MRT Dosimetry Methodology

Manuel Bardiès (manuel.bardies@inserm.fr)
Institut de Recherche en Cancérologie de Montpellier

Declaration of interest

- M Bardiès supervises 2 PhD students (JA Fragoso and S Veloza Awad) sponsored by DOSIsoft
- M Bardiès is a consultant for CLARIO

Journal of Nuclear Medicine, published on December 21, 2023 as doi:10.2967/jnumed.123.265987

Prediction of ^{177}Lu-DOTATATE PRRT Outcome Using Multimodality Imaging in Patients with Gastroenteropancreatic Neuroendocrine Tumors: Results from a Prospective Phase II LUMEN Study

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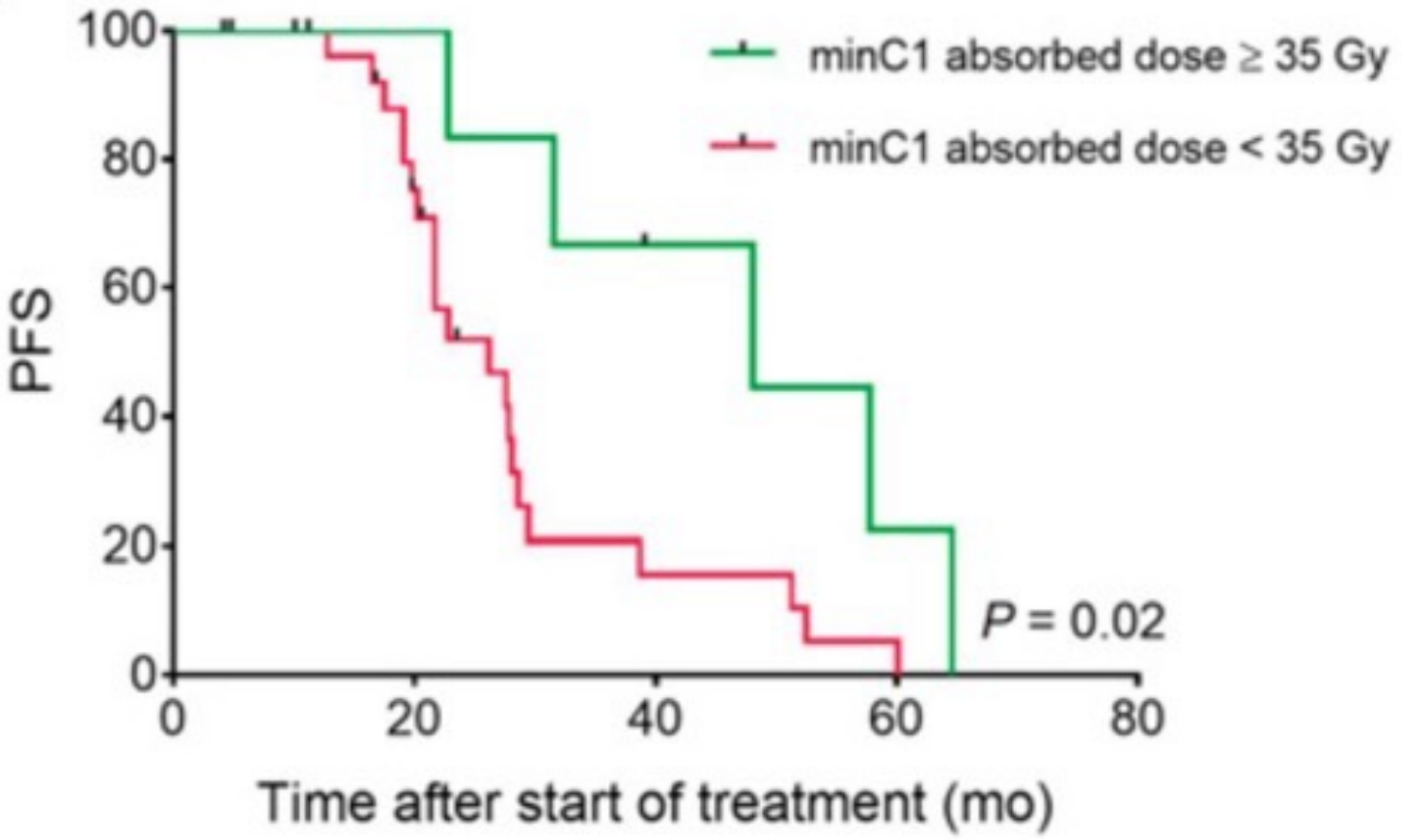

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Kévin Hebert*[1], Lore Santoro*[1,2], Maeva Monnier[3], Florence Castan[3], Ikrame Berkane[1], Eric Assénat[4], Cyril Fersing[1–5], Pauline Gélibert[6], Jean-Pierre Pouget[2], Manuel Bardiès[1,2], Pierre-Olivier Kotzki[1,2], and Emmanuel Deshayes[1,2]

