ASSESSING AND REDUCING EXPOSURES TO NUCLEAR MEDICINE STAFF

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Radiological risks: Sources of exposure of nuclear medicine workers

Nuclear medicine implies the manipulation of unsealed radioactive sources

- Risk of internal contamination
  - Valid for all radionuclides and specially for iodine (volatile)
Monitoring for internal contamination

- Monitoring: mostly not done
- Screening measurement should be possible
  - Simple, fast, inexpensive, frequent
  - Directly at the workplace by local staff

Source: S. Baechler et al. RPD 144 (1-4), 2011
Radiological risks: Sources of exposure of nuclear medicine workers

- Risk of external irradiation
  - Whole body (WB), extremities and eye lens irradiation when manipulating radioactive sources

Labelling with Tc-99m
- Whole body irradiation from the patient

Injection in diagnostics
Typical annual whole body staff doses at conventional Nuclear Medicine facilities are 0.1 mSv to few mSv.

<table>
<thead>
<tr>
<th>Technologist Dose per procedure (µSv)</th>
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<tbody>
<tr>
<td>WB Tc-99m bone scan</td>
<td>0.3 ± 0.2</td>
</tr>
<tr>
<td>Tc-99m MIBI SPECT</td>
<td>1.7 ± 0.2</td>
</tr>
</tbody>
</table>

Source: IAEA course
For a technologist assisting, 10 patients per week, 46 weeks/y (average activity administered per patient 300 MBq), the radiation dose will be around 2 mSv/y.
Attention with Contamination

- Especially with therapy...

Dose rate > 200mSv/h approx. 5cm over the contamination spot (Y-90)

Source: Ilona Barth and Arndt Rimpler, BfS
Renewed attention because of recommendation in BSS to lower the dose limit to 20 mSv/year

Very few data available
- Large individual variability
- Largely dependent on workload and procedural technique

- Ratio Hp(10)/Hp(3):
  - Scintigraphy: 1,1 ± 0,2
  - PET: 0,9 ± 0,5

- Typical yearly workload: (Tc-99m and I-131):
  - around 4,5 mSv
Nuclear medicine: main point of attention are the doses to the extremities

ICRP recommendations:

Dose limit for the extremities for workers is the same as for the skin

500mSv for 12 months over 1cm² independently of the exposed surface
WP4-ORAMED: objectives

- Level of exposure?
- Good and bad practices?
- Maximum dose
  - Dose distribution?
  - Parameters of influence?
  - Recommendations for RP
- Routine monitoring?

\[ \text{Dose distribution?} \]

\[ \text{Maximum dose} \]

\[ \text{Parameters of influence?} \]

\[ \text{Recommendations for RP} \]

\[ \text{Routine monitoring?} \]
Measurements

Common protocol:

✓ A pair of gloves equipped with 11 TL dosemeters each was worn by the worker
  - 8 TLDs on palm side, 3 on nail side
  - Only 1 type of radionuclide
  - Only preparation or administration
  - During: few days for Tc-99m
    ~1 day for F-18
    a single procedure for Y-90

→ 1 pair of instrumented gloves = 1 measurement

✓ For diagnostic applications:
  - At least: 5 measurements per worker

Analyzed: 7 countries; 34 different hospitals; 124 different workers, more than 600 measurements
Five measurements per worker

[Graph showing measurements for different body parts (wrist, thumb, base of index, base of middle, base of ring, index tip, middle tip, ring tip, index nail, middle nail, ring nail) on the non-dominant and dominant hand.]
Overview on finger doses in diagnostic NM

- Very large range of maximum finger doses among the same procedure.
- The preparation of the radiopharmaceutical involves higher finger doses per activity than the administration.
- F-18 involves higher finger doses per activity than Tc-99m.
Overview on finger doses in therapy NM

**Y-90 Zevalin® preparation**
- Range: 0.7 - 63.7 mSv/GBq
- Mean: 11.0 mSv/GBq
- N=15 (without outliers)

**Y-90 Zevalin® administration**
- Range: 0.7 - 24.6 mSv/GBq
- Mean: 4.8 mSv/GBq
- N=19 (without outliers)

- Very large range of maximum finger doses among the same procedure.
- Very large doses even for a single procedure.
- The preparation of the radiopharmaceutical involves higher finger doses per activity than the administration.
Good practices

- **Tc-99m administration**
- **Tc-99m preparation**
- **F-18 administration**
- **F-18 preparation**

Maximum annual dose (mSv)

Workers
Bad practices

<table>
<thead>
<tr>
<th>Tc-99m administration</th>
<th>Tc-99m preparation</th>
<th>F-18 administration</th>
<th>F-18 preparation</th>
</tr>
</thead>
</table>

Maximum annual dose (mSv)

- Tc-99m administration
- Tc-99m preparation
- F-18 administration
- F-18 preparation
Bad practices

Y-90 Zevalin® preparation

Y-90 Zevalin® administration
Overview on finger doses in diagnostic NM

→ Are these finger doses a matter of concern from the point of view of radiation protection?
Some workers were monitored for only one type of procedure for the ORAMED project when actually they performed more. In these cases, the estimation of the annual dose has been calculated only considering the monitored procedures, from which real measured values were available.

