Occupational Exposure of Medical Staff: an overview

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SCK•CEN

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Occupational Exposure of Medical Staff

• Introduction: UNSCEAR data
• Diagnostic Radiology:
  ➢ Fluoroscopy
    ♣ Double dosimetry, active dosemeters, extremity dosimetry
  ➢ CT fluoroscopy
• Dental Radiology
• Nuclear Medicine
  ➢ Extremity dosimetry
  ➢ Internal Dosimetry
• Radiation Therapy
• Conclusion
Radiation protection of medical staff

Limiting quantities

\[ H_T = \sum w_R D_{T,R} \]
\[ E = \sum w_T H_T \]

Operational quantities

\[ H_p(0.07) \text{ (skin)} \]
\[ H_p(3) \text{ (eye lens)} \]
\[ H_p(10) \text{ (whole body)} \]

Dose limit for the stochastic effects:

\[ 20 \text{ mSv/year} \]

Dose limit for the skin:

\[ 500 \text{ mSv/year averaged over 1 cm}^2 \]

Dose limit for eye lens:

\[ 150 \text{ mSv/year} \]
Average effective dose decreases for all fields, but the least for medical field
UNSCEAR: Number of monitored workers worldwide is highest in medical field
Collective dose: now is highest in medical field
As an example: dose distribution for one big university hospital in Belgium

Dose results 2008 (Total body dose)
Levels of exposure

- From 0 – 1 mSv
  - Laboratories
  - Cyclotron
  - Dentistry
  - Entrance to controlled areas
  - Limited contact with radiopharmaceuticals
  - Radiotherapy
  - Low dose RX-procedures
Levels of exposure

**Above 1 mSv**
- Nuclear medicine
- Radiopharmacy
- High dose RX-procedures
  - Interventional radiology
  - Cathlab
  - Digestive radiology
UNSCEAR Data: Number of medical workers in diagnostic radiology
Average dose in diagnostic radiology: no further decrease due to interventional radiology
Diagnostic radiology

- Increasing sophistication and new techniques
- Still, 80% of CT technologists and general radiographers
  - Non measurable dose
- Conventional:
  - Leakage much reduced
  - Normally stand in control booth that is shielded
    - Less than 1 µSv for film taken
  - Mobile units can be of greater concern
- Highest doses in interventional radiology
Interventional staff is mainly exposed to scattered radiation
Interventional radiology: highest doses

- Numbers are increasing (also therapeutic procedures)
- Considerable equipment development: longer and more complicated procedures
  - Higher doses
  - Although per case decreasing
- Large variation case per case: orders of magnitude
  - E between 0,2 and 40 µSv per procedure
  - Between 1 to 10 mSv/year
    - ISEMIR project will give overview of whole body doses
- Highlights:
  - Double dosimetry
  - Active personal dosemeters
  - Extremity (and eye lens) dosimetry
  - CT fluoroscopy
Double dosimetry

- Some results from an EURADOS/CONRAD study by H. Järvinen et al.

- Interventional radiological procedures: use of lead aprons
  - Inhomogeneous irradiation

- Single dosemeter above lead apron: clearly overestimate of $E$
- Single dosemeter under lead apron: possibility of underestimate of $E$
  - Measurement with 2 dosemeters (above+under): to improve accuracy of estimation of $E$

- ICRP 85: “Interventional radiology departments should develop a policy that staff wear 2 dosemeters”
Double dosimetry

- Problems:
  - Different algorithms:
    - influence of Pb thickness, thyroid collar, position of dosemeters, kVp,…
  - Calibration issues
  - Practical issues: mis-use…

- Literature search: 140 publications, 14 different algorithms
\[ E = \frac{H_o}{\gamma} \]