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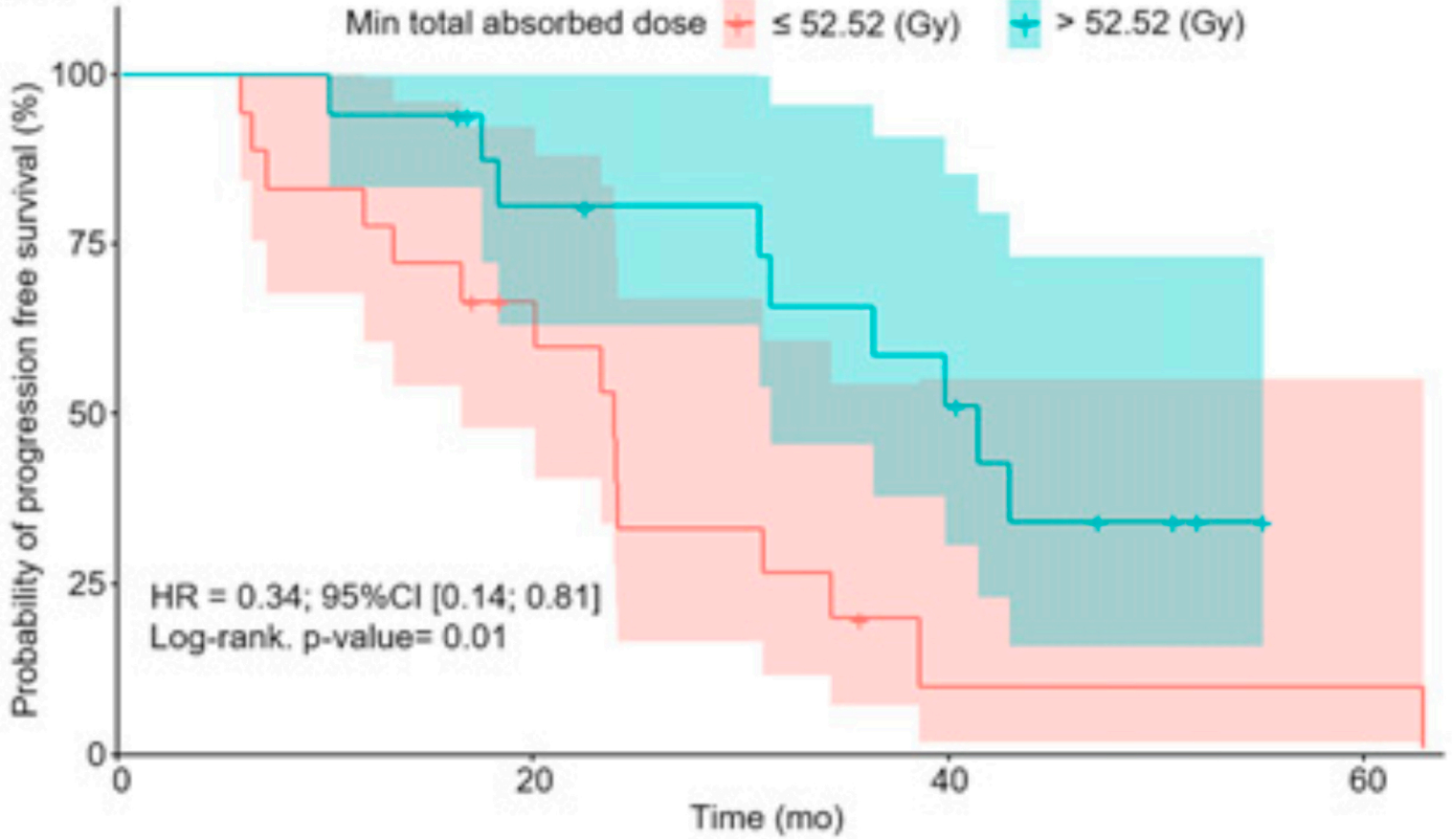

European Journal of Nuclear Medicine and Molecular Imaging
https://doi.org/10.1007/s00259-024-06863-y

ORIGINAL ARTICLE

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Received: 19 December 2023 / Accepted: 26 July 2024