Even considering this hypothesis, it is found that the extrapolated doses reach the annual limit for 19% of the workers.
Syringe shield: higher doses with unshielded syringe?

**Preparation of Tc-99m**
- Unshielded vial excluded
- Differences not statistically significant

**Preparation of F-18**
- Statistically significant differences

**Administration of Tc-99m**
- Statistically significant differences

**Administration of F-18**
- Not enough data
The most exposed positions on the hand are the tip of the index finger and the thumb, usually of the non-dominant hand.
Ratios for diagnostics procedures

→ General ratios considering all data independently of the procedure.

<table>
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<tr>
<th></th>
<th>ND hand</th>
<th>D hand</th>
</tr>
</thead>
<tbody>
<tr>
<td>(outliers excluded)</td>
<td>&lt;max / wrist&gt;</td>
<td>&lt;max / base index&gt;</td>
</tr>
<tr>
<td></td>
<td>144</td>
<td>38</td>
</tr>
</tbody>
</table>

• The recommended monitoring position is the base of the index finger of the ND hand (low ratio, high correlation with the maximum) which underestimates the maximum dose by a factor of 5.5.
The recommended position is the base of the index finger of the ND hand (low ratio, high correlation with the maximum) which underestimates the maximum dose by a factor of 7.
From real to numerical world

1. Defining the case
2. Creating a moulding
3. Scanning the moulding
4. Generating a voxel phantom
5. Adding the source and dosemeters
Tc-99m

- Tc-99m: 2 mm W provide about more than 2 orders of magnitude of attenuation
- There is little differences between Pb and W
General observations

- Whole body doses: generally well below limit: still need for optimization.
- Monitoring for internal contamination can be advisable
- Eye lens doses: need for more data
- Extremity doses are most critical
- Wide ranges of individual exposures (min/max) for similar procedures, different equipment, radiation protection means and tools.
- Skin dose limit (500 mSv/y) can be exceeded by numerous workers in hospitals where RP standard is low, and/or the workload is high
- There is adequate potential to further improve radiation protection and decrease exposures
Recommendation 1 - extremity monitoring

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.

For diagnostics procedures:

• The annual dose estimation is above 250mSv (half of the annual limit) for 35% of the workers.
• 20% of the workers exceed the annual dose limit of 500mSv.

Extremity monitoring is a necessity in nuclear medicine.
Recommendation 2 - routine monitoring

The base of the index finger of the non dominant hand with the detector (TLD) placed towards the inside of the hand is the recommended position for routine extremity monitoring in nuclear medicine.

Best monitoring position: index tip of the non dominant hand BUT not feasible for routine monitoring with ring dosemeters

Recommended monitoring position: base index finger of non dominant hand with TLD directed to the inner side
• low ratio
• high correlation with the maximum
• comfortable for manipulating
A rough estimate of the maximum dose to the hand can be obtained by multiplying the reading of the dosemeter worn in the base of the index of the non-dominant hand by 6.
Recommendation 4 - **shielding**

Shielding of vials and syringes are essential and a precondition but not a guarantee for low exposures.
Recommendation 5 - minimum syringe shield

The minimum acceptable shielding required for a syringe is 2 mm of tungsten for $^{99m}$Tc and 5 mm of tungsten for $^{18}$F. For $^{90}$Y 10 mm PMMA completely shield beta radiation, nevertheless 5mm shielding of tungsten provides a better shielding cutting down bremsstrahlung radiation too.
Recommendation 6 - *minimum vial shield*

The minimum acceptable shielding required for a vial is 3mm and 3cm lead for $^{99m}$Tc and $^{18}$F respectively. For $^{90}$Y an acceptable shielding is obtained with 10 mm PMMA with an external layer of few mm of lead.
Recommendation 7 – training and education

Training and education on good practice (e.g. procedure planning, repeating procedures using non radioactive sources) are more relevant parameters than the experience of the worker.

Procedure planning: preparation of tools, estimation of doses to be received, first trial with inactive sources.
All tools increasing the distance (e.g. forceps) between the hand/finger and the source are very effective for dose reduction.

The effectiveness of using forceps is also demonstrated when working with shielded sources.
Recommendation 9 - time

Working fast is not sufficient, the use of shields or increasing the distance are more effective than pushing on the working speed.

It is very difficult to correctly estimate the influence of time on the dose during a complete procedure, especially for the preparation of radiopharmaceuticals.

Different steps, very different dose rates in each step, usually for trained workers the use of shields or increasing the distance are more effective than pushing on the working speed.
Thank you for your attention

Special thanks to all the workers and hospitals that have collaborated

www.oramed-fp7.eu