<table>
<thead>
<tr>
<th>Single dosimetry algorithm</th>
<th>( \gamma )</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>NCRP Report 122 (1995)</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Huyskens et al. (1994)</td>
<td>5</td>
<td>Or: ( E = 3 \times H_u )</td>
</tr>
<tr>
<td>Padovani et al. (2001)</td>
<td>14 (without TS)</td>
<td>\textit{Assuming} ( H_u \sim 0.01 \times H_o )</td>
</tr>
<tr>
<td></td>
<td>33 (with TS)</td>
<td></td>
</tr>
<tr>
<td>McEvan (2000)</td>
<td>12.5</td>
<td>Or: ( E = 2 \times H_u )</td>
</tr>
<tr>
<td>Franken and Huyskens (2002)</td>
<td>5</td>
<td></td>
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</table>
\( E = \alpha H_u + \beta H_o \)

<table>
<thead>
<tr>
<th>DD algorithm without TS</th>
<th>( \alpha )</th>
<th>( \beta )</th>
<th>Remarks</th>
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<tr>
<td>Wambersie and Delhove (1993)</td>
<td>1</td>
<td>0,1</td>
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<td>Rosenstein and Webster (1994), NCRP Report 122 (1995)</td>
<td>0,5</td>
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<td>Niklason et al. (1994)</td>
<td>1</td>
<td>0,06</td>
<td>( H_o \rightarrow H_o - H_u )</td>
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<td>Swiss ordinance (1999)</td>
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<td>0,1</td>
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<td>McEvan (2000)</td>
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<td>0,05</td>
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<td>Von Boetticher et al. (2003), Lachmund (2005)</td>
<td>0,65</td>
<td>0,074</td>
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<tr>
<td>Clerinx et al. (2007)</td>
<td>1,64</td>
<td>0,075</td>
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\[ E = \alpha H_u + \beta H_o \]

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<td>(H_o \rightarrow H_o - H_u)</td>
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<td>Swiss ordinance (1999)</td>
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<td>0,033</td>
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<td>1,64</td>
<td>0,075</td>
<td></td>
</tr>
</tbody>
</table>
Some results from experiments with RA phantom and MC simulations

<table>
<thead>
<tr>
<th>Irradiation geometry</th>
<th>Overestimation of E</th>
</tr>
</thead>
<tbody>
<tr>
<td>RPO30 80</td>
<td>Niklason et al (1994)(8)</td>
</tr>
<tr>
<td>AP 80</td>
<td>Franken and Huyskens (2002)(23)</td>
</tr>
<tr>
<td>RAO30 80</td>
<td>Swiss ordinance (1999)(7)</td>
</tr>
<tr>
<td>LLAT 80</td>
<td>McEwan (2000)(22)</td>
</tr>
<tr>
<td>PA 60</td>
<td>Sherbini and DeCicco (2002)(24)</td>
</tr>
<tr>
<td>AP 80</td>
<td>Clerinx et al. (2007)(29)</td>
</tr>
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<td>LLAT 80</td>
<td></td>
</tr>
</tbody>
</table>
Conclusions on double dosimetry

- No harmonized regulations and practices for DD --> estimations of E not comparable
- No firm consensus of the best DD algorithm
  - There is no 'ideal' algorithm
- Most algorithms overestimate E
- If estimated E approaches limit: further study of used algorithm needed
- DD generally recommended, mainly due to the risk of underestimations of E
Active personal dosemeters: useful as ALARA dosemeter, also in hospitals

- APD use common practise in nuclear installations
- More and more popular in smaller companies and hospitals
  - Could be useful in interventional radiology
  - Differences in use of results
    - Sometimes just alarm dosemeter
    - Sometimes check of passive dosemeter
    - ALARA dosemeter
- Important for hospitals:
  - should be able to respond to low-energy [10-100 keV] and pulsed radiation with relatively high instantaneous dose rates
  - With the current APD technology is not always the case
## Typical Parameters in IR

