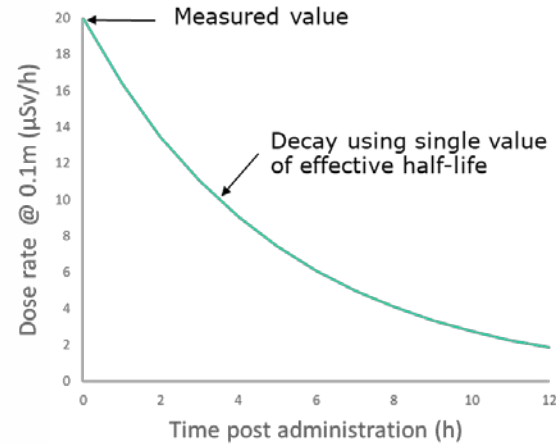
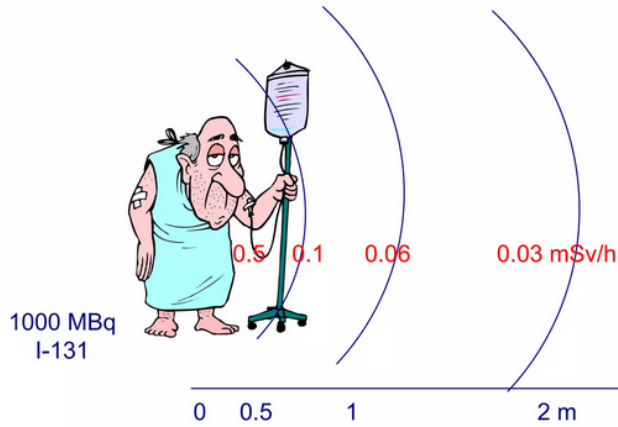

Computational approach to assess external dose rates from nuclear medicine patients

November 25th, 2024

Webinar: Release of the NM patients in Europe: from basics to a computational approach – A joint EURADOS-EANM initiative

Lara.Struelens@sckcen.be

Background



Dose rate @ distance from patient

Dose rate < patient release criterion

Exposure of ...

Nuclear medicine patient as a radioactive source

- Physically large source
 - Patient-specific biokinetics change the activity distribution over time
 - Isotope- and pharmaceutical-specific
 - Combination of 'point measurement' and 'unique effective half life'
- ⇒ can result in errors for typical 'close-contact scenarios'

Public

Caregiver

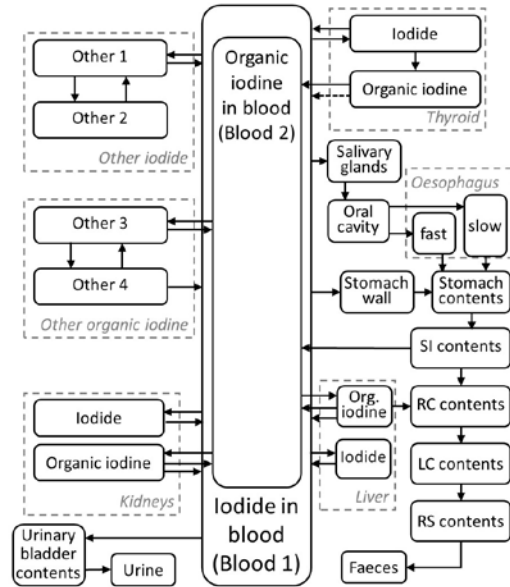
Family



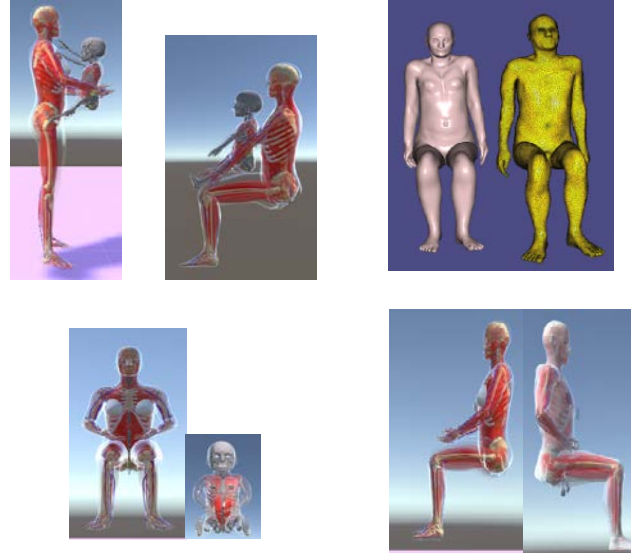
Description NM patient

Exposure of caregiver/family/...

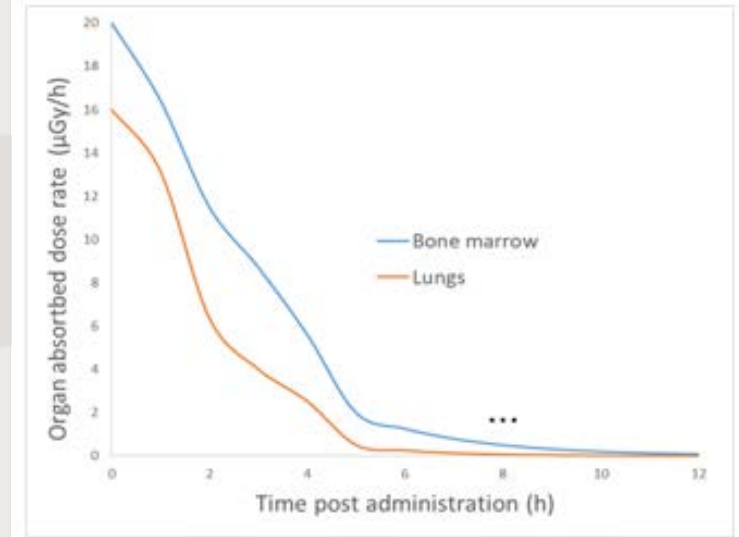
Biokinetic models



Flexible mesh-based computational models



Organ absorbed dose rate over time



Monte Carlo modelling

Computational approach to assess external dose rates from NM patients

- Different EURADOS working groups
 - *Computational dosimetry; biokinetic modelling ; access to NM departments*
- EANM Radiation Protection committee
 - *Access to NM departments*

