EXTREMITY EXPOSURE IN NUCLEAR MEDICINE: WORK PACKAGE 4 OF THE PROJECT

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Barcelona, 20-22 January 2011 Workshop on Optimization of Radiation Protection of Medical Staff

2007 - 2013

Aim of this talk

To present the objectives of Work Package 4 (WP4) of ORAMED and the implemented methodology

- ✓ Context
- ✓ Selected radionuclides
- ✓ Dosimetric and detection issues
- ✓ Program and methods of measurements
- ✓ Program and methods of simulations

Why?

Nuclear medicine: manipulation of (unsealed) radioactive sources




➔ The hands are particularly exposed to ionizing radiations

Previous experience (CONRAD Project 2005-2007):

- ✓ The doses can exceed operational limits
- ✓ Large dose gradients are observed across the hands
- ✓ Extremity dosemeters are not systematically used and frequently are not appropriately used
- ✓ Poor information is available: absence of systematic studies

Vanhavere, F. et al., Radiat. Prot. Dosim. 129 (2008) 350-355
Donadille, L. et al., Radiat. Prot. Dosim. 131 (2008) 62-66
Carinou, E. et al.,. Radiation Measurements 43 (2008) 565-570
Ginjaume, M. et al., Radiat. Prot. Dosim. 131 (2008) 67-72

What's new?

- ✓ To perform a **systematic measurement and simulation campaign**
  - **Measurements**: Distributions of the doses across the hands
  - **Simulations**: Analyze separately the parameters influencing the doses
- ✓ To provide **guidelines** for reducing the doses of the medical staff
- ✓ To propose "**levels of reference doses**" for standard NM procedures

⬇

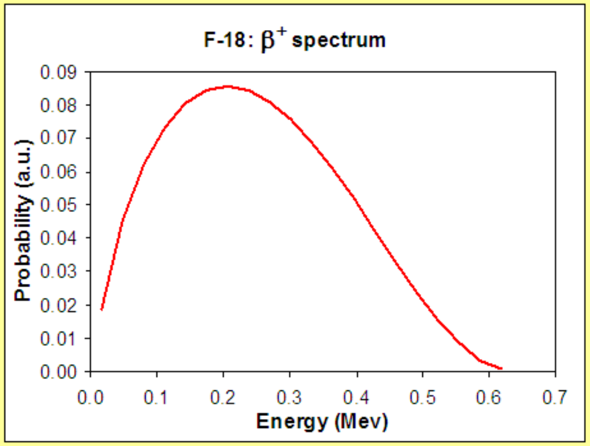
ORAMED WP4: Extremity dosimetry in nuclear medicine

Radionuclides of interest

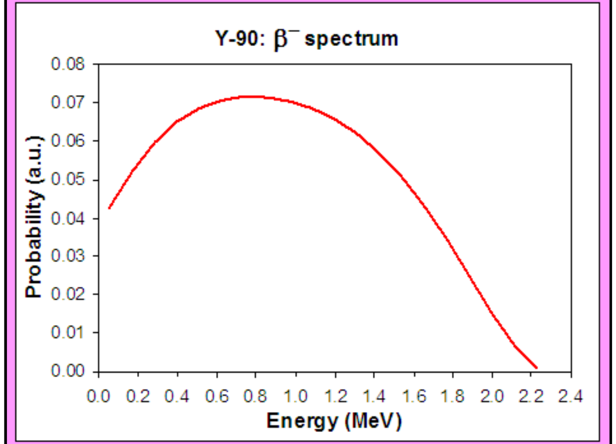
- ✓ **Diagnosis** with **Tc-99m** and **F-18**
- ✓ **Therapy** with **Y-90** (RIT with Zevalin®; PRRT with Dotatoc)
  + others

Tc-99m
Pure γ emitter
E_{γ} = 140.5 keV (87%)

F-18
Mixed β^{+} and γ emitter
$E_{\beta+max}$ = 634 keV (97%)
E_{γ} = 511 keV (194%)

