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Original paper

Wrist dosimeter in nuclear medicine – An alternative for the ring dosimeter?

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ABSTRACT

Purpose: Individual dosimetry is undoubtedly one of the best methods of assessing the exposure of personnel to ionizing radiation, however in case of nuclear medicine, the method applied to measure the dose does not always present a picture of the worker's actual exposure. The highly non-homogeneous dose distribution on the hand means that the ring dosimeter, routinely used to measure the H*p*(0.07), provides only approximate dose values received by fingertips, the body part most exposed to ionizing radiation. This paper is an attempt to answer the question whether the wrist dosimeter used as a replacement for the ring dosimeter is able to provide information on doses for the most exposed fragments of the hand of an employee during handling procedures with the use of radiopharmaceuticals.
Materials: Throughout measurements performed in five nuclear medicine facilities, high-sensitivity thermoluminescent detectors were used.
Results: Correction coefficients have been determined, which constitute an amendment to be made to move from the dose recorded by the wrist dosimeter to the doses received by the most exposed hand fragments. The fingertips received on average 25 times higher doses, compared to the values recorded by the wrist dosimeter.
Conclusions: A wrist dosimeter can be used to measure the H*p*(0.07) in nuclear medicine, including as a gauge of the most exposed parts of the hand – the fingertips. However, the applicability of correction coefficients makes it necessary to ensure a stable position of the wrist dosimeter during routine procedures.

1. Introduction

Individual dosimetry, and with it the measurement of effective and equivalent dose, is the best way to assess occupational exposure of medical personnel to ionizing radiation. Nevertheless, the nature of some branches of medicine, especially nuclear medicine, requires more attention when it comes to routine monitoring of occupational exposure. This is because the so-called open radiation sources are used in nuclear medicine. This form of the source is associated with the need to perform manual procedures with little (if any) use of manipulators, which in turn may contribute to increased exposure of the personnel's hands [1–13].

The personal dosimeter, used to measure the personal dose equivalent H*p*(10) and usually worn at chest level, is not able to provide proper information on the actual exposure of the staff. It is also a natural consequence of the effectiveness of shields, e.g. lead bricks and leaded glass, used against ionizing radiation. Nowadays, special full-protection chambers are often used. All these elements mean that nearly 80% of the effective doses obtained by employees of nuclear medicine and medical physics units registered by the Laboratory of Individual and Environmental Dosimetry (LADIS) of the Institute of Nuclear Physics in Krakow are in the range up to 0.1 mSv/quarter at the annual dose limit of 20 mSv [14]. This means that typical monitoring of occupational exposure with an individual personal dosimeter worn at the chest level may not provide real information about the dose received by hands that directly handle the radiation source.

It seems equally obvious that the need to perform procedures manually requires a more reliable method of assessing the dose received by the employee's hands. It is possible thanks to the use of the so-called "ring dosimeter". The ring dosimeter is worn in the majority of cases at the base of the middle finger; however, the highest exposure concerns the fingertips handling the radiation source – a radiopharmaceutical collected in a vial or syringe. In this case, the ideal solution would be to register ionizing radiation doses directly on the fingertips. Technical difficulties preclude continuous monitoring of the exposure of the fingertips during handling. Publications, among others Wrzesień et al. [6] and the Oramed report [2] prove however, that the ring dosimeter can be used as a device to measure the dose received by the fingertips when handling radioactive isotopes.

But what about the facilities where the wrist dosimeter is used to

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assess the personal dose equivalent Hp(0.07)? The work attempts to determine whether the wrist dosimeter can be routinely used in the case of procedures that use radiopharmaceuticals and be an alternative to a ring dosimeter, as well as whether a wrist dosimeter, just like a ring dosimeter, can be used as a standard dosimeter of exposure of the fingertips? What conditions should a wrist dosimeter meet to be used for this purpose?

2. Materials and methods

The measurements forming the basis of this work were performed in five nuclear medicine facilities in Poland. High-sensitivity thermoluminescent detectors type MCP-N (LiF: Mg, Cu, P) manufactured by RADCARD were used in the measurements. The detectors were calibrated in the Secondary Standard Laboratory of the Nofer Institute of Occupational Medicine in Łódź in accordance with the ISO 4037-3 [15] standard in the range of 0.05–30 mGy as the air kerma. The Hp(0.07) for finger was calculated taking into account the conversion coefficient $h_{pK}(0.07)$ given in the ISO standard. The X-ray generated at 118 keV was used in the process of calibrating the detectors. Correction was made for the difference between the energies of X-ray quantum and ^{99m}Tc gamma photons. This was done by testing the calibration curve within the 100–250 keV photon energy range, which allowed the determination of a correction factor of 0.962 for the energy of photons emitted by ^{99m}Tc. The results were compared to TLD calibration with ^{99m}Tc source, whereas the activity of the source was independently calibrated via a ionization chamber.

The applied method of detectors' calibration is described in work [6].

The thermoluminescent detectors (TLDs) were read out using the RA'94 reader, produced by the Mikrolab Co. The detectors were subjected to a typical process of annealing in a TLD oven produced by PTW so that they could be re-used in subsequent measurements.