¹ICRP Publication 128 (2015)

²Kamp A, et al. (2023)

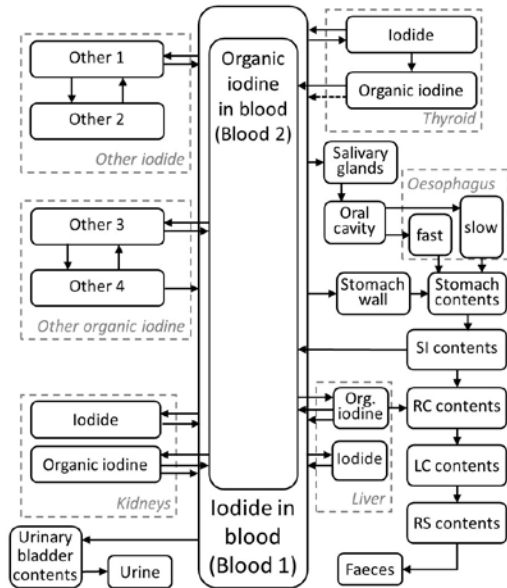
³Taprogge J, et al. (2021)

⁴Siebinge H, et al. (2024)

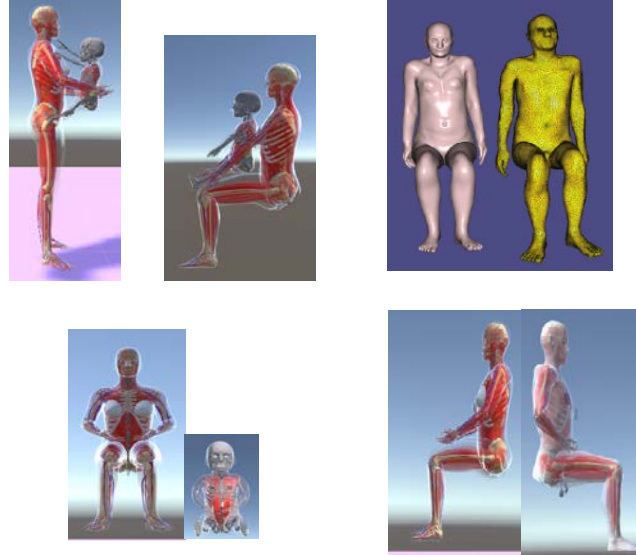
⁴ICRP Publication 145 (2020)

⁵Lombardo P, et al. (2018)

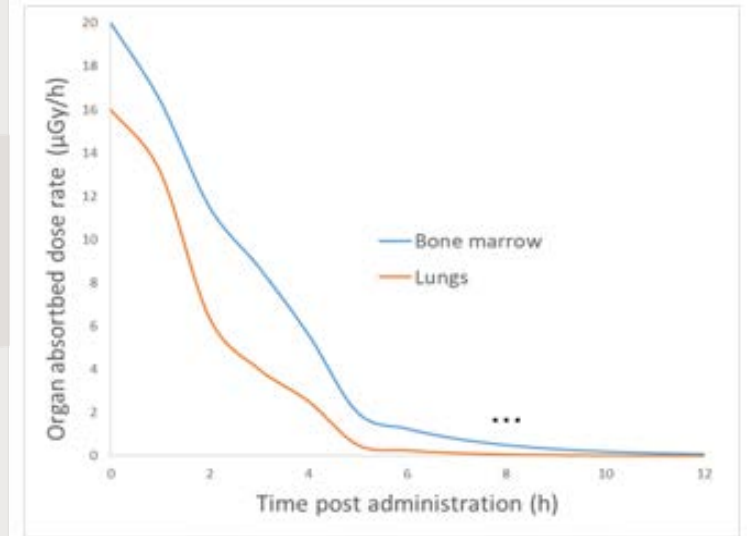
Biokinetic models



Flexible mesh-based computational models



Organ absorbed dose rate over time



Monte Carlo modelling

- ICRP reference Biokinetic models^{1,2}
- Biokinetic data based on patient data^{3,4}

- ICRP reference phantoms⁴
- In-house developed phantoms⁵
- Incl. software to change the posture