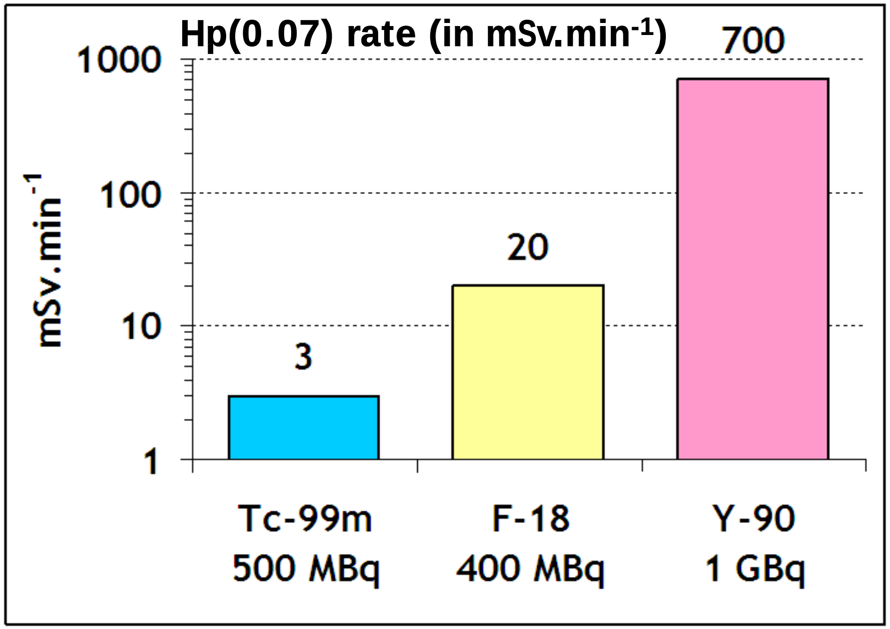


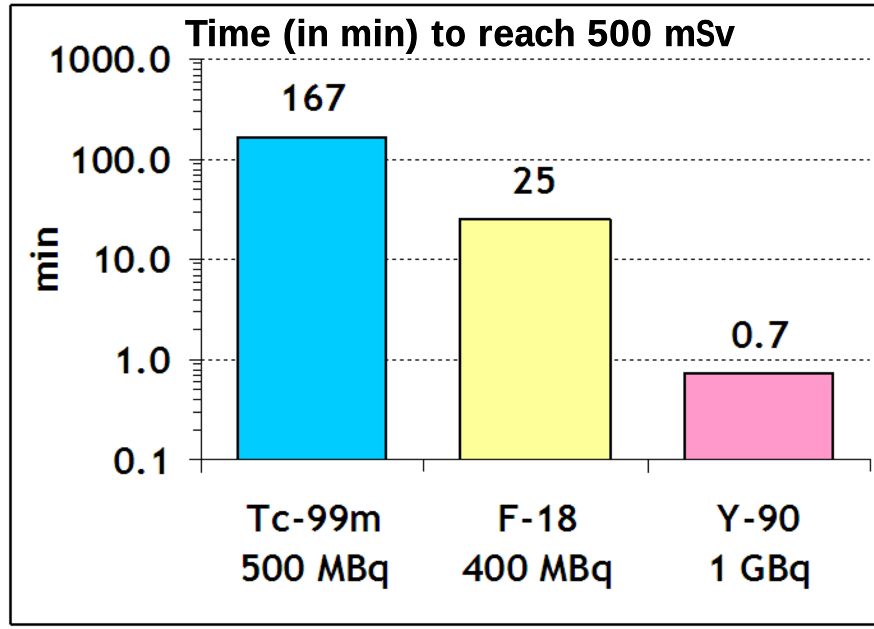
Y-90
Pure β^{-} emitter
$E_{\beta-max}$ = 2280 keV (100%)



Dosimetric issues

In contact of an unshielded (5 ml) syringe





✓ Dose rates are VERY different

✓ For Y-90 the annual limit can be reached in less than 1 minute

➔ Shielding is essential

✓ However, the frequencies of manipulation are VERY different

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Detection issues

- ✓ **Photons and electrons**
- ✓ **Energy range**: 0 – 2.28 MeV
- ✓ **Hp(0.07) range**: ~10 μSv → > 100 mSv

→ **TL dosemeters ^{7}LiF:Mg,Cu,P adapted**

Thickness	≤ 100 mg.cm^{-2}	for F-18 and Y-90
	≥ 100 mg.cm^{-2}	for Tc-99m

- ✓ An **intercomparison exercise** was organized to ensure consistency of the results between WP4 partners