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>High peak voltage</td>
<td>50-120 kV</td>
</tr>
<tr>
<td>Intensity</td>
<td>5-1000 mA</td>
</tr>
<tr>
<td>Inherent filtration</td>
<td>4.5 mmAl</td>
</tr>
<tr>
<td>Additional filtration</td>
<td>0.1 – 0.9 mmCu</td>
</tr>
<tr>
<td>Pulse duration</td>
<td>1 - 20 ms (typically 10-20 ms)</td>
</tr>
<tr>
<td>Pulse frequency</td>
<td>1 – 30 pulse.s⁻¹</td>
</tr>
<tr>
<td>Dose rate in the direct beam (table)</td>
<td>2 to 360 Gy.h⁻¹</td>
</tr>
<tr>
<td>Dose rate in the scattered beam (operator)</td>
<td>5.10⁻³ to 10 Gy.h⁻¹</td>
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</tbody>
</table>
Scattered spectra at the operator position considering a filtration of 4.5 mmAl + 0.9 mmCu
EURADOS work: catalogue of APD’s

• Selection of 31 dosemeters from 16 manufacturers
• Three types
  ➢ Photon dosemeters with Geiger-Muller tube
    ♠ Automess, Graetz, Mini Instruments, Polimaster, SAIC
  ➢ Photon or beta-photon dosemeters with one or more silicon detectors
    ♣ AEA Technology, Aloka, Canberra Dosicard, Comet, Dositec, Fuji Electric, MGP, Saphymo, Rados, Thermo Electron
  ➢ Others:
    ♠ Rados DIS dosemeter, Unfors (extremity)
• Information gathered:
  ➢ Radiological performance, physical characteristics, environmental performance, mechanical performance, dose recording procedure, type test
Energy range according manufacturers

[Bar chart showing energy ranges for different manufacturers.]

- Unfors (sensor-extremity)
- Saic (sensor-extremity)
- Polimaster PM1603 (wrist)
- Thermoelctron MK2
- Thermoelctron EPD1
- Saphydose Gamma
- Saic PD-2i/PD-3i
- Rados RDD-20/RDR-20
- Rados RAD-60/62
- Rados RAD-51/51T
- Rados DIS-100
- Rados DIS-1
- Polimaster PM1203
- Mini Instruments 6100
- MGP SOR/R
- MGP DMC 2000XB
- MGP DMC 2000X
- MGP DMC 2000S
- Graetz ED 150
- Fuji Electric NRY 20001
- Dositec L36
- Comet APD
- Canberra Dosicard
- Automes ADOS
- Aloka PDM112
- AEA Tech. DoseGuard S10

Phonon energy (keV)

Lower limit (IEC 61526)
Lower limit (IEC 61283)
Upper limit (IEC)
Energy response of some APD’s
### Typical Parameters in IR

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ORAMED project (FP7): Optimization of Radiation Protection of Medical Staff

- WP3: active personal dosemeter: testing specifically for IR fields
  - High dose rates
  - Pulsed fields
  - Low energies

- Seven APDs were identified as suitable for IR and used in Europe:
<table>
<thead>
<tr>
<th>APD response function of dose rate:</th>
<th>APD response function of pulse frequency:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Multi-pulsed mode:</strong></td>
<td>Multi-pulsed mode:</td>
</tr>
<tr>
<td>- 20 msec, 10 pps</td>
<td>- Dose rate: 1.8 Sv/h</td>
</tr>
<tr>
<td>Dose rate: from 1 to 50 Sv/h</td>
<td>- 20 msec, 1 pps</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>APD response function of pulse width:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Single-pulsed mode:</strong></td>
</tr>
<tr>
<td>- Dose rate 1.8 Sv/h and 6.8 Sv/h</td>
</tr>
<tr>
<td>- Pulse duration between 1 and 1000 msec</td>
</tr>
</tbody>
</table>
Work achieved in WP3 – APD response in pulsed mode

APD response function of pulse frequency
Work achieved in WP3 – APD response in pulsed mode

APD response function of pulse frequency

Siemens EPD Mk2.3
Work achieved in WP3 – APD response in pulsed mode
Conclusions APD

