgen's landmark discovery of X-rays in 1895 signaled the beginning of medical physics, which all started near the close of the 19th century. The pioneering work of people like Marie and Pierre Curie during this time helped to establish radiology and raise public awareness of the possible health risks posed by ionizing radiation. They undertook ground-breaking research on radioactive elements. The relevance of internal dosimetry was further highlighted when medical physics' field of study grew to include nuclear medicine, diagnostic imaging, and radiation therapy. By defining the fundamental guidelines for radiation protection, the International Commission on Radiological Protection (ICRP), which was founded in 1928, played very important contribution. The importance of internal dosimetry increased with the development of medical technology, and advanced computational tools like OLINDA and IDAC-DOSE were created to produce accurate dosage estimations. Internal dosimetry, which optimizes the delivery of radiation therapy and personalized radionuclide therapies while reducing any potential dangers to patients, is now an important part of personalized medicine.

1.2 Radiopharmaceutical:

The term radiopharmaceutical consists of two terms. Radio means some radioactive elements for example technetium-99m which can emit low energy gamma radiation so we can detect its movement inside the body through special devices such as gamma camera and PET scanners. Pharmaceutical is a chemical substance attached to the radioactive substance to take maximum amount of that radioactive substance into desired organ for detection of ailments in that organ for example MIBI (2-methoxy-iso-butyl-isonitrile) is attached to technetium-99m for nuclear medicine cardiac scan.

1.3 Gamma Camera:

The distribution of gamma-emitting radiopharmaceuticals throughout the human body is detected and visualized using a gamma camera, sometimes referred to as a scintillation camera in nuclear medicine. It is frequently employed for organ function evaluation and diagnostic purposes. A photomultiplier tube (PMT) or an array of PMTs are connected to a large detector, which is often outfitted with a scintillation crystal (such as sodium iodide or cesium iodide). Scintillation, which is produced when gamma rays interact with the scintillation crystal, results in light flashes that are picked up by PMTs. The gamma camera captures the location and strength of these scintillation events to produce an image of the distribution of the radiopharmaceutical inside the patient's body [2].

1.4 Cumulated activity:

Cumulated activity is a quantitative measure of the total amount of a radioactive substance (radiopharmaceutical) that has been taken up by a particular organ or tissue. By plotting time in hours on the x-axis and the percentage of administered activity on the y-axis on a graph, we can calculate the cumulative activity in an organ. From there, we can find the area under the curve, which gives us the cumulative activity per unit of administered activity in that organ. Calculations for cumulative activity are done in MBq-hr or mCi-hr. Mathematically:

$$\tilde{A} = \int_0^{\infty} A(t)dt$$

2. MATERIALS AND METHADOLOGY:

2.1 Technetium-99m:

Technetium-99m is one of the most widely used radiopharmaceutical in the world for diagnostic purposes. It is obtained by the decay of molybdenum-99 and transported into nuclear medicine facilities in a device known as ^{99}Mo – ^{99m}Tc “molly” Generator in which Mo-99 is decaying into Tc-99m [3] and then collected after every 24 hours for a specific period of time usually for 3 to 7 days. Tecnetium-99m has physical half-life of 6.015 hours and emit gamma radiation of 140.51 KeV. It has biological half-life of approximately 24 hours and effective half-life of approximately 4.80 hours.

2.2 2-methoxy-isobutyl-isonitrile (MIBI):

2-methoxy-isobutyl-isonitrile usually referred as MIBI [4] is a pharmaceutical attached to the radioactive substances mainly to Tc-99m. It is widely used for nuclear medicine cardiac and thyroid imaging. It has chemical formula $C_6H_{11}NO$ and molecular weight of 113.16 g/mol.

2.3 Conjugate View Method for Internal Dose Assessment:

Conjugate view method is from early and widely used methods used in internal dosimetry for the estimation and calculation of radiation dose received by organs or specific part of the body. It is based on the planar gamma camera images acquired in the resting position of body. Mostly two gamma camera images are taken in anterior and posterior position and the region of interest ROI analysis are performed on the images for internal dose estimation. Background radiation correction is done by calculating transmission factor for the gamma camera used, taking geometric mean of counts and using conjugate view subtraction method. Mathematical formula of conjugate view method is given below in which the counts in the opposing (anterior and posterior) images' regions of interest ROI are C_A and C_P. The system calibration factor is C, and τ is the transmission factor: [5]