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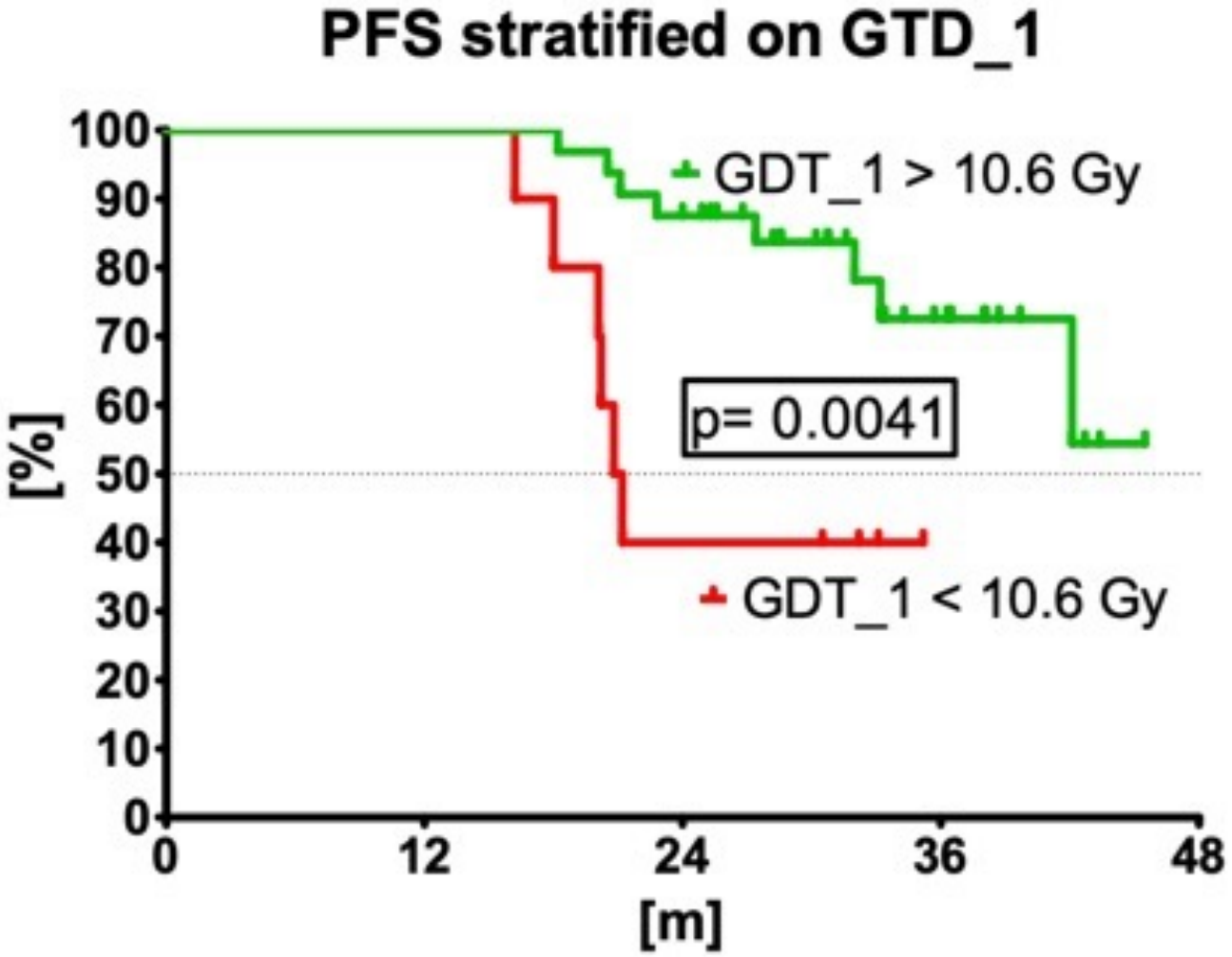