Analyses in progress: ORAMED workshop in January 2010

• General dosimetric performance
  ➢ Comparable or better than passive systems
• But !!
  ➢ Caution in
    ♦ Beta fields
    ♦ Low energy X-rays
    ♦ Pulsed fields
  ➢ Not all dosemeters designed for all fields: IR/IC
Interventional staff:
- Whole body protected by lead apron
- Non protected parts?
  - Thyroid
  - Finger, wrist, arms
  - Legs, feet
  - Eye lens
Yearly extremity doses

- With good practise and protective measures: limits are not reached
- Martin and Whitby

<table>
<thead>
<tr>
<th>Group</th>
<th>Range of annual doses [mSv]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interventional radiologists (hands)</td>
<td>10-200</td>
</tr>
<tr>
<td>Interventional radiologists (legs)</td>
<td>10-200</td>
</tr>
<tr>
<td>Interventional radiologists (legs, with shield)</td>
<td>1-15</td>
</tr>
<tr>
<td>Cardiologists (hands)</td>
<td>5-100</td>
</tr>
<tr>
<td>Cardiologists (legs)</td>
<td>5-100</td>
</tr>
<tr>
<td>Cardiologists (legs, with shield)</td>
<td>0.5-10</td>
</tr>
</tbody>
</table>
ORAMED project

- Systematic measurement campaign performed in European hospitals
  - More than 1300 procedures followed!
  - Extremity doses

- Wide range of staff doses
  - Even for same centre and procedure
  - Very dependend on protective measures, personal habits, staff experience, X-ray geometry
Hp(0.07): normalized to KAP values
Protection measures important

- Highest dose not necessarily on hands
- Under-couch / over couch tube:
  - Dose to legs compared to dose to hands
- No fixed relation between DAP and extremity doses
  - Too much dependent on protective devices and different protocols
  - E.g. moving away from patient during acquisition
### Some extrapolated yearly doses from ORAMED

<table>
<thead>
<tr>
<th>Operator</th>
<th>Annual Dose (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ref</strong></td>
<td><strong>Finger</strong></td>
</tr>
<tr>
<td>B11</td>
<td>CA&amp;PTCA</td>
</tr>
<tr>
<td>G3</td>
<td>CA&amp;PTCA</td>
</tr>
<tr>
<td>B17</td>
<td>CA&amp;PTCA</td>
</tr>
<tr>
<td>A15</td>
<td>CA&amp;PTCA</td>
</tr>
<tr>
<td>A19</td>
<td>CA&amp;PTCA</td>
</tr>
<tr>
<td>E3</td>
<td>CA&amp;PTCA</td>
</tr>
<tr>
<td>E10</td>
<td>CA&amp;PTCA</td>
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<tr>
<td>E12</td>
<td>CA&amp;PTCA</td>
</tr>
<tr>
<td>G2</td>
<td>CA&amp;PTCA</td>
</tr>
<tr>
<td>G4</td>
<td>CA&amp;PTCA</td>
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<tr>
<td><strong>F5</strong></td>
<td>ERCP</td>
</tr>
<tr>
<td><strong>F8</strong></td>
<td>ERCP</td>
</tr>
<tr>
<td><strong>D5</strong></td>
<td>ERCP</td>
</tr>
<tr>
<td><strong>E11</strong></td>
<td>ERCP</td>
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<tr>
<td><strong>E13</strong></td>
<td>ERCP</td>
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Some extrapolated yearly doses from ORAMED

<table>
<thead>
<tr>
<th>Operator</th>
<th>Ref</th>
<th>PM &amp; ICD</th>
<th>RF ablation</th>
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<tr>
<td>Ref</td>
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<td>514</td>
<td>256</td>
<td>14</td>
<td>64</td>
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<tr>
<td>E15</td>
<td>vertebroplasty</td>
<td>648</td>
<td>275</td>
<td>28</td>
<td>72</td>
</tr>
</tbody>
</table>
Eye lens doses: recent concerns

- Some publications show increased cataract with interventionalists
- No deterministic threshold
- Discussion on reducing the dose limit