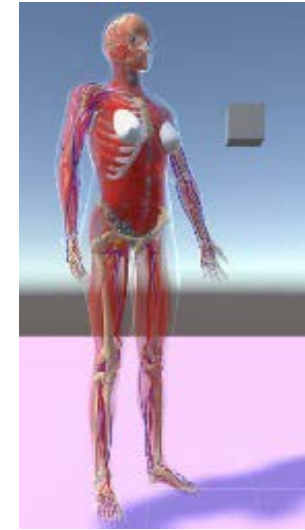
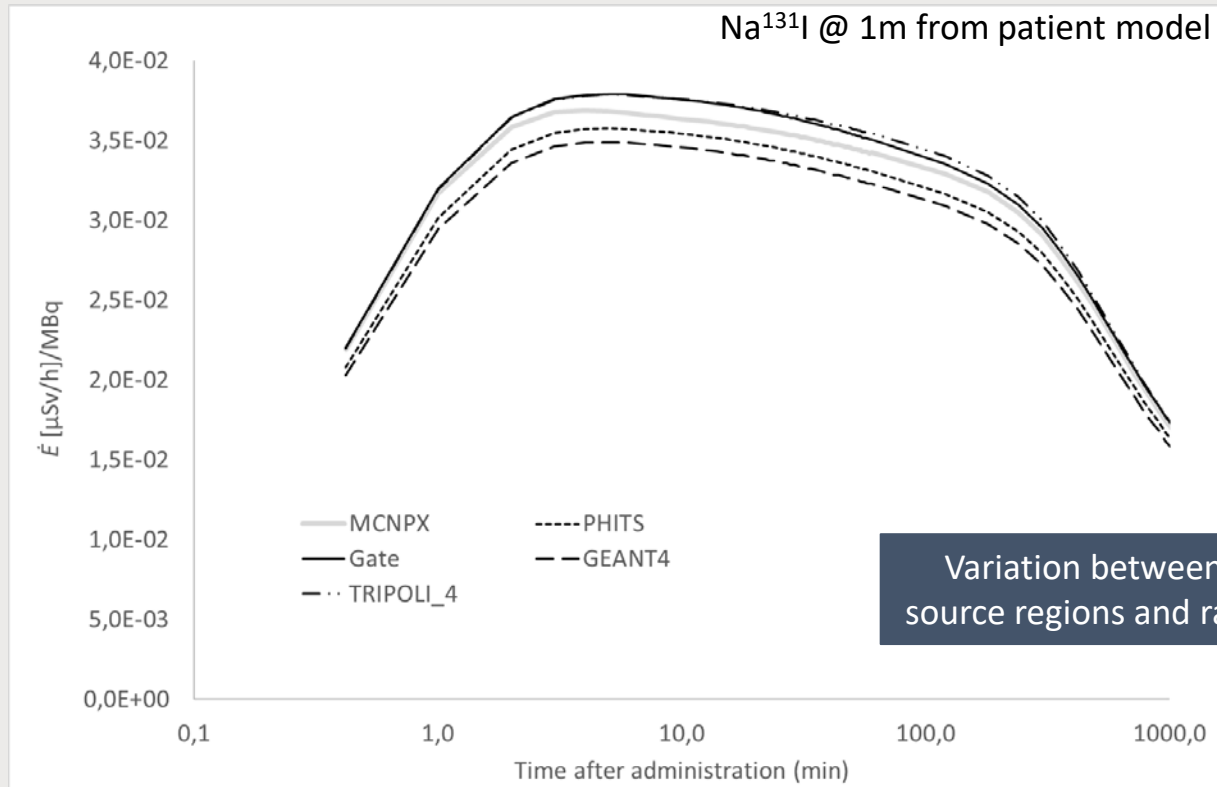
- Monte Carlo codes
 - MCNP-X
 - PHITS
 - GATE
 - GEANT4
 - TRIPOLI-4

$$\dot{D}(t) = A_{adm} \sum_{source\ region} a_{source\ region}(t) \dot{D}_{source\ region}$$

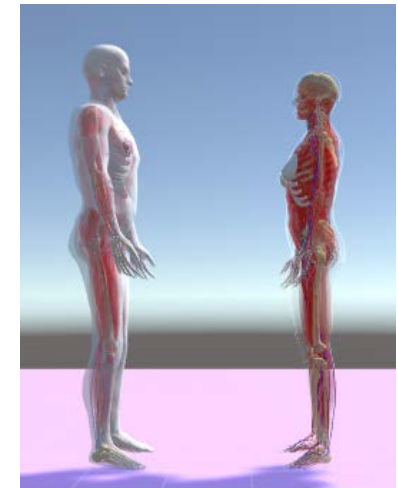
$\dot{D}_{source\ region}$: organ absorbed dose rate in target per activity in a source region
 $a_{source\ region}(t)$: fractional activity on time t in a source region
 A_{adm} : administered activity to NM patient

Benchmark computational framework

- Comparison between different Monte Carlo codes
- Comparison against experimental dose rate data from NM patients



Ambient dose equivalent rate $\dot{H}^*(10)$

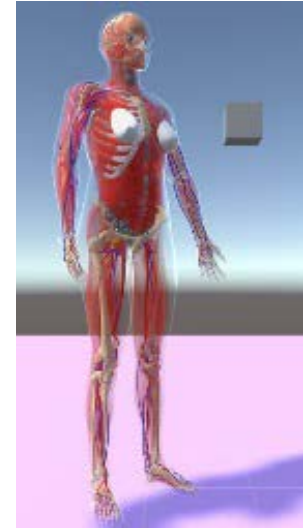
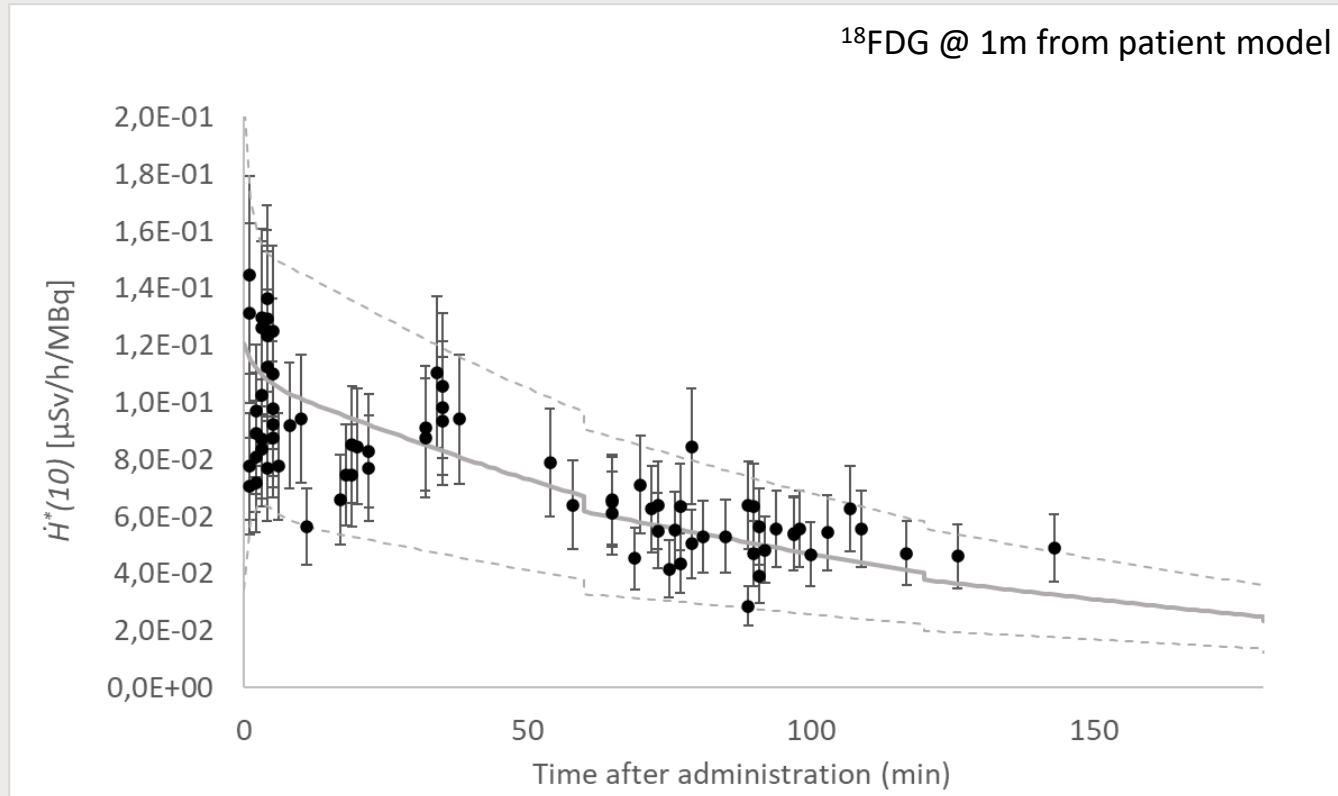