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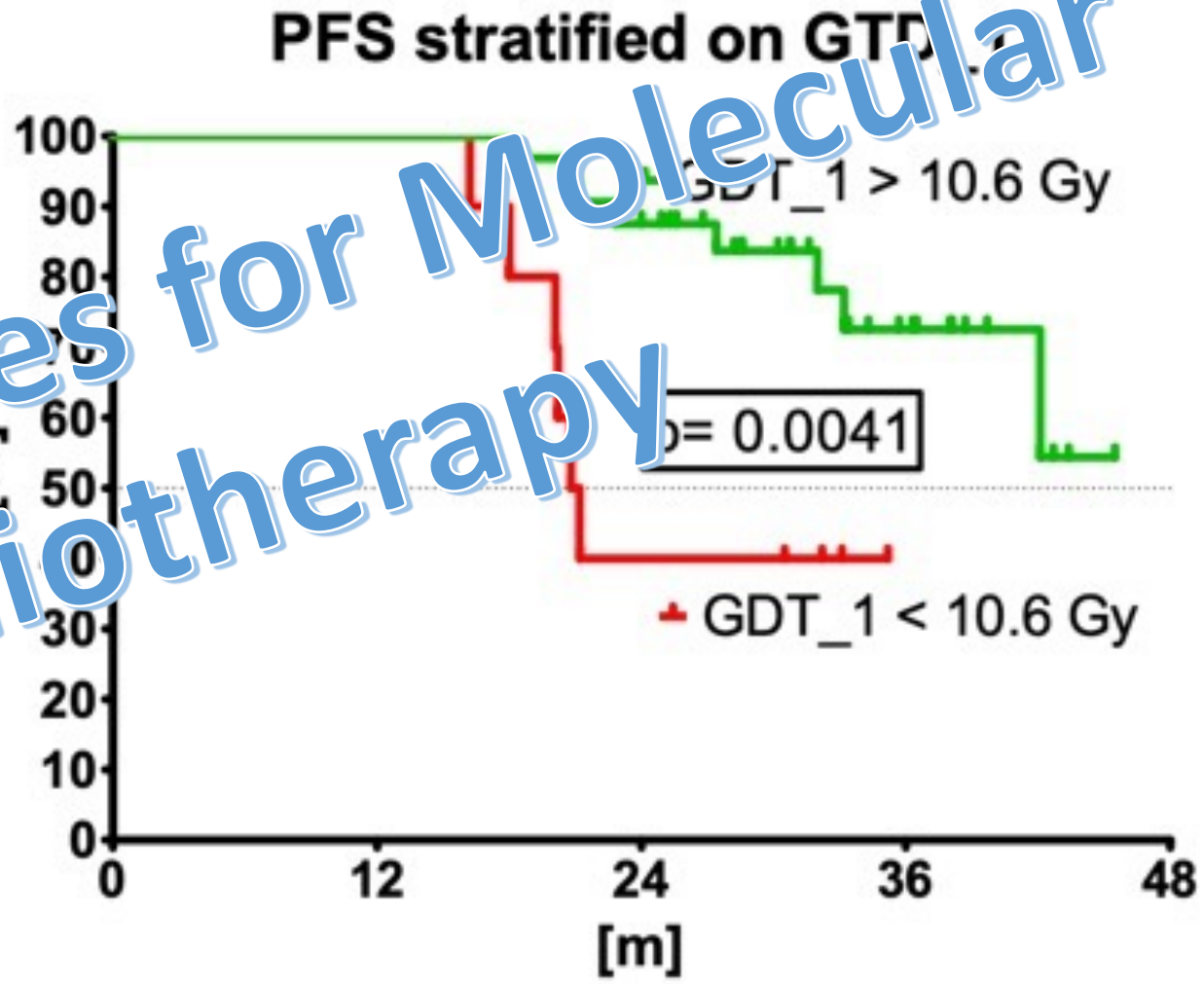
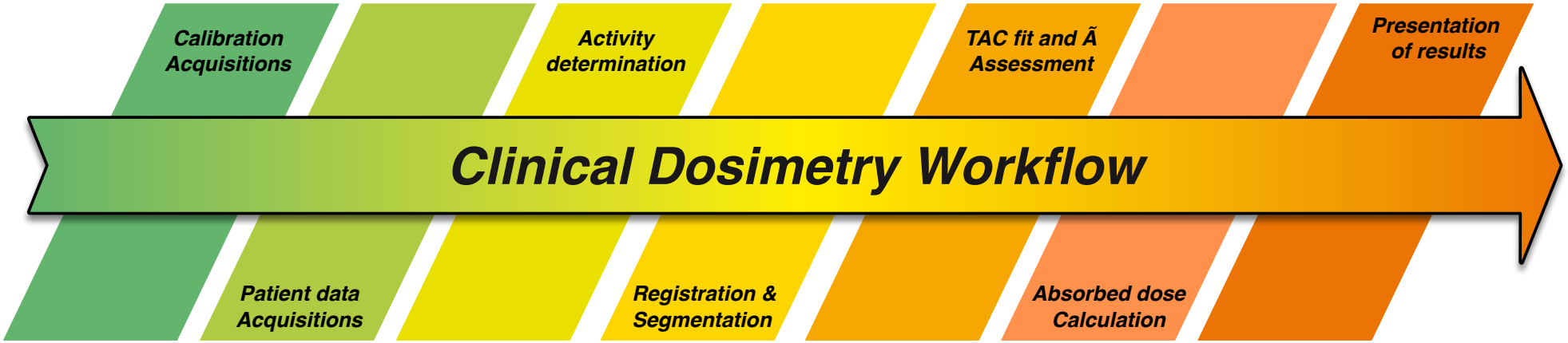


Same pathology, different approaches, similar conclusions…

	Mileva et al.	Hebert et al.	Maccauro et al.
Modality	SPECT/CT	SPECT/CT	SPECT/CT
Time points	3	4	2
Patients	35 patients/83 lesions	35 patients/146 lesions	29 patients/165 lesions
Segmentation	SPECT from PET ^{68}Ga pretherapy	CT lung pretherapy	SPECT or CT during therapy
Dosimetric Index	D_{mean} at t_1	$D_{Cumulated\ mi}$	Global Tumour Dose (GTD) at C_1