- Also: $H_p(3)$ is recommended quantity
  - Is this extra quantity needed?
  - No calibration procedures exist, no phantom
  - No dosemeters exist

- ORAMED:
  - Develop formalism to measure $H_p(3)$: conversion factors, type test and calibration procedures, phantom development
  - Design and development of new practical dosemeter that is suitable to respond in terms of $H_p(3)$
Eye lens dosemeter under development

Mounted on headband, ear or glasses
Measured eye lens values in ORAMED project: Embolization

Effect of tube configuration

- Middle Eye (below+BP)
- Middle Eye (above)
- L/R Eye (below+BP)
- L/R Eye (above)

Hp/KAP (mSv/μGy/m²)
CA/PTCA: ceiling shield reduces doses to eye lens

Effect of ceiling suspended shield to the eyes

Effect of ceiling suspended shield to the eyes

Middle Eye (no shield)  Middle Eye (with shield)  L/R Eye (no shield)  L/R Eye (with shield)
Conclusions

• IR/IC:
  - Very difficult to compare extremity doses or set general expected doses
  - Dependend on complexity of procedures, X-ray equipment, personal habits, protective measures
  - Training necessary
  - Protective measures can reduce doses substantial
  - Need for use of extremity dosemeter
    - ♣Not generally done
  - Eye lens doses are point of attention
Some results from EURADOS WG12
(F. Becker)$^2$

Relatively new development with high staff dose risk: Typical situation in CT fluoroscopy
CT-Fluoroscopy - staff dosimetry

CTF biopsy showing biopsy needle and lesion
CT-Fluoroscopy - staff dosimetry

<table>
<thead>
<tr>
<th>Location</th>
<th>Dose Rate (µGy/s)</th>
<th>Dose for typical 120s procedure (mGy)</th>
<th>Number of procedures for 3/10 Dose Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skin (hands, in x-ray beam)</td>
<td>3-4 mGy/s</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Skin (hands, with needle holder)</td>
<td>17 µGy/s</td>
<td>2 mGy</td>
<td>75</td>
</tr>
<tr>
<td>Body Trunk (above lead apron)</td>
<td>9 µGy/s</td>
<td>1 mGy</td>
<td>6</td>
</tr>
<tr>
<td>Eyes</td>
<td>1.5 µGy/s</td>
<td>0.4 mGy</td>
<td>375</td>
</tr>
</tbody>
</table>

Scattered dose rates to equipment operator from CT
(Exposure parameters: 120 kV, 50 mA)
Dental practices
Number of monitored workers in dental practices
Dental practices

- Very large number of devices
- Leakage is very small, mostly scatter from patient
- Mostly not measureable, not always monitoring required

- Average effective dose E per year = 0.05 mSv
Nuclear medicine
Number of monitored workers in Nuclear Medicine

![Bar chart showing the number of monitored workers in Nuclear Medicine from 1975-1979 to 2000-2002.](chart.png)
Average effective dose in Nuclear Medicine

![Bar chart showing average effective dose in different periods]
Nuclear Medicine

- Preparation of radiopharmaceuticals and administration to patients (preparation, dispensing, injection)
- More for technicians instead of doctors and nurses
- Typically: 85% Tc\textsuperscript{99m}, 10% F\textsuperscript{18}, 5% other

- Whole body normally shielded
  - Annual up to 5 mSv/yr
- Extremities can be up to limit
- PET in general higher than Tc\textsuperscript{99m}
- Therapeutic procedures even higher
Protective measures important

- Major protective measure: syringe shield
- Theoretical attenuation factor: 100
- Actual observed decrease: factor 2
  - Not always possible to use syringe shield: activity measurements
  - Sometimes higher doses with shield !
    - Less experienced staff work slower with shield
- Procedure is important for extremity dose
  - Reports: changing techniques can lower dose with factor 2
  - Large differences from one technician to another
Annual extremity doses in Nuclear Medicine