Effective dose rate $\dot{E}$

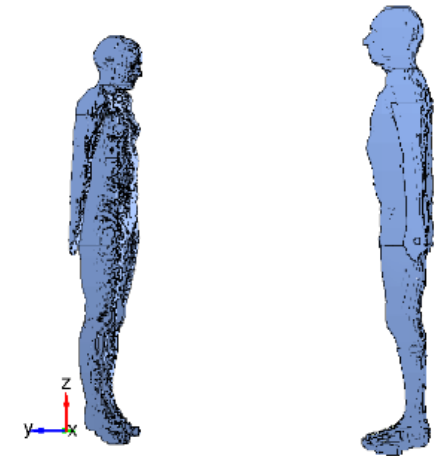
^{99m}Tc-HDP/MDP ; **¹⁸F**FDG ; Na¹³¹I ; **¹⁷⁷Lu**-DOTATATE/PSMA

Benchmark computational framework

- Comparison between different Monte Carlo codes
- Comparison against experimental dose rate data from NM patients



Ambient dose equivalent rate $\dot{H}^*(10)$

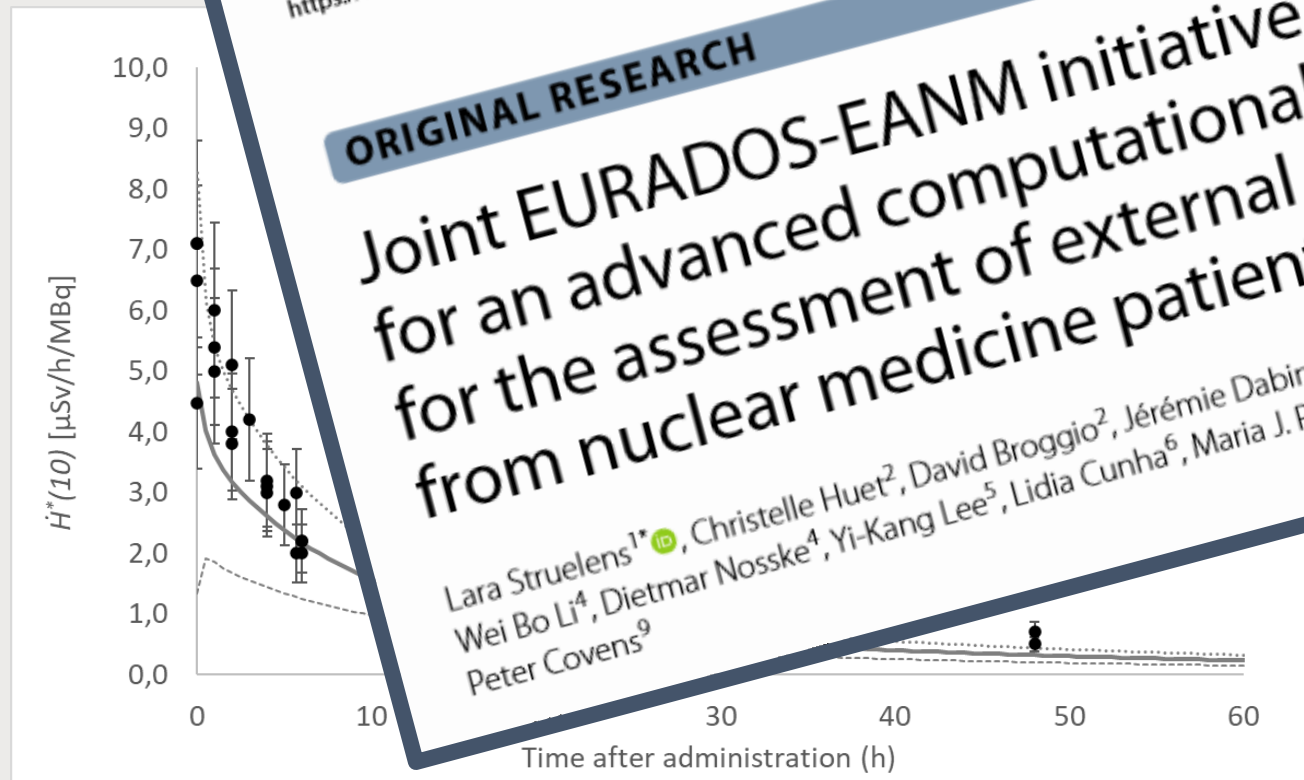


Effective dose rate $\dot{E}$

$^{99\text{m}}\text{Tc}$ -HDP/MDP ; ^{18}F FDG ; Na^{131}I ; ^{177}Lu -DOTATATE/PSMA