Standardisation & Traceability: Quality Assurance

Clinical Dosimetry Workflow

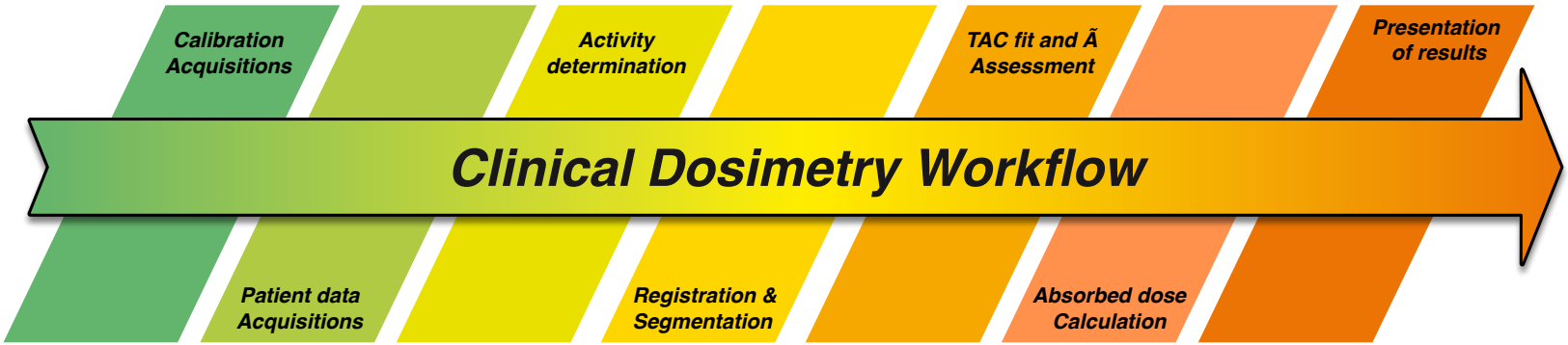


Adapted from: Bardiès and Gear (2021)
Scientific Developments in Imaging and Dosimetry for Molecular Radiotherapy. Clinical Oncology 33(2) 117-124

- Clinical dosimetry is a sequence of steps:
- All steps should be treated with the same care!
- Software may address some parts of the clinical dosimetry workflow (CDW)

RATIONALE COST Deliverable 4.1

- **Clinical dosimetry workflow (CDW):**
  - Ensemble of steps that lead from Calibrations to Reporting
  - CDW is composed by Individual Building Blocks



cost
EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

RATIONALE

RATIONALE COST Deliverable 4.1

- **Clinical dosimetry workflow (CDW):**
  - Ensemble of steps that lead from Calibrations to Reporting
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- **Individual Building Blocks (IBB)**
  - Independent steps that compose the CDW.
  - Example: Reconstruction, Registration, Radiation transport and energy deposition, etc.
  - IBBs have an input and an output

cost
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IN SCIENCE & TECHNOLOGY

RATIONALE

Examples of IBB

- **Registration**
- **Input:** Images or Structures, for the whole FOV or for specific VOIs

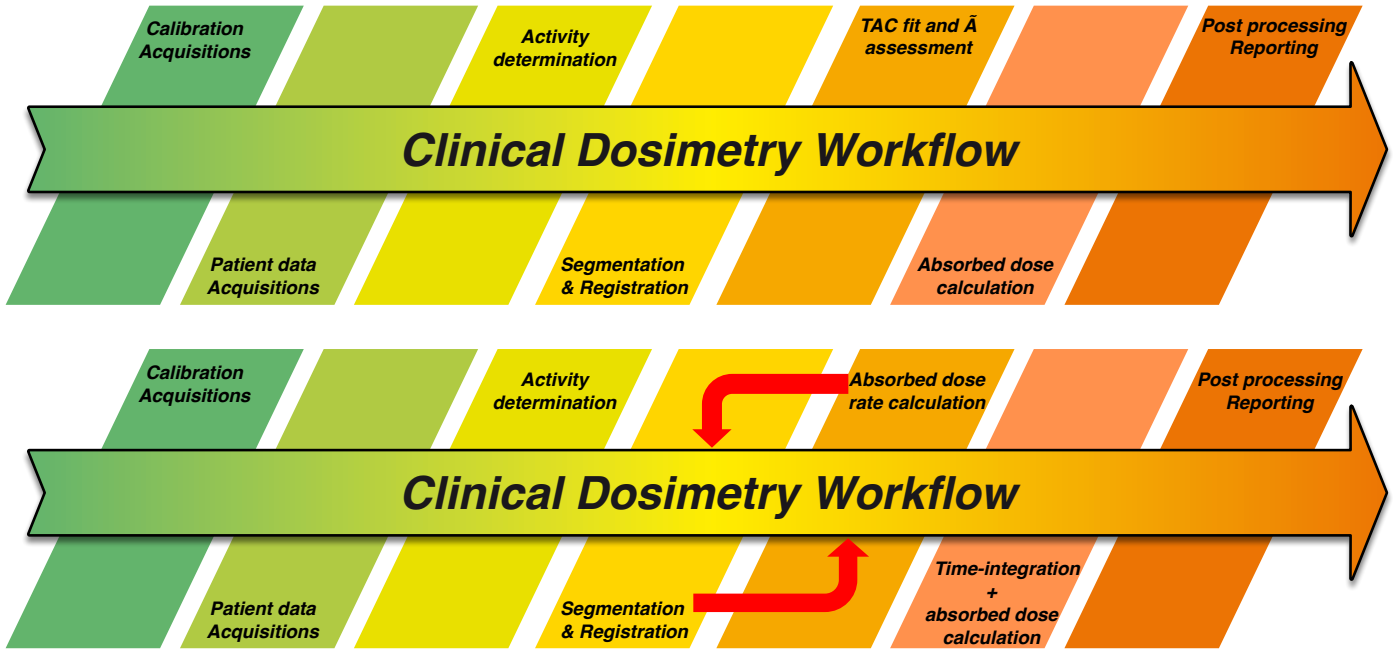
  Rigid, elastic, or AI-based
- **Output:** Images or Structures

