Differences between the Doses to Skin from $^{99m}$Tc, Measured with the Use of the Hand Phantom and the Extremity Dosimeter

B. Majowska¹, M. Tuszyński¹, K. Rudzki²

¹ Medical Physics Dpt., Institute of Physics, University of Silesia, Katowice, Poland
² Dpt. Of Radiology and Nuclear Medicine, Silesian Medical School, Katowice, Poland

Abstract

This paper presents results of measurements using the hand phantom and highly sensitive LiF:Mg,Cu,P thermoluminescence detectors. All procedures beginning at the technetium elution, through proportioning of radiopharmaceutical in syringes, up to giving the radioisotope to a patient, were simulated by means of this phantom. All measured doses are relative. The doses were compared with the dose from the extremity dosimeter. The coefficients: the average hand phantom coefficient $C_{\text{HP},\text{av}}$ and the maximum hand coefficient $C_{\text{HP},\text{max}}$ from phantom measurements were calculated. The extremity dosimeter dose estimates according to the recommended coefficients allowed obtaining more reliable values.

Keywords: thermoluminescence dosimetry, TLD, radiological protection, phantom

Introduction

Use of pharmaceuticals marked with $^{99m}$Tc is one of the most frequent in vivo radioisotope diagnostic procedures. The preparation of radioisotope $^{99m}$Tc embraces the procedure of technetium elution from the Mo- Tc generator, proportioning of radiopharmaceutical and giving them to a patient. All those procedures are done manually. During direct contact with radiopharmaceuticals the skin of the hands of medical personnel is the area that is most exposed to radiation [1].

The aim of this paper was to show the dose distribution to the hand in simulated situations when the hand was exposed to radiation and the difference between the dose from an extremity dosimeter and the doses measured on the inside of the hand. For this purpose, the hand phantom was constructed.

Materials and methods

During the examination, all procedures with $^{99m}$Tc were simulated using the hand phantom, which was described in [2]. Additionally, the extremity dosimeter was applied and placed on the middle finger where it is usually worn in radiation protection measurements. The highly sensitive LiF:Mg,Cu,P thermoluminescence detectors made by the TLD POLAND, Cracow were used in the experiment. The detectors were individually calibrated at the Institute of Nuclear Physics (INP) in Kraków in the accredited calibration laboratory in terms of air kerma free-in-air by applying a reference 1 mGy gamma ray dose from a $^{137}$Cs source. Every time before exposure to radiation all the detectors were annealed at 240°C in air for 10 min, next they were fast cooled on an iron block. After irradiation, the thermoluminescence spectra were taken by the use of a TL Ra-94 reader (MikroLab, Cracow, Poland). During the readout, the temperature was linear increasing with a 4°C/s gradient over the range 50–225°C. The GCANEW glow
curve analyzing program written by J. M. Gomez Ros and A. Delgado was used to calculate individual glow peak parameters [2].

**Table 1.** The results of experiments with the hand phantom

<table>
<thead>
<tr>
<th></th>
<th>Elution from Tc-99m generator</th>
<th>Proportioning of radiopharmaceuticals</th>
<th>Administration the radiopharmaceuticals to a patient</th>
</tr>
</thead>
<tbody>
<tr>
<td>The average of dose</td>
<td>108.2 %</td>
<td>224%</td>
<td>115.6%</td>
</tr>
<tr>
<td>Values below the extremity dosimeter dose</td>
<td>30%</td>
<td>19%</td>
<td>57.1%</td>
</tr>
<tr>
<td>Values above the extremity dosimeter dose</td>
<td>70%</td>
<td>81%</td>
<td>42.9%</td>
</tr>
<tr>
<td>The average hand phantom coefficient $C_{HP\text{Ph}}$</td>
<td>1.1</td>
<td>2.24</td>
<td>1.16</td>
</tr>
<tr>
<td>The maximum hand phantom coefficient $C_{HP\text{Ph\max}}$</td>
<td>1.7</td>
<td>8.31</td>
<td>4.45</td>
</tr>
</tbody>
</table>

**Result and discussion**

The radiation doses were applied to 21 measurement points placed inside of the hand phantom and the dose measured by the extremity dosimeter for all simulated situations. The dose distribution on the hand phantom was compared with the dose from the extremity dosimeter that latter showing the dose only in one point outside of the hand. The doses were normalised to the extremity dosimeter dose. All values from the hand phantom were converted to the proportional dose from the extremity dosimeter and they were expressed in percents. The maximum error for dose measurements amounted to 5%. On the basis of these values in all measurement points the dose distribution graphs were made using Surfer Program Version 6.01 (Surface Mapping System Copyright © 1993-95, Golden Software, Inc.), which was described in [2]. The picture of an example of the relative dose distribution was presented in Fig. 1. in [2] the application of two coefficients was suggested which enable to get more reliable information from the extremity dosimeter measurement. Both coefficients were estimated and their values were after-mentioned.

When the hand phantom was placed on the Mo-Tc generator (simulation of elution) only six detectors showed lower doses than extremity dosimeter (30%), but fifteen (70%) dosimeters showed values above the extremity dosimeter dose. The average dose registered by the dosimeters in the hand phantom was 108.2% of the extremity dosimeter dose. The average hand phantom coefficient $C_{HP\text{Ph}}$ was 1.1 and the maximum hand phantom coefficient $C_{HP\text{Ph\max}}$ was 1.7.

While the ampoule with radiopharmaceutical was in inside of the hand phantom (simulation of radiopharmaceutical proportioning) four dosimeters (19%) showed lower doses than extremity dosimeter, but seventeen dosimeters (81%) showed higher doses. The average dose registered by the dosimeters in the hand phantom was 224%
of the extremity dosimeter dose. The average hand phantom coefficient $C_{HP_{avr}}$ was 2.24 and the maximum hand coefficient $C_{HP_{MAX}}$ was 8.31.

In the experiment when syringe in lead cover with radiopharmaceuticals was placed inside of the hand phantom (simulation of administration of radiopharmaceuticals to a patient) nine dosimeters showed higher doses than extremity dosimeter. The average dose registered by the dosimeters in the hand phantom was 115.6% of the extremity dosimeter dose. The average hand phantom coefficient $C_{HP_{avr}}$ was 1.16 and the maximum hand coefficient $C_{HP_{MAX}}$ was 4.45. The obtained results were included in Table 1.

Conclusions

The measurements showed that there were places on the hand receiving a higher dose than shown by the extremity dosimeter. If the situation would be regular exceeding the permissible dose in those places may be occur. The experiment with radiopharmaceutical Na$^{99m}$TcO$_4$ showed that the standard method using the extremity dosimeter sometimes is not sufficient in radiological protection. It is necessary to remember that in some situations the extremity dosimeter may show dose a few times lower than is present in some places inside of the hand. The reliable value of the dose may be calculated by multiplying mentioned coefficients by the extremity dosimeter dose.

References