Benchmark computational framework

- Comparison between different computational frameworks
- Comparison between different computational frameworks



Struelens et al. EJNMMI Physics (2024) 11:38
<https://doi.org/10.1186/s40658-024-00638-y>

ORIGINAL RESEARCH

Joint EURADOS-EANM initiative for an advanced computational framework for the assessment of external dose rates from nuclear medicine patients

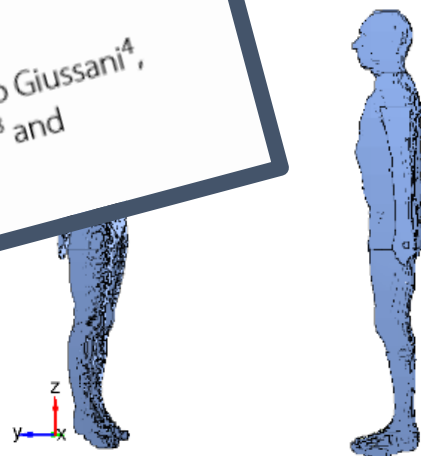
Lara Struelens^{1*}, Christelle Huet², David Broggio², Jérémie Dabin¹, Laurent Desorgher³, Augusto Giussani⁴, Wei Bo Li⁴, Dietmar Nosske⁴, Yi-Kang Lee⁵, Lidia Cunha⁶, Maria J. R. Carapinha⁷, Mario Medvedec⁸ and Peter Covens⁹