Measurements of personal dose equivalent Hp(0.07) were carried out in five centers of nuclear medicine in the country. The measurements were made during the routine work of the personnel of nuclear medicine facilities. The generator elution procedures, measurement of ^{99m}Tc activity obtained in elution procedure, labelling and dispensing the individual activities of radiopharmaceuticals for the patients were included.

The measurements included 13 right-handed radiopharmacists performing all the above-mentioned procedures as part of their daily duty. In total, measurements were made throughout 42 working days. During the performed measurements, radiopharmacists prepared the radiopharmaceuticals for a total of 769 patients. It should be emphasized that during the measurements, TL detectors were placed in a total of 19 points per hand of an employee including fingertips (all fingers), middle phalanges (all fingers), fingernails (all fingers), palmar and dorsal metacarpus and wrists, and in a standard ring dosimeter location, as shown in Fig. 1.

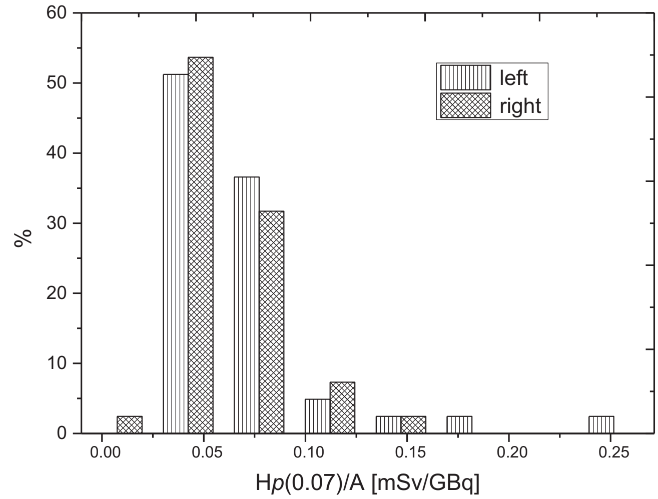

Fig. 2. Distribution of Hp(0.07)/A measured by using a ring dosimeter.

In total, 1265 measurements were performed. For the needs of the prepared work, the number of points was limited to measuring points at the fingertips of three fingers, wrists and the standard ring dosimeter location both of hands. The rationale for the choice of three fingers (thumb, index and middle finger) is the fact that these are the most exposed points while handling radioactive isotopes, which is also confirmed, among others, by the following publications: [1,2,6].

The detectors were placed in transparent foil to protect them from sweat as well as a layer of glue and then affixed on the workers' hands with adhesive tape.

The statistical analysis was performed using the STATISTICA v. 10.0 software. Any differences found were considered statistically significant if $p < 0.05$.

3. Results

Figs. 2 and 3 present, respectively, the distributions of the values of Hp(0.07)/A measured by a ring dosimeter and TL detectors placed on the wrists of employees of all nuclear medicine facilities.

Statistically significant differences were found when comparing the distribution of Hp(0.07)/A recorded in one working day on wrists and at the place of standard ring dosimeter location of the left and right hand by using the Kolmogorov-Smirnov test ($p < 0.001$).

Using the values of Hp(0.07)/A, the Pearson correlation coefficients **r** were determined for the three fingertips in relation to the values measured at the place of a standard ring dosimeter and on the wrist. A

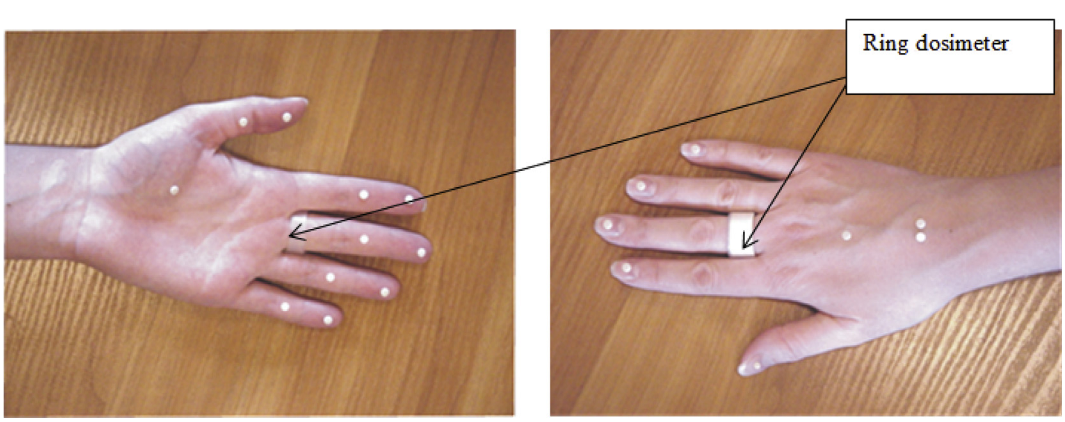

Fig. 1. Location of TLDs on radiopharmacists' hands.