  - Fields: Cs-137 and Kr-85
  - At least 2 TL dosemeters were irradiated per partner

TL dosemeters'response

	Cs-137 E_{γ} = 662 keV	Kr-85 $E_{\beta-max}$ = 687 keV $E_{\beta-av}$ = 252 keV
Mean	1.00	1.03
Std. Dev.	0.09	0.10

→ Adequate consistency

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Measurements

Protocol:

✓ **A pair of gloves equiped 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

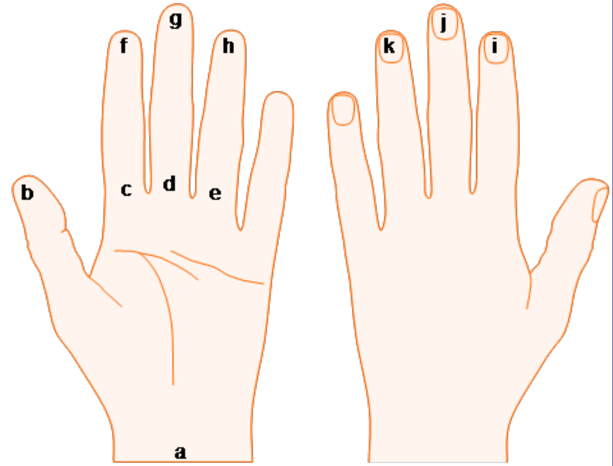
➔ **1 pair of instrumented gloves = 1 measurement**

✓ For diagnostic applications:

- At least: 5 measurements per worker
  2 workers per hospital
  2 hospitals per WP4 partner

✓ For therapeutic applications:

- As many measurements and workers as possible



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Measurements

Recorded information:

- Type of **radionuclide** (Tc-99m, F-18, Y-90 …)
- **Hospital**'s ID
- **Worker**'s ID
- **Right-** or **left**-handed
- Worker's **experience**

  beginner: ≤ 1 year experienced: > 1 year
- **Radiation protection devices** used

  vial-shield, syringe-shield, forceps, semi-automatic devices
- Total **manipulated activity**
- **Dose** measured for every TL dosemeter

\+ any additional comment to help understanding some results, e.g. a contamination event

All information gathered in a common database

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Measurements

Definition of the manipulated activity:

✓ For preparation

it's the total **activity withdrawn from**

- the **elution vial** for Tc-99m

  which is less than the eluted activity!

- the **mono- or multi-dose vial** for F-18

  which is less than the vial activity!

- the **radioactive vial** for Y-90

✓ For administration

it's the total **activity in the injection syringe**

Measurements

Where?

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Measurements

			Measurements	Workers	Hospitals
Tc-99m		Preparation	178	36	21
		Administration	157	32	20
F-18		Preparation	160	30	17
		Administration	146	30	17
		Total	**641**		
Y-90	RIT Zevalin®	Preparation	49	20	16
		Administration	45	27	15
Y-90	PRRT Dotatoc®	Preparation	16	5	4
		Administration	17	7	4
		Total	**127**		
Y-90	SIRT SIR-Spheres®	Preparation	20	4	3
I-131	RIT	Preparation and Administration	4	1	1
Sm-153	PPT	Preparation	2	1	1
Re-186	RSO	Preparation	4	3	3
		Administration	4	3	3
		Total	**34**		

ANALYZED

Analyzed: 7 countries; 34 different hospitals; 124 different workers

Analysis of measurements

- ✓ Separation of **Tc-99m**, **F-18** and **Y-90** applications
- ✓ Separation of **preparation** and **administration** stages
- ✓ Doses normalized per manipulated activity (e.g. mSv/GBq)

✓ For **diagnostic** applications:

- Workers with **at least 4 measurements** series considered
- Doses averaged over the measurement series for each worker
- Identification of the **position receiving the maximum dose**
- Classification of workers according to their maximum doses
- Effect of **shielding**, operator's **experience**, **nd** *vs* **D** hands
- **Ratios** Maximum dose / Dose at possible monitoring positions
- Extrapolations to **annual doses**

✓ For **therapeutic** applications:

- Analysis focused on RIT with Zevalin® and PRRT with Dotatoc
- **All workers** were considered
- Rest of the analysis similar to that for diagnostic applications