EJNMMI Physics

Open Access



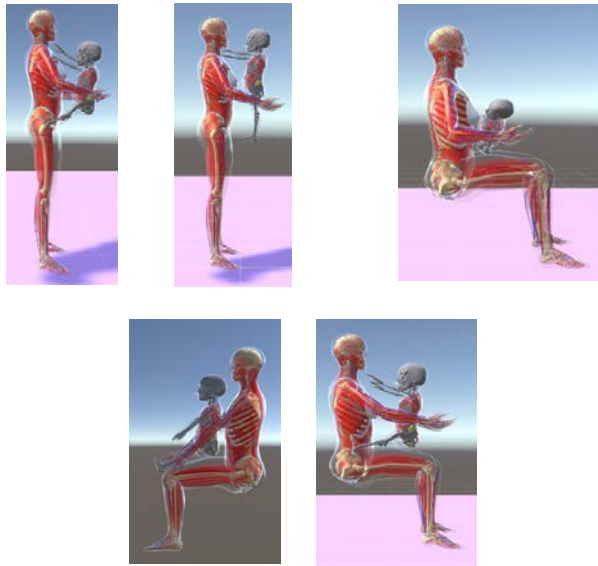
dose equivalent rate $\dot{H}^*(10)$



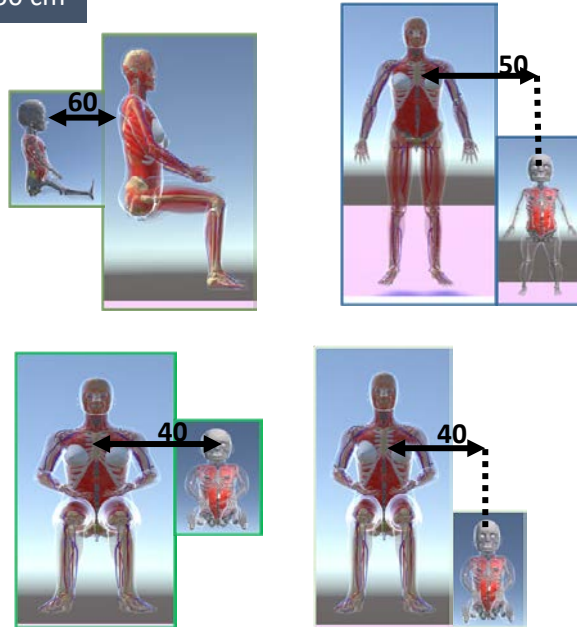
Effective dose rate $\dot{E}$

^{99m}Tc-HDP/MDP ; ¹⁸F-FDG ; Na¹³¹I ; ¹⁷⁷Lu-DOTATATE/PSMA

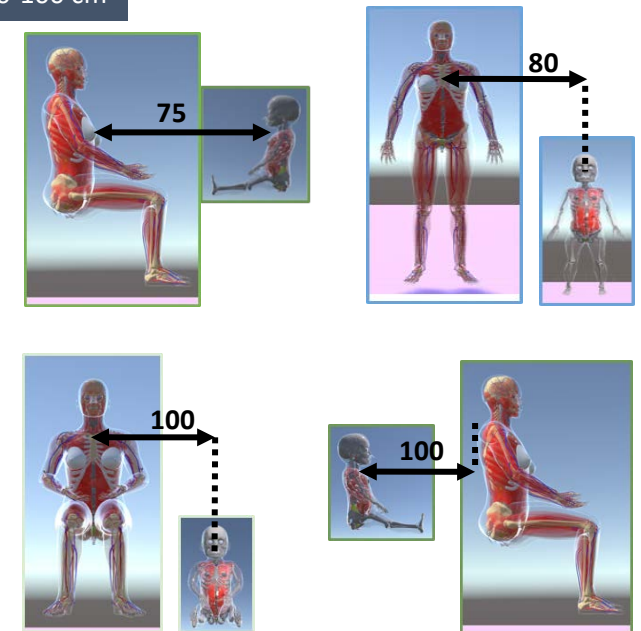
Close-contact



30-50 cm



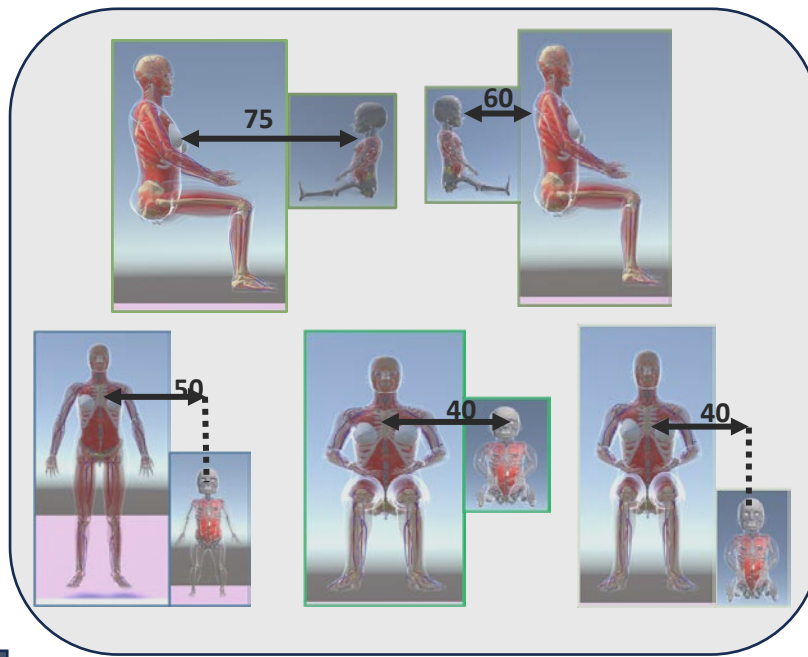
80-100 cm



Application of computational approach

- Impact of different postures on the external dose rates
- CASE STUDY: "Mother – child" configurations

The figure consists of three separate illustrations, each showing a mother holding a child. The mother's body is depicted with a red, semi-transparent skin layer revealing the underlying skeletal structure (ribs, spine, pelvis, and legs). The child is shown in a smaller, similar red-skeletal form. The background is a simple gradient from light blue at the top to light purple at the bottom. The three illustrations show the mother in different postures: standing and holding the child in front of her, sitting and holding the child on her lap, and standing and holding the child on her hip. These illustrations likely represent different ergonomic assessments of the physical strain on the mother during childcare activities.



I-131 biokinetics

Source regions

- Blood
- Liver
- St wall
- Thyroid
- Colon
- Others
- Kidneys
- Salivary glands
- St contents
- SI contents
- UBC

Fractional activity $a(t)$

Time after administration (min)

- Mother = hyperthyroidism patient (out-patient)
- I-131 ; $A_{\text{adm}} = 400 \text{ MBq}$

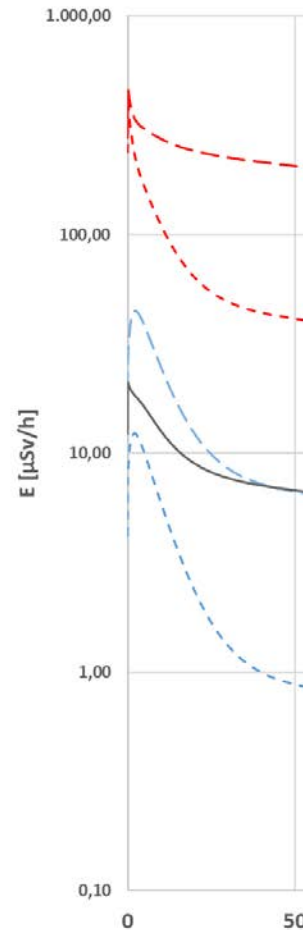
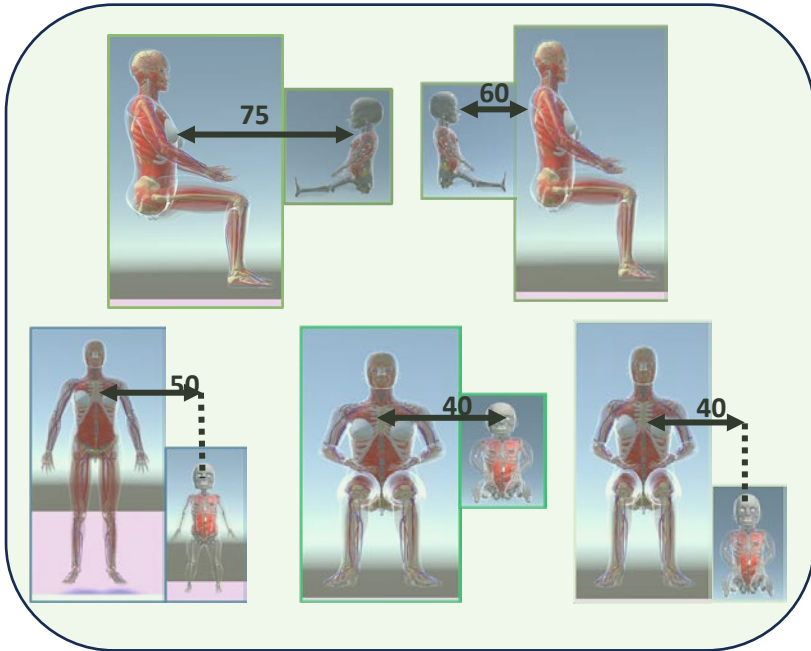
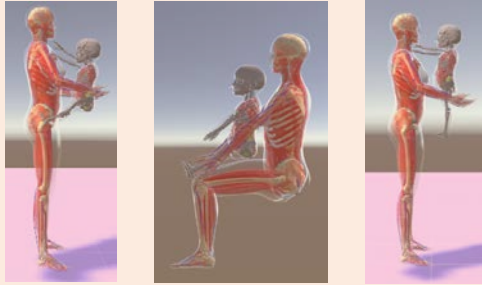
$$\dot{E}(t) = A_{adm} \sum_{source\ region} a_{source\ region}(t) \dot{E}_{source\ region}$$