$$A = \frac{\sqrt{(C_A C_P)}}{\sqrt{\tau}} \times \frac{1}{C}$$

3. MODELS AND SOFTWARE:

3.1 Internal Dose Assessment by Computer (IDAC-DOSE):

The International Commission of Radiation Protection (ICRP) has approved IDAC-Dose1.0 (Internal Dose Assessment by Computer), which was developed by Professor Lennart Johansson at Umeå University in 1987 for evaluating radiation risks in nuclear medicine diagnostics. Multiple ICRP publications has been utilized by it for dose estimations involving different radiopharmaceuticals. IDAC-Dose 2.1, a later version, uses a computational framework and specific absorbed fraction data from ICRP recommendations for reference adults [6]. Based on cumulated activities, this software computes absorbed and effective doses for 1,252 radionuclides spread across 97 elements. It is appropriate for patients receiving nuclear medicine and in line with ICRP criteria for internal dose assessment.

3.2 Organ Level Internal Dose Assessment (OLINDA):

The 2004-created OLINDA/EXM program is a useful resource for figuring out organ doses and effective doses in nuclear medicine investigations. Organ Level Internal Dose Assessment/Exponential Modeling is the abbreviation. It performs regression analysis on user-supplied biokinetic data to calculate the radiation doses to various organs because of systemically administered radiopharmaceuticals. Dr. Michael Stabin, who also developed the popular MIRDOSE 3.0 and 3.1 programs for internal dose estimations [7], is the creator of OLINDA. In comparison to MIRDOSE, OLINDA version 1 included updates and improvements, such as more radionuclides, more organ phantoms, an enhanced bone model, and the capacity for kinetic analysis. A comprehensive and adaptable tool for internal dose assessments in nuclear medicine, Version 2 added more than 1000 radionuclides, voxel-based realistic phantoms for different populations, and patient-specific organ mass adjustments.

4. CONCLUSION:

During Tc-99m-MIBI cardiac scan**,** ICRP given effective dose value is 7.9 uSv/MBq for stress condition and 9 uSv/MBq for resting condition of heart. In this study, three planar whole-body scans at three different times of each patient are performed in resting condition for the purpose of internal dose assessment. The myocardial perfusion imaging scans performed at the mentioned facility is safe for the patients because the effective dose values calculated is in the limits provided by International Commission on Radiological Protection (ICRP). This study concluded that the quantification of planar gamma camera images is accurate enough for effective dose assessment research and studies involving radiation safety but the quantification and dose calculation for radiotherapy purposes required more advanced techniques and equipment such as SPECT/CT capable gamma camera equipment and software.

5. CHALLENGES AND FUTURE RECOMMENDATIONS:

Radiation dose calculations and quantification from planar gamma camera images is a complicated task in which correction of many factors are required. Initially, some scientists questioned the accuracy of quantification of planar gamma camera images but with time the process improved significantly with the introduction of advanced correction techniques, computational models, and software. Conjugate view subtraction technique is used in this study along with calculating transmission and calibration factors for the gamma camera. The process improved further with the introduction of SPECT/CT capable equipment and related software. It is recommended that SPECT gamma camera equipment should be replaced by the current more modern SPECT/CT gamma camera equipment which provides more accurate and better results.

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7. REFERENCES:

[1] International Commission on Radiological Protection. (2015). Radiation Dose to Patients from Radiopharmaceuticals: A Compendium of Current Information Related to Frequently Used Substances (ICRP Publication 128). Annals of the ICRP, 44(2 Suppl).

[2] Norrgren, K., Svegborn, S. L., Areberg, J., & Mattsson, S. (2003). Accuracy of the Quantification of Organ Activity from Planar Gamma Camera Images. Cancer Biotherapy and Radiopharmaceuticals, 18(1), 125–131.

[3] Eckelman W, et al. Unparalleled Contribution of Technetium-99m to Medicine Over 5 Decades. J Am Coll Cardiol Img. 2009 Mar, 2 (3) 364–368.

[4] Worsley, D.F., Fung, A.Y., Coupland, D.B. et al. Comparison of stress-only vs. stress/rest with technetium-99m methoxyisobutylisonitrile myocardial perfusion imaging. Eur J Nucl Med 19, 441–444 (1992).

[5] Pereira, J., et al., Image quantification for radiation dose calculations–limitations and uncertainties. Health physics, 2010. 99(5): p. 688.

[6] Andersson M., Johansson L., Eckerman K. and Mattsson S. IDAC-Dose 2.1, an internal dosimetry program for diagnostic nuclear medicine based on the ICRP adult reference voxel phantoms. EJNMMI Research 2017.

[7] Stabin MG, Sparks RB, Crowe E. OLINDA/EXM: the second-generation personal computer software for internal dose assessment in nuclear medicine. J Nucl Med. 2005; 46:1023–1027.