



# ORAMED: Extremity dosimetry in nuclear medicine (Work Package 4)

## Practical guidelines to reduce hand exposure for standard nuclear medicine procedures

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# GUIDELINES FOR REDUCING DOSE TO THE HANDS DURING STANDARD NUCLEAR MEDICINE PROCEDURES

These guidelines were established in the framework the ORAMED project (2008-2011), a Collaborative Project supported by the European Commission within its 7th Framework Program.

## General problematic



Since the dose limit for the skin (500mSv/year) must be applied to 'the dose averaged over any area of 1 cm<sup>2</sup> regardless of the area exposed' it is advisable to measure the local skin dose at the location with the highest presumed exposure. This consideration is the central dilemma of extremity dosimetry and causes severe practical difficulties. In the daily practice of nuclear medicine, the part of the hand receiving the highest dose is often unknown. Moreover, the dose distribution over the hand may vary during a single process as well as when different operators perform the same procedure.

## Description of the work

Skin dose equivalents  $H_p(0.07)$  at different positions (see Figure 1) on the hands were measured for several nuclear medicine procedures using appropriate dosimeters. Measurements were based on a unified protocol that included all relevant information for radiation exposure. Procedures were selected according to their frequency and their potential level of hand exposure, and they covered the most commonly used radionuclides in nuclear medicine: <sup>99m</sup>Tc, <sup>18</sup>F, <sup>90</sup>Y. Furthermore, Monte Carlo simulations were performed to analyse the sensitivity of hand doses to different parameters. Based on the results of this work performed within the framework of the ORAMED project, these guidelines were established in order to propose recommendations regarding the positioning of dosimeters for routine monitoring as well as practical tools and techniques to reduce exposure.

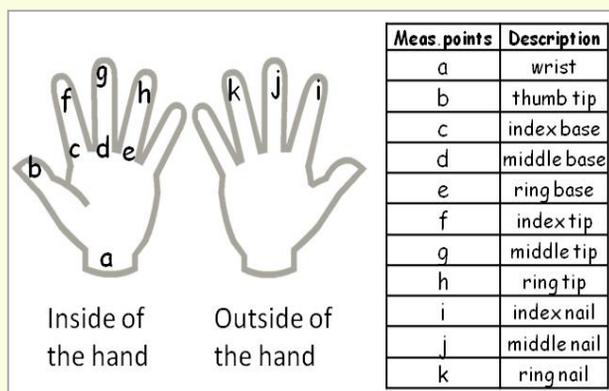


Figure 1. Location of the measuring points on the hands.

### MEASUREMENT CAMPAIGN

#### Diagnostic procedures considered:

- <sup>99m</sup>Tc preparation and administration
- <sup>18</sup>F preparation and administration

#### Therapeutic procedures considered:

- <sup>90</sup>Y Zevalin® preparation and administration
- <sup>90</sup>Y DOTATOC preparation and administration



The aim was to evaluate hand doses and dose distributions across the hands of medical staff.

Data comes from:

- 34 hospitals across Europe
- 7 different European countries
- 124 monitored workers

### SIMULATION CAMPAIGN

- Simulation code: MCPNX
- 6 scenarios : 2 for the injection procedure and 4 for the preparation of the radiopharmaceutical.
- 3 hand phantoms moulded out of wax were scanned and voxelized to be introduced into the simulation input files



Figure 2. Hand model used for the simulations representing the injection scenario



The aim was to evaluate the efficacy of different radiation protection measures by comparing hand dose distributions according to various parameters such as:

- active volume of the source,
- displacement and/or rotation of the source,
- shielding thickness and material.

## Recommendations for positioning dosimeters for accurate monitoring

The dose distribution over the hand depends on:

- the physical properties of the radionuclide (highly inhomogeneous dose distribution with  $^{90}\text{Y}$ , less inhomogeneous with  $^{18}\text{F}$  and homogeneous with  $^{99\text{m}}\text{Tc}$ ),
- the distance between the source and the hand,
- the use of shields,
- the nature of the manipulations performed,
- the workers individual habits; even performing the same procedure with the same devices, it may vary significantly from one worker to another.