SCENARIO 1

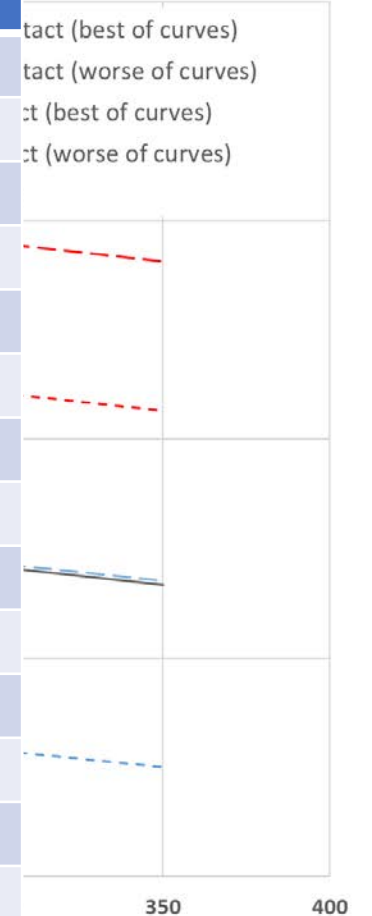
- Mother = hyperthyroidism patient (out-patient)
- I-131 ; $A_{adm} = 400 \text{ MBq}$
- $\dot{H}^*(10) @ 1\text{m} = 20 \mu\text{Sv/h} \rightarrow$ reached after 2 min (typical release criterion)

Close-contact
postures

- 'Effective dose' to the child after 14 days if
- 1h physical contact / day
 - 6h social contact / day



	Range of Effective dose (μSv)
Day 1	391 - 624
Day 2	63 - 285
Day 3	48 - 253
Day 4	42 - 224
Day 5	39 - 205
Day 6	36 - 187
Day 7	33 - 170
Day 8	30 - 156
Day 9	27 - 142
Day 10	25 - 130
Day 11	23 - 119
Day 12	21 - 109
Day 13	19 - 99
Day 14	18 - 90
Day 15	18 - 90
Total	831 - 2883



SCENARIO 1

- Mother = hyperthyroidism patient
- I-131 ; $A_{\text{adm}} = 400 \text{ MBq}$
- $\dot{H}^*(10) @ 1\text{m} = 20 \text{ }\mu\text{Sv/h} \rightarrow 2 \text{ min}$

	Range of Effective dose (μSv)
Day 1	391 - 624
Day 2	63 - 285
Day 3	48 - 253
Day 4	42 - 224
Day 5	39 - 205
Day 6	36 - 187
Day 7	33 - 170
Day 8	30 - 156
Day 9	27 - 142
Day 10	25 - 130
Day 11	23 - 119
Day 12	21 - 109
Day 13	19 - 99
Day 14	18 - 90
Day 15	18 - 90
Total	831 - 2883

SCENARIO 2

- Mother = hyperthyroidism patient
- I-131 ; $A_{\text{adm}} = 1000 \text{ MBq}$
- $\dot{H}^*(10) @ 1\text{m} = 20 \text{ }\mu\text{Sv/h} \rightarrow 24 \text{ h}$

	Range of Effective dose (μSv)
Day 1	977 - 1559
Day 2	157 - 713
Day 3	119 - 632
Day 4	105 - 560
Day 5	97 - 512
Day 6	89 - 467
Day 7	82 - 426
Day 8	75 - 390
Day 9	69 - 356
Day 10	63 - 326
Day 11	58 - 297
Day 12	53 - 272
Day 13	48 - 248
Day 14	44 - 226
Day 15	44 - 225
Total	2079 - 7208

SCENARIO 3

- Mother = **thyroid cancer patient**
- I-131 ; $A_{\text{adm}} = 7400 \text{ MBq}$
- $\dot{H}^*(10) @ 1\text{m} = 20 \text{ }\mu\text{Sv/h} \rightarrow 2\text{d } 10\text{h}$

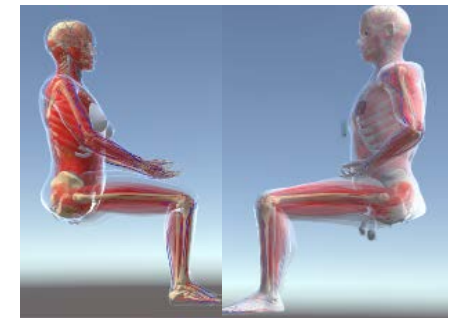
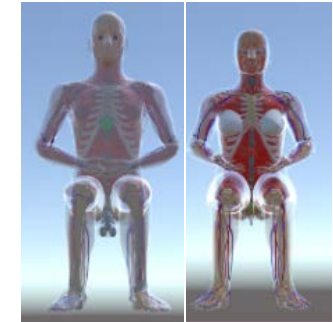
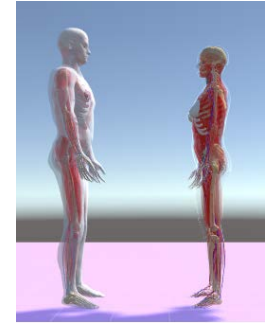
Biokinetics !!