Simulations

- ✓ Aims:
  - To analyze separately the parameters influencing the doses
    - ➔ Sensitivity study to understand intra- and inter-operator variabilities
  - To calculate surface dose distributions (dose mapping) for some selected cases

- ✓ 6 configurations were defined

  Considered as representative of different manipulation stages

Simulations

6 defined configurations:

Preparation

Holding a vial in hand

Holding a vial with forceps

Holding a syringe by the piston

Holding a syringe by the needle

Administration

Holding a syringe in hand

Injecting

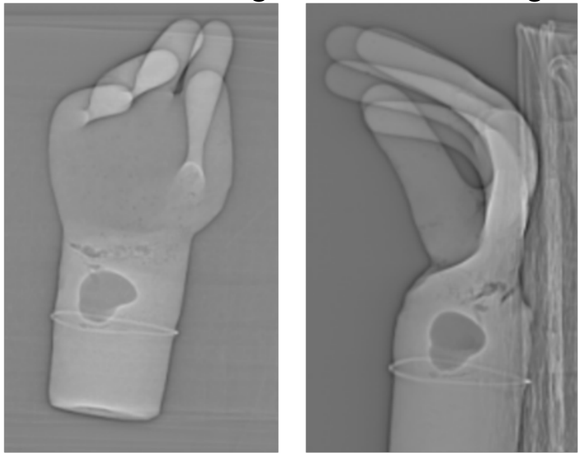
Simulations

From real to numerical worlds: the procedure

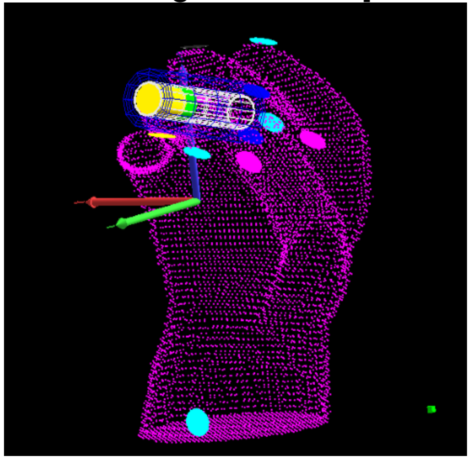
1. Defining the case

2. Creating a moulding

3. Scanning the moulding



4. Generating a voxel phantom



5. Adding the source and dosemeters

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Simulations

- ✓ **Tc-99m**, **F-18** and **Y-90** considered
- ✓ Use of the MC code **MCNPX** (Pelowitz (Ed.), 2005)
- ✓ Their **emission characteristics** taken into account
- ✓ Dose calculated at (70 ± 5) µm in the dosemeters [**Hp(0.07)**]
- ✓ Hand phantoms and dosemeters made of ICRU-44 **soft tissue** (1 g.cm^{-3})
- ✓ For Tc-99m: **only photons** transported
- ✓ For F-18 and Y-90: **photons and electrons** transported