- Annual doses: large variability:
  - Harding: up to 550 mSv
  - Chruscielewski: 4 to 200 mSv
  - Jankowski: 14-90 mSv
  - Withby and Martin: 5 – 200 mSv
  - Wrzesie: 1.6-4 Sv (most exposed parts of hands)
### Official extremity dosimetry: Number of workers with extremity dosimeters

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of whole body monitored workers in the medical field</th>
<th>Number of workers with extremity dosimeters</th>
<th>Number of workers wearing ring dosimeters</th>
<th>Number of workers wearing wrist dosimeters</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>43000</td>
<td>9%</td>
<td>5%</td>
<td>95%</td>
</tr>
<tr>
<td>CH</td>
<td>50823</td>
<td>2%</td>
<td>100%</td>
<td>0%</td>
</tr>
<tr>
<td>D</td>
<td>308666</td>
<td>3%</td>
<td>100%</td>
<td>0%</td>
</tr>
<tr>
<td>GR</td>
<td>9227</td>
<td>1%</td>
<td>0%</td>
<td>100%</td>
</tr>
<tr>
<td>F</td>
<td>159116 (*)</td>
<td>5%</td>
<td>19%</td>
<td>81%</td>
</tr>
</tbody>
</table>
### Nuclear medicine doses in 2005

<table>
<thead>
<tr>
<th>Country</th>
<th>number of workers</th>
<th>average doses [mSv]</th>
<th>number of yearly doses &gt; 5mSv</th>
<th>number of yearly doses &gt; 50mSv</th>
</tr>
</thead>
<tbody>
<tr>
<td>E (cr), ring</td>
<td>129</td>
<td>29.1</td>
<td>75</td>
<td>23</td>
</tr>
<tr>
<td>CH (cr), ring</td>
<td>404</td>
<td>9</td>
<td>119</td>
<td>19</td>
</tr>
<tr>
<td>D (cr), ring</td>
<td>3104</td>
<td>7.13</td>
<td>78</td>
<td>46</td>
</tr>
<tr>
<td>BE (2), ring</td>
<td>9</td>
<td>10.13</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>E (cr), wrist</td>
<td>698</td>
<td>6.5</td>
<td>206</td>
<td>11</td>
</tr>
<tr>
<td>GR (cr), wrist</td>
<td>45</td>
<td>1.88</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>DK (1), wrist</td>
<td>531</td>
<td>4.5</td>
<td>6</td>
<td>0</td>
</tr>
</tbody>
</table>
Nuclear medicine therapy

- Sealed and unsealed sources for therapy purposes
  - Radiosynoviorthesis $^{90}$Y, $^{186}$Re, $^{169}$Er
  - Radio-immunotherapy Zevalin ($^{90}$Y)
  - Peptide-receptor guided radiotherapy for neuroendocrine tumors ($^{90}$Y, $^{177}$Lu)
  - Vascular brachytherapy with $^{188}$Re

- Concern for radiation protection of staff
  - High activities (100s of MBq to GBq)
  - Use of beta emitters and higher dose rates/activity
  - Handling close skin of hands/fingers
  - Risk for contamination
Even higher doses with betas

- Study by *Barth et al*
- Vascular brachytherapy with $^{188}$Re
  - Up to 700 mSv/day !!!
- Radiosynoviorthesis $^{90}$Y
  - Maximum 100 mSv/day during preparation, 200 mSv/day during injection
- Radio-immunotherapy Zevalin ($^{90}$Y)
  - 25 mSv/treatment
- Even if this is performed at low frequencies
  - Risk of surpassing limits
- But with proper protection measures:
  - Doses decrease drastically
ORAMED project: objectives

• To evaluate extremity doses (and dose distributions across the hands) of medical staff working in nuclear medicine departments: measurements and simulations.
  ➢ Preparatio, dispensing and administration
  ➢ Tc-99m, F-18
  ➢ Special attention to NM therapy applications (mostly Y-90)

• To study the influence of protective devices such as syringe and vial shields.