	Range of Effective dose (μSv)
Day 1	
Day 2	
Day 3	268 - 601
Day 4	153 - 358
Day 5	78 - 189
Day 6	52 - 125
Day 7	39 - 92
Day 8	31 - 70
Day 9	24 - 54
Day 10	19 - 42
Day 11	15 - 32
Day 12	9 - 16
Day 13	9 - 19
Day 14	7 - 14
Day 15	5 - 11
Total	709 - 1623

In summary

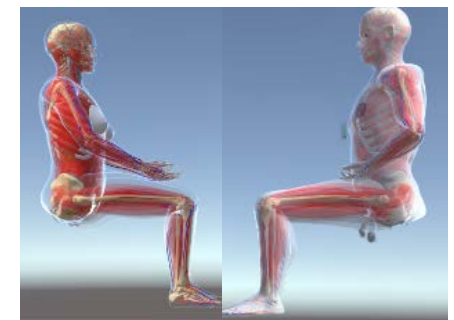
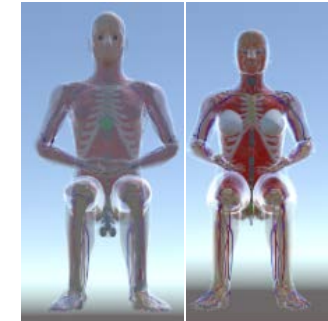
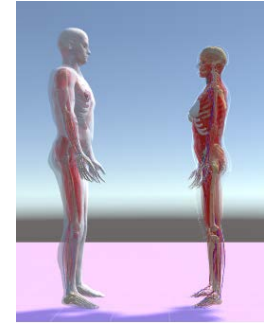
Benchmarked computational framework

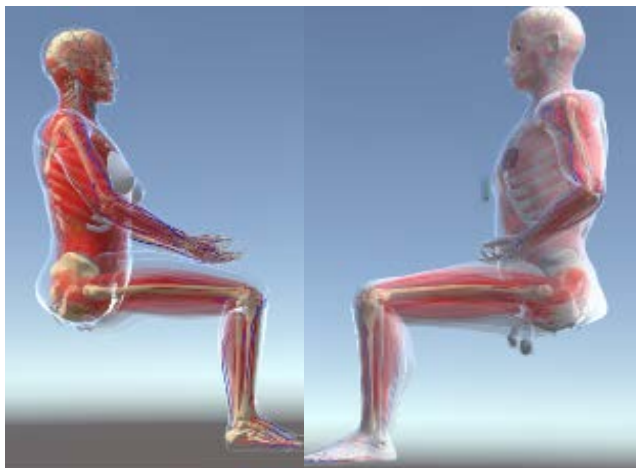
- 2 separate modules
 - Monte Carlo-based external dose rate calculations
 - Time-activity distribution for each source region
- Any postures and spatial arrangement between a nuclear medicine patient and a member of 'critical groups'
- Any radiopharmaceutical
 - *Current limiting factor: appropriate biokinetic models for NM patients*
(work in progress ...)



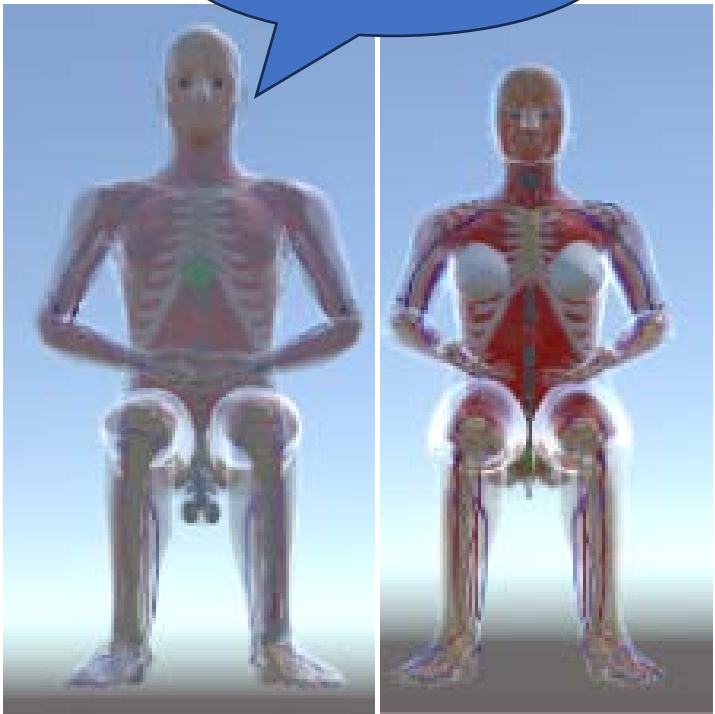
Future

- Tool of organ absorbed dose rates per unit of administered activity for **a large variety of close-contact configurations, for a range of radiopharmaceuticals** (both for diagnostic and therapeutic procedures)
 - Incl. patient-specific information to account for individualized features
- ⇒ evaluate the expected exposure to caregivers or the public for specific scenarios as **part of risk assessment studies**
- ⇒ with choice of appropriate dose constraints
- facilitate the setting of **hospital release criteria and patient restrictions**

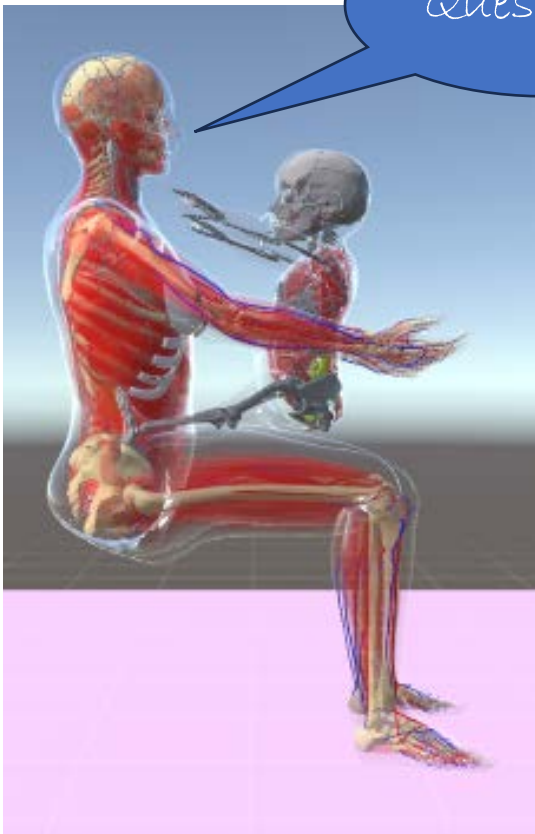




Thank you



Questions?



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