Physical dosimetry and mathematical dose calculation in nuclear medicine: A comparative study

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OBJECTIVES: This paper addresses a comparison between physical dosimetry and mathematical dose calculation in nuclear medicine. Materials and Methods: Dose rate was calculated by mathematical external dose calculation formula and by physical dosimetry from the surface of 38 adult patients’ body referred to nuclear medicine department. Results of the methods were compared and correlation and regression tests were also performed. Results: Although the physical dosimetry data in this study are in good consistency with other researches, they are much lower than the results of mathematical dose calculation formula. The correlation coefficient between measured dose rate with calculated values derived by mathematical formula was found to be 0.852 (P value = 0.148). Conclusion: It seems that physical dosimetry data are more accurate than the results of mathematical dose calculation. In case of using mathematical dose calculation formula, other correction factors should be considered and applied for getting reliable data. Keywords: Physical dosimetry, mathematical dose formula, nuclear medicine

INTRODUCTION

Evaluation of radiation effects on health in diagnostic imaging using radiopharmaceuticals needs the determination of radiation doses received by patients, technologists and environment. In nuclear medicine, patients underwent diagnostic imaging after radiopharmaceutical administration may give radiation dose to other patients, staff and members of public, which are in proximity to the patient. Potential radiation doses due to nuclear medicine procedures have been widely studied[1-4]. However, the mathematical calculation in nuclear medicine still need to be adopted.

The aim of the present study is to compare the results obtained for dose calculation by using the mathematical formula and physical measurement.

MATERIALS AND METHODS

Thirty-eight adult patients (17 Bone, 14 Cardiac, 2 Renal, and 5 Thyroid scan) who were consecutively referred to the Nuclear Medicine Department of ‘Shahid Beheshti’ Hospital (Babol University of Medical Sciences, Babol, Iran) were included in the study. The chief complaint / disease of the patients and the reports of the corresponding scans were also recorded. The net injected activity was recorded for each patient by measuring the remaining activities in the syringes. The dose rate was calculated by the mathematical external dose calculation formula[6] as shown a little later in the text and also by the calibrated dose rate meter (Graetz X5c Plus- Germany), one meter from the surface of the patient’s body at the diaphragmatic level, such as patient’s mid torso, just before the scan.

Dose rate \( = \frac{A(Bq)}{4\pi R^2} \left( \mu \rho E \right) \frac{1}{1.6 \times 10^{-9}} \)

Each dosimetric measurement was repeated thrice and the mean and standard deviation of the measured data were calculated and considered for further analysis. The correlation between the mathematically calculated and experimentally measured values was also derived by using the Pearson’s correlation test.

RESULTS

The mean age and weight of the patients were 45.8 ± 16.0 years and 70.8 ± 14.2 Kg, respectively. Ten patients (26.3%) were male and 28 were female. The global mean net administered activity was found to be 19.5 ± 6.1 mCi. Table 1 summarizes the results
of the calculated and measured dose rate at 1 m distance from the patient’s body, for the corresponding scans [Figure 1].

**DISCUSSION**

Results show that although the physical dosimetry data in this study are quite consistent with other researches,[7,9] they are much lower than the results of the mathematical dose calculation formula. The differences might be due to the source / measurement point geometry, radiopharmaceutical biological washout, and other physical factors that affect the results in practice (actual measurement). Meo et al have reported a good correlation between the experimental measurements and the Monte Carlo simulation for assessing the radiation dose from patients administered 90Y-labeled radiopharmaceuticals.[10] It may be due to the ability of Monte Carlo, as a strong and precise method, versus the simple mathematical dose calculation formula, which considers the patient as a static point source of radioactive material. Hippeläinen et al have indicated that physical dosimetry for personnel and dose calculations, according to AAPM TG-108 guidelines, provide similar results.[11] A report by Siegel et al shows a major difference between point source versus line source model of dosimetry for patients undergoing nuclear medicine experiments.[12] However, they mentioned that in some cases of shielding, calculations should be carried out carefully to prevent the underestimation of shielding requirements. It seems that physical dosimetry data are more accurate than the results of the mathematical dose calculation. In case of using the mathematical dose calculation formula, other correction factors should be considered and applied for getting reliable data.

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**Table 1: Calculated and measured dose rate for the corresponding scans. Physical dosimetry data show mean ± SD from three repeated measurements**

| Study          | Bone   | Cardiac | Renal  | Thyroid  |
|----------------|--------|---------|--------|----------|
| dose rate (µGy / h.m) | 22.53 ± 3.06 | 21.09 ± 3.25 | 15.88 ± 0.03 | 6.34 ± 1.09 |
| Tc99m net activity (mCi) | 80.28 | 75.15 | 56.58 | 22.59 |
| Mathematical formula | 3.95 ± 1.62 | 2.94 ± 0.78 | 2.39 ± 2.67 | 2.03 ± 1.09 |

**Figure 1:** The curve estimation between the calculated and measured dose rate (µGy / h.m) (Correlation coefficient = 0.852; P = 0.148)