General trends observed among the monitored workers for all procedures

- Doses to the non-dominant hand are usually higher than doses to the dominant hand.
- The tip of the index finger is generally the most exposed position on the hand but not a comfortable position for routine monitoring.
- Good correlations are found between the maximum dose to the hand and the dose in usual monitoring positions for ring dosimeters (e.g. ring finger).
- The correction factor for the base of the index finger of the non-dominant hand as regards the position of the maximum dose has lower values and smaller variability than those factors corresponding to other positions for the different diagnostic procedures. 

- 1) Extremity monitoring is essential in nuclear medicine.**
- 2) To determine the position for routine monitoring, the most exposed position on the hand for each worker should be found by individual measurements for a short trial period. If for practical reasons, these measurements are not possible, the base of the index finger of the non-dominant hand with the sensitive part of the dosimeter placed towards the inside of the hand is the recommended position for routine extremity monitoring in nuclear medicine.**
- 3) To estimate the maximum dose, the reading of the dosimeter worn at the base of the index finger of the non-dominant hand should be corrected by a factor of 6.**

## Recommendations regarding the parameters influencing the hand dose

General trends

- In several cases the estimation of annual dose to hands exceeded the annual dose limit.
- The extremely wide range of maximum doses measured for an identical procedure indicates that good and bad practices were performed and thus, that workers who received larger doses could potentially optimize their working procedures or habits.
- Three main factors are associated with workers receiving higher doses: working without shield, direct contact with the source container and skin contamination.
- Some workers associated with very low doses use advanced techniques, including semi-automatic dispensing tools.
- A worker's experience level was not decisive of reduced hand exposure.
- Training and the use of appropriate radiation protection measures can reduce doses to acceptable levels.
- In absence of good practices (no use of appropriate shielding and tools, lack of training...) the annual maximum dose is likely to exceed the annual limit of 500 mSv. 

- 1) Shielding of vials and syringes is essential. This is a precondition but not a guarantee for low exposure, since sometimes shielding is not properly used.**
- 2) The minimum acceptable thickness of shielding for a syringe is 2 mm of tungsten for  $^{99\text{m}}\text{Tc}$  and 5 mm of tungsten for  $^{18}\text{F}$ . For  $^{90}\text{Y}$ , 10 mm of PMMA completely shields beta radiation, but a shielding of 5 mm of tungsten provides better protection, as it cuts down bremsstrahlung radiation.**
- 3) The minimum acceptable shielding required for a vial is 3 mm of lead for  $^{99\text{m}}\text{Tc}$  and 3 cm of lead for  $^{18}\text{F}$ . For  $^{90}\text{Y}$ , acceptable shielding is obtained with 10 mm of PMMA with an external layer of a few mm of lead.**
- 4) Any tool increasing the distance (e.g. forceps, automatic injector) between the hands/fingers and the source is very effective for dose reduction.**
- 5) Training and education in good practices (e.g. procedure planning, repeating procedures using non radioactive sources, estimation of doses to be received) are more relevant parameters than the worker's experience level.**
- 6) Working fast is not sufficient, the use of shields or increasing the distance are more effective than working quickly.**

# APPENDIX - Main results of WP4

## MAXIMUM DOSES FOR THE DIFFERENT PROCEDURES

Table 1. Mean, median, maximum and minimum values of the maximum doses, normalized to the manipulated activity, for all workers and procedures (P stands for preparation and A for administration).

	Mean values of maximum doses from all workers (mSv/GBq)	Median values of maximum doses from all workers (mSv/GBq)	Minimum values of maximum doses from all workers (mSv/GBq)	Maximum values of maximum doses from all workers (mSv/GBq)
P- <sup>99m</sup> Tc	0.43	0.25	0.03	2.06
A- <sup>99m</sup> Tc	0.15	0.09	0.01	0.76
P- <sup>18</sup> F	1.31	0.88	0.10	4.55
A- <sup>18</sup> F	0.72	0.62	0.14	2.42
P- <sup>90</sup> Y Zevalin®	9.62	8.87	0.90	32.06
A- <sup>90</sup> Y Zevalin®	5.25	2.92	0.32	32.05

For a given procedure, the mean, median, maximum and minimum value have been determined considering the maximum doses registered among all 22 measured positions for each worker for a specific procedure

- Preparation usually delivers higher doses than administration
- Dose values for diagnostics remain much lower than those measured for therapeutic procedures.