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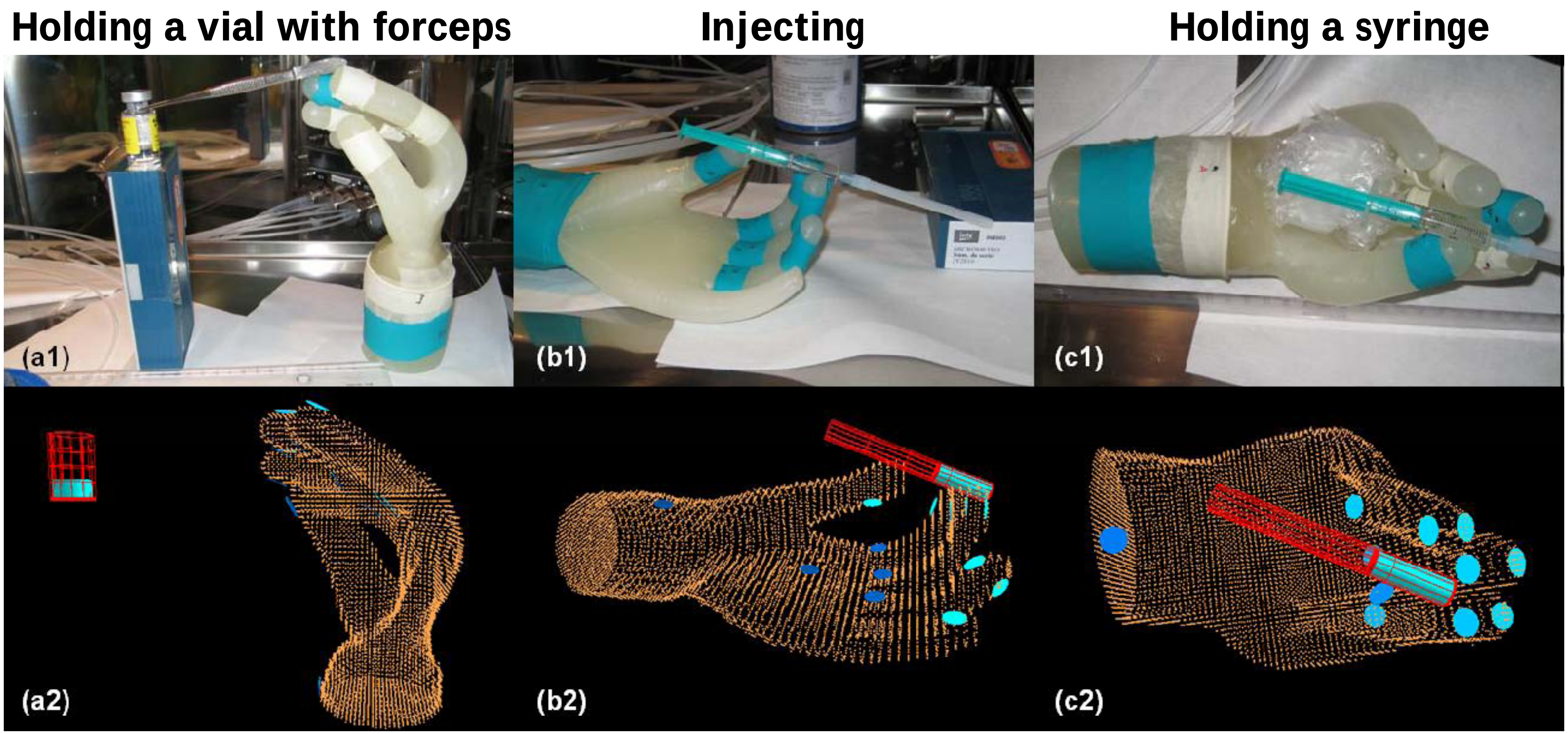
Simulations

A validation study was done

– Comparing calculations with measurements for Tc-99m and F-18



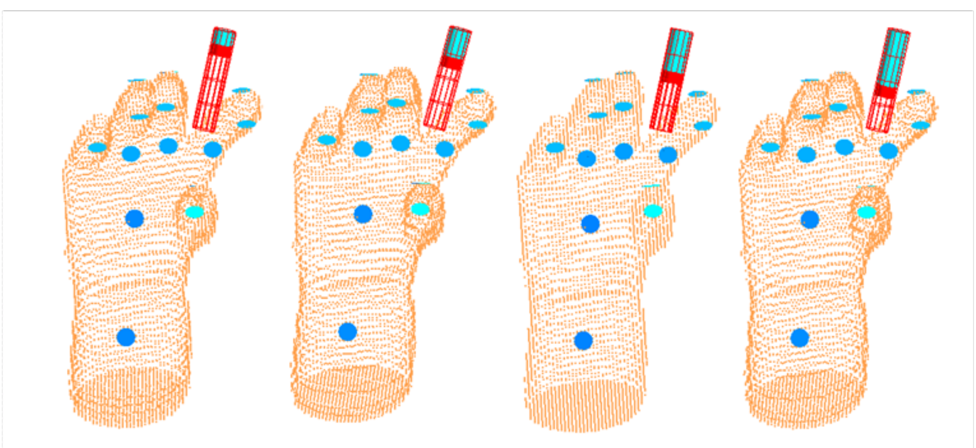
→ **Simulations validated** (see Carnicer, A. et al., poster P15)