- **S Value Calculation (part of calibrations)**
- **Input:** Segmented anthropomorphic models (mathematical or voxel-based or hybrid), radionuclide emission data (radiation type, yield and energy)

  Radiation transport and energy deposition algorithm
- **Output: SAFs or** S Values tables for the segmented structures of the model

IBBs are independent, but may be connected (Registration and Segmentation)

Examples of Clinical dosimetry workflows:



"Conventional" Activity workflow

ADR workflows

Different Clinical Dosimetry Workflow if:

- Changing IBBs in the CDW,
- Changing the order of the IBBs in the CDW
- Changing how IBBs are treated (rigid vs. elastic segmentation for example

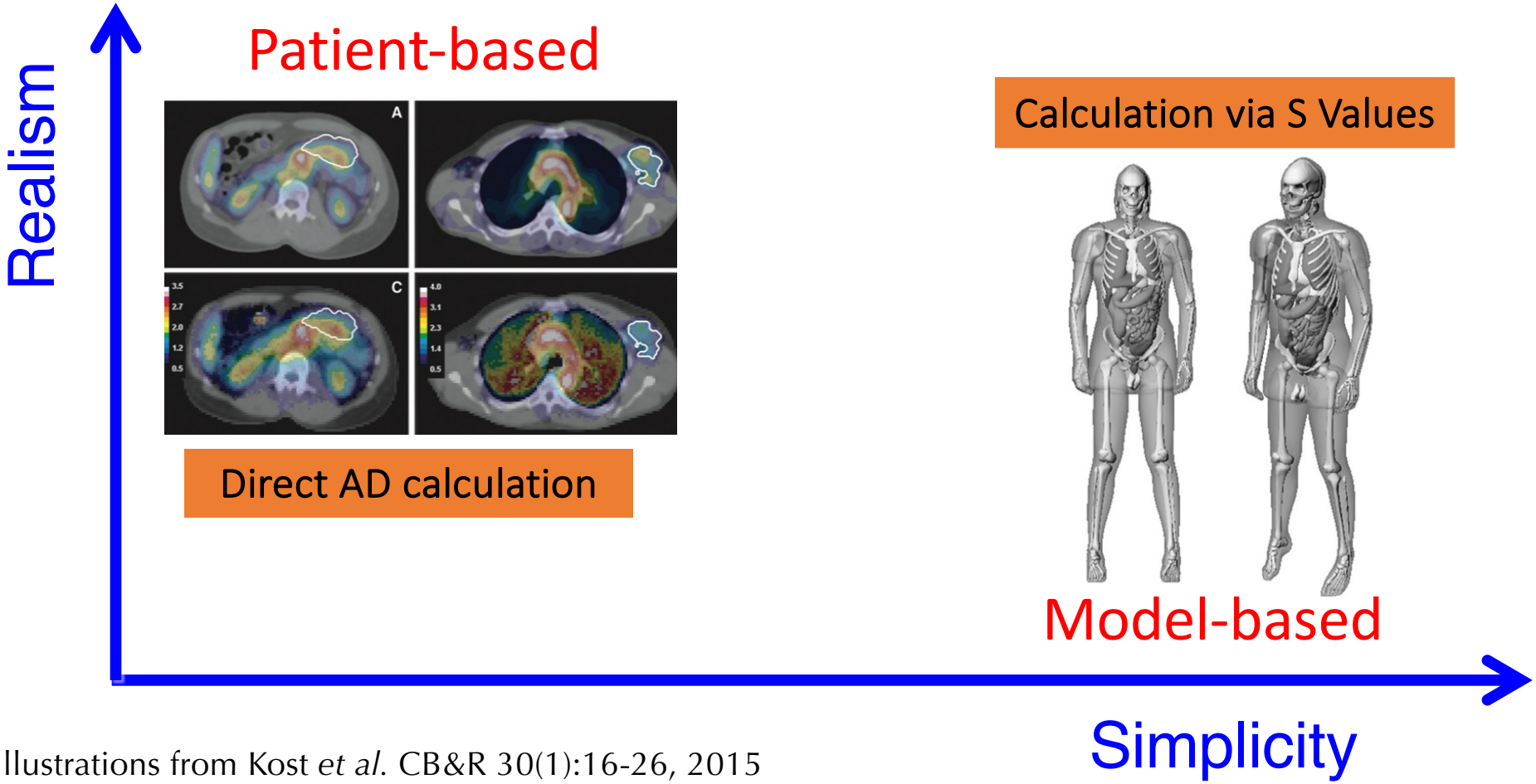
Approaches

- Group CDWs that share a common characteristic that impacts the CDW
- Examples:
  - Treatment planning vs. Verification dosimetry
  - Model-based vs. Patient-based dosimetry
  - Reference dosimetry vs. Patient-specific dosimetry
  - Imaging-based vs. Non-imaging-based dosimetry
  - Multi-time points vs. Single time point…