## POSITION OF DOSEMETER FOR ROUTINE MONITORING

Table 2. Mean values for the correction factors for the different positions and for each procedure (P stands for preparation and A for administration). Correction factors are evaluated by considering the ratios between  $H_{p,max}$ , the maximum of the mean  $H_p(0.07)$  ( $\mu$ Sv/GBq) when both hands are considered simultaneously, and  $H_{p,base\ ring}$ ,  $H_{p,wrist}$ ,  $H_{p,base\ index}$  and  $H_{p,index\ tip}$  the mean dose at the base of the ring finger, the wrist, the base of the index and the tip of the index, respectively, for the non dominant and dominant hand.

	Non dominant hand				Dominant hand			
	Max/wrist	Max/base index	Max/base ring	Max/index tip	Max/wrist	Max/base index	Max/base ring	Max/index tip
P - <sup>99m</sup> Tc	27	5	11	2	20	6	9	3
A - <sup>99m</sup> Tc	15	5	10	2	15	7	10	4
P - <sup>18</sup> F	14	4	6	2	12	5	7	2
A - <sup>18</sup> F	30	7	12	4	27	7	12	4
P - <sup>90</sup> Y	16	7	11	4	16	22	30	16
A - <sup>90</sup> Y	26	8	17	3	23	20	17	10

- Doses are statistically higher in the non-dominant hand than in the dominant hand.
- The highest dose is often found to be received by the index tip of the non-dominant hand.
- Dose distribution over the hand is inhomogeneous.
- The ratios between the maximum skin dose and the dose at the possible monitoring positions in the non-dominant hand are smaller than those in the dominant hand, except for the wrist.
- The smallest ratio between the dose at the maximum and the dose at a given position is found in the tip of the index finger of the non-dominant hand. However, this is not a practical monitoring position.
- The second smallest ratio is found for the index base of the non-dominant hand and thus the index base, on the inner side of the hand, is the recommended monitoring position.

## ANNUAL HAND DOSE ESTIMATION FOR DIAGNOSTIC PROCEDURES

The annual dose of 60% of the workers monitored for the ORAMED project has been estimated only considering the procedures from which real measured values were available and only for those whom their workload was known.

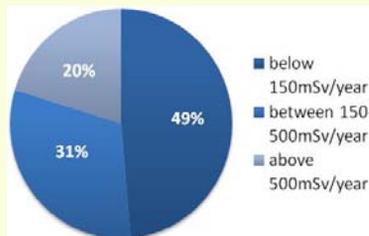


Figure 3. Percentage of workers with a given annual hand dose estimation.

- The annual dose estimation is above 150 mSv (3/10 of the annual limit) for 51% of the workers.
- 20% of the workers exceed the annual dose limit of 500mSv.

N.B. considering only the procedures measured within the ORAMED project.

## PARAMETERS INFLUENCING THE HAND DOSE

- A dose reduction between 1 and 3 orders of magnitude is achieved when using the appropriate shielding.
- The participants in therapy measurements achieved a reduced hand dose during the project due to feedback received on their measurement results and therefore, on radiation protection standards.
- Radiation protection tools, such as forceps, significantly influence the doses (when manipulating a <sup>18</sup>F shielded vial with 5 cm long forceps doses are reduced by a factor of 6).

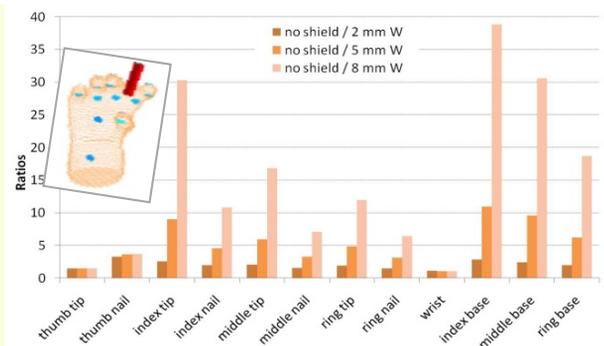


Figure 4. Ratios between unshielded syringes and shielded syringes of <sup>18</sup>F with 2, 5 and 8 mm of tungsten (W).