Simulations

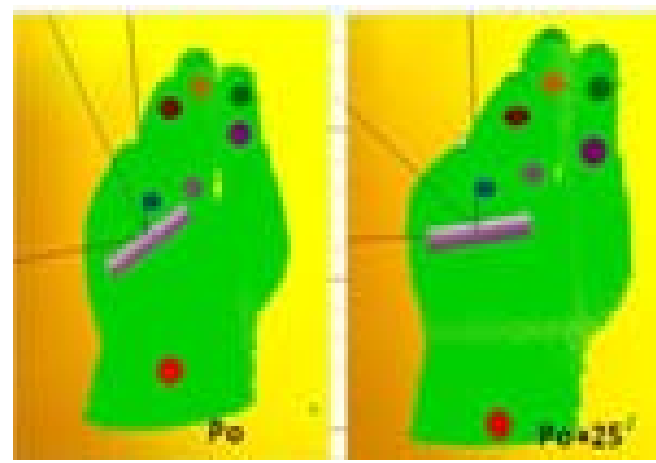
Parameters for the sensitivity study:

- Radionuclide
- Shielding
- Displacement of the source
- Orientation of the source
- Volume of the source

Example 1: variation of the active volume



Example 2: rotation of the syringe

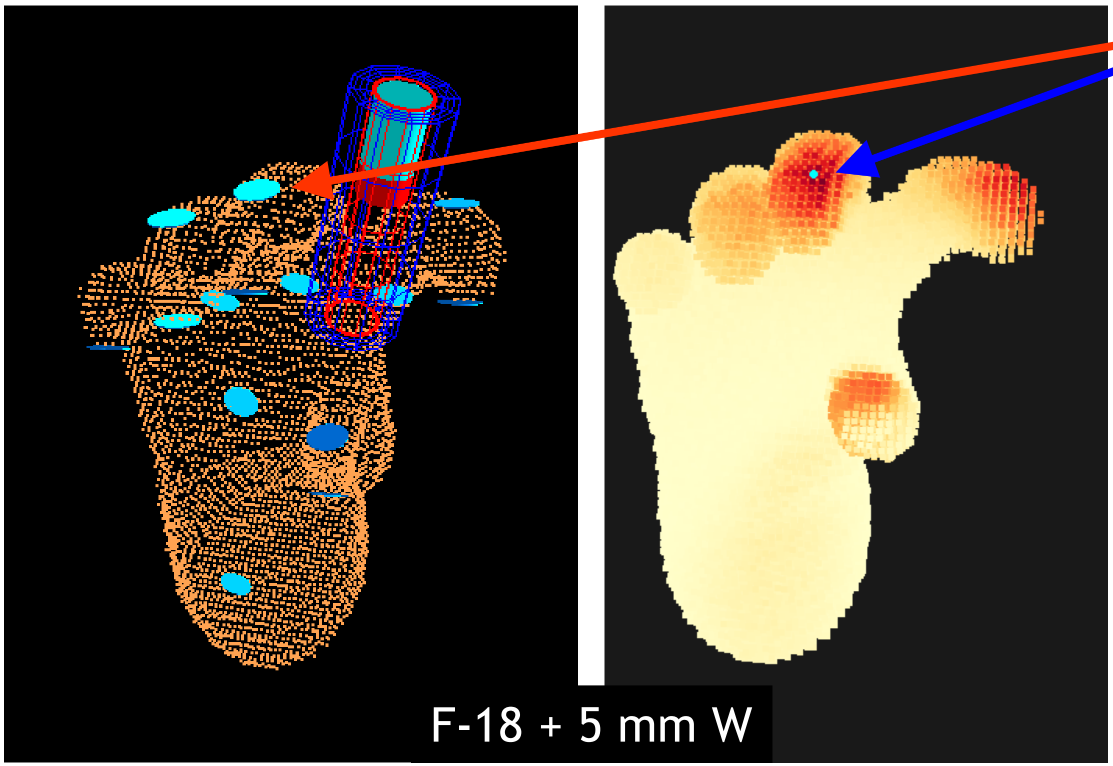


Simulations

Dose mapping of the hand's surface:

The location of the maximum can be at a different place to that of the dosemeters.

➔ How large is the underestimation?



Comparison is made between the calculated doses identified as the maximum in the dosemeters and in the surface voxels

WP4 presentations

Analysis of the **measurements for diagnostic applications**

→ Carnicer A. et al.

Analysis of the **measurements for therapeutic applications**

→ Rimpler A. et al.

Analysis of the **Monte Carlo simulations**

→ Ferrari P. et al.

Guidelines → Sans Merce, M. et al.

Training → Sans Merce, M., Ginjaume, M. et al.

THANK YOU!

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