Patient dosimetry procedures

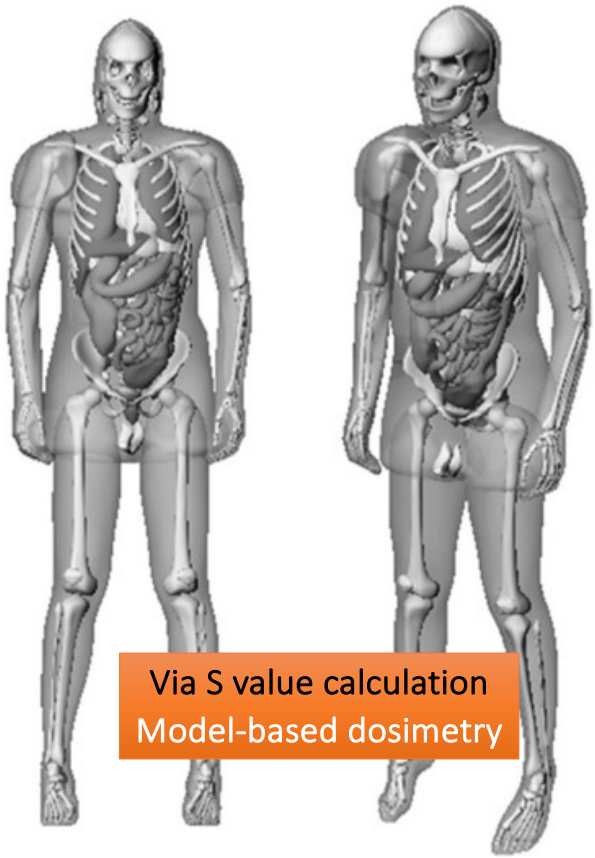
- **3 levels of description:**
  - Individual Building Blocks
  - Clinical Dosimetry Workflows
  - Approaches
- Should allow characterising ALL patient dosimetry procedures reported in the literature
- Dosimetry reporting should ALWAYS document IBBs, CDWs and Approaches
- A step in direction of traceability…

Patient-based vs. Model-based



Illustrations from Kost *et al*. CB&R 30(1):16-26, 2015

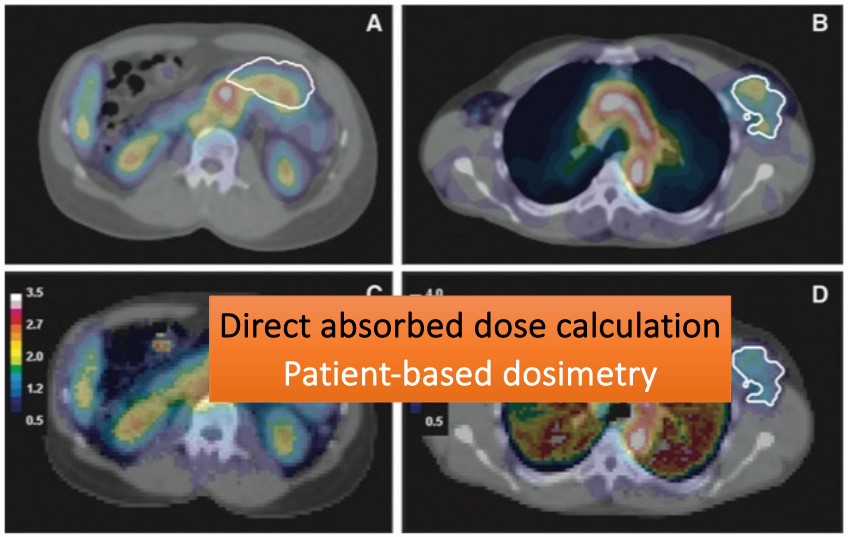
Patient-based vs. Model-based



Via S value calculation
Model-based dosimetry

FIG. 3. Anterior views of the RADAR adult male NURBS phantom. NURBS, Non-Uniform Rational B-Spline; RADAR, Radiation Dose Assessment Resource.

- Different clinical dosimetry workflows!
- Different software



Direct absorbed dose calculation
Patient-based dosimetry

FIG. 5. Fused SPECT/CT images for patient 1 **(A)** and patient 2 **(B)** with matching 3D dose maps overlaid on CT for patient 1 **(C)** and patient 2 **(D)**. The dose maps are displayed in units of Gy. Color images available online at www.liebertpub.com/cbr