• Over 800 procedures measured!
Example from ORAMED measurements:
F-18 administration

11 measurement positions on each hands, 5 procedures followed, normalised to activity

[Graph showing distribution of Hp(0.07)/manipulated act [µSv/GBq] for H1 T11]
•Maximum mostly at finger tips: monitoring at wrist or base of finger

•Multiplication factor needed for routine dosemeters: 2 to 30 !!
ORAMED measurements: extrapolation to yearly extremity doses

<table>
<thead>
<tr>
<th>Worker</th>
<th>Total max annual dose (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T4HF2</td>
<td>24</td>
</tr>
<tr>
<td>T5HF2</td>
<td>26</td>
</tr>
<tr>
<td>T8HF2</td>
<td>315</td>
</tr>
<tr>
<td>T12HF2</td>
<td>154</td>
</tr>
<tr>
<td>T9HF2</td>
<td>524</td>
</tr>
<tr>
<td>T10HF2</td>
<td>302</td>
</tr>
<tr>
<td>T11HF2</td>
<td>349</td>
</tr>
<tr>
<td>T1HF3</td>
<td>216</td>
</tr>
<tr>
<td>T1HF4</td>
<td>1781</td>
</tr>
<tr>
<td>T2HF4</td>
<td>1630</td>
</tr>
<tr>
<td>T6HF7</td>
<td>546</td>
</tr>
<tr>
<td>T1HF7</td>
<td>2976</td>
</tr>
<tr>
<td>T2HF7</td>
<td>35</td>
</tr>
<tr>
<td>T3HF7</td>
<td>144</td>
</tr>
<tr>
<td>T5HF7</td>
<td>1</td>
</tr>
<tr>
<td>T4HF7</td>
<td>3</td>
</tr>
</tbody>
</table>

Workload (number of technicians) very important
Nuclear Medicine: internal exposures

- Normally no internal exposures
- Contaminations can occur regularly
- Short physical half lives:
  - No practical routine monitoring
  - Screening methods
    - No determination of committed effective dose
    - Verify threshold
    - Gamma camera (I-isotopes), dose rate measurements, contamination monitoring, check of airborne concentrations, routine bio assays (rare)
    - In practise not very often implemented

- Exact doses not well known
Conclusions

- **Nuclear medicine:**
  - Whole body doses order of 5 mSv/yr
  - Biggest problem is extremity doses
  - Doses depend on personal habits and experience, protective measures
    - ♣ Training necessary
  - Yearly dose limit can be reached
  - Very difficult to measure maximum exposed area
    - ♣ Correction factor
  - More studies on internal doses needed
Radiation Therapy
UNSCEAR: Number of monitored workers in radiation therapy: steady increase
Average doses in Radiation therapy: clear decrease
Radiation therapy

- Staff normally not in treatment room when external beam is on
- Hardly any radiographers, radiotherapists, technicians, support staff receive annual doses >1 mSv
- Co-60 sources: leakage normally very low
- LINACS: above 10 MeV
  - Photo neutrons are produced
    - Can penetrate the protective barrier
    - Often maze: neutrons scatter to outside
    - Small neutron dose rates during beam on at entrance of maze
      - Staff should not be seated there
      - Only small doses (order of µSv/h): no monitoring needed
  - Activation in treatment room
    - Immediately after irradiation
    - Normally low
  - Can increase with IMRT (longer beamtime, more neutrons)
  - Can also be problem in hadron therapy
Brachytherapy

- Nowadays: use of afterloading machines
  - Staff doses are highly reduced: low doses
Conclusion

• Doses to medical staff are high compared to other fields
  ➢ Less decreasing
• Highest staff doses:
  ➢ Interventional procedures: whole body doses and extremity doses
  ➢ Nuclear medicine: extremity doses
• Eye lens doses in IR/IC should be followed
• Continuous training and education
  ➢ Constantly introduction of new techniques and evolutions
  ➢ Working habits very important
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  ➢ P. Covens (AZ-VUB)
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  ➢ F. Becker (KIT)