Model-based approach

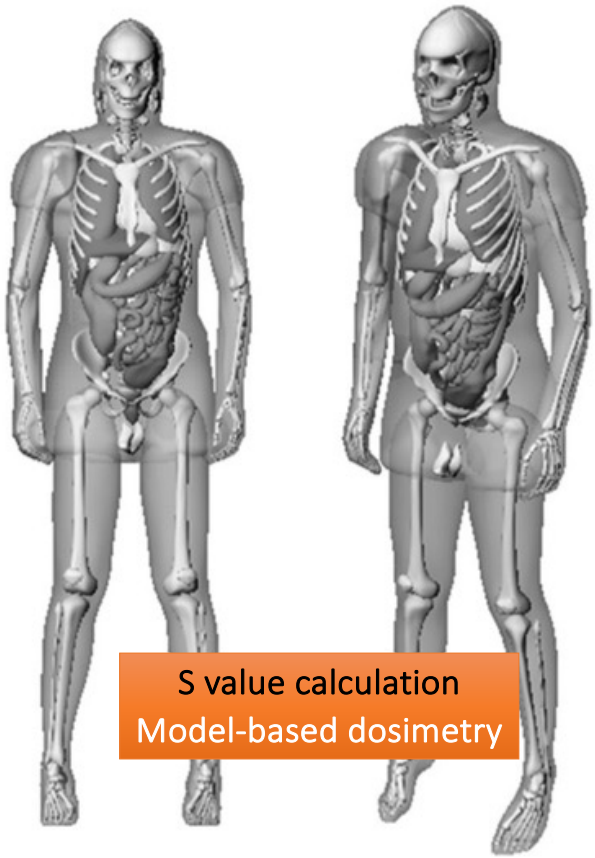


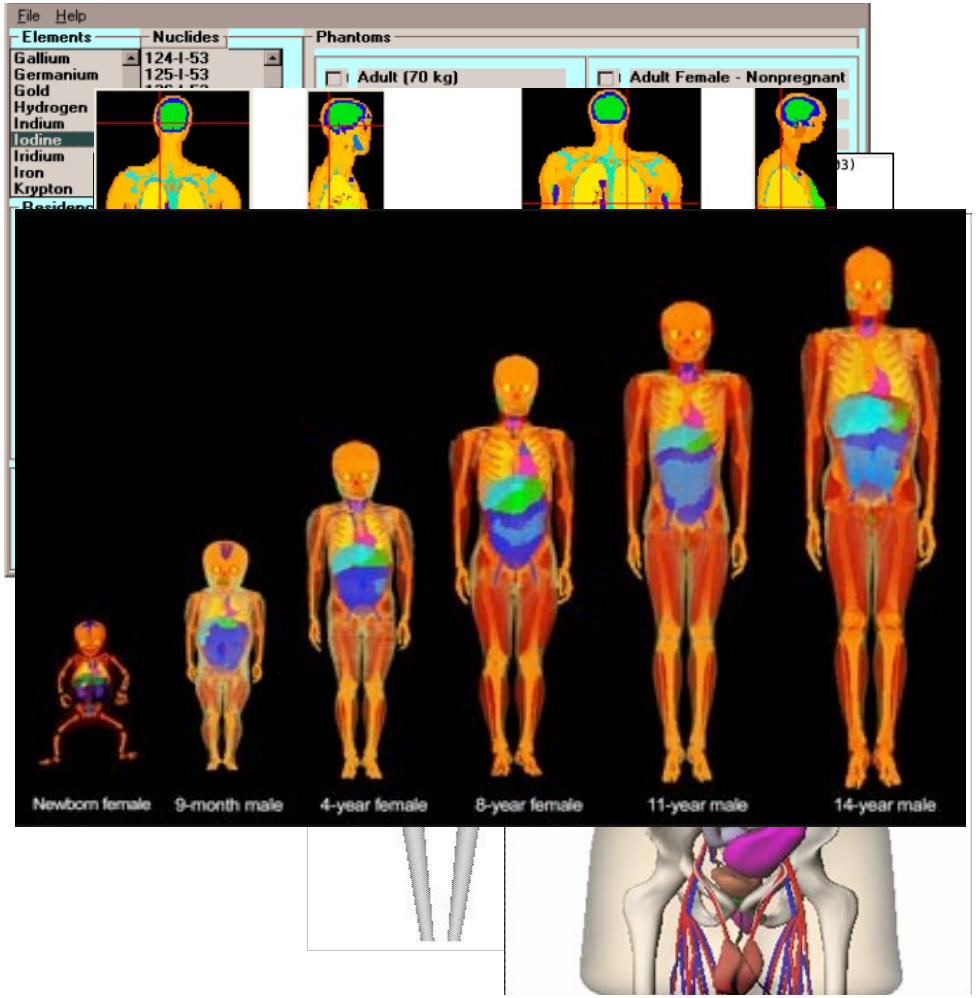
FIG. 3. Anterior views of the RADAR adult male NURBS phantom. NURBS, Non-Uniform Rational B-Spline; RADAR, Radiation Dose Assessment Resource.

- S: absorbed dose in the target per decay in the source
- **Consequences:**
  - S: for one radionuclide & one model
  - ≠ algorithms (LED, Conv., Monte Carlo)
  - Pre-computation: 1 source, many targets (may take a while – calibration IBB)
  - Allows for absorbed dose calculation for targets outside image FOV!
  - Allows for reference dosimetry (diagnostics)
  - For a reference model, not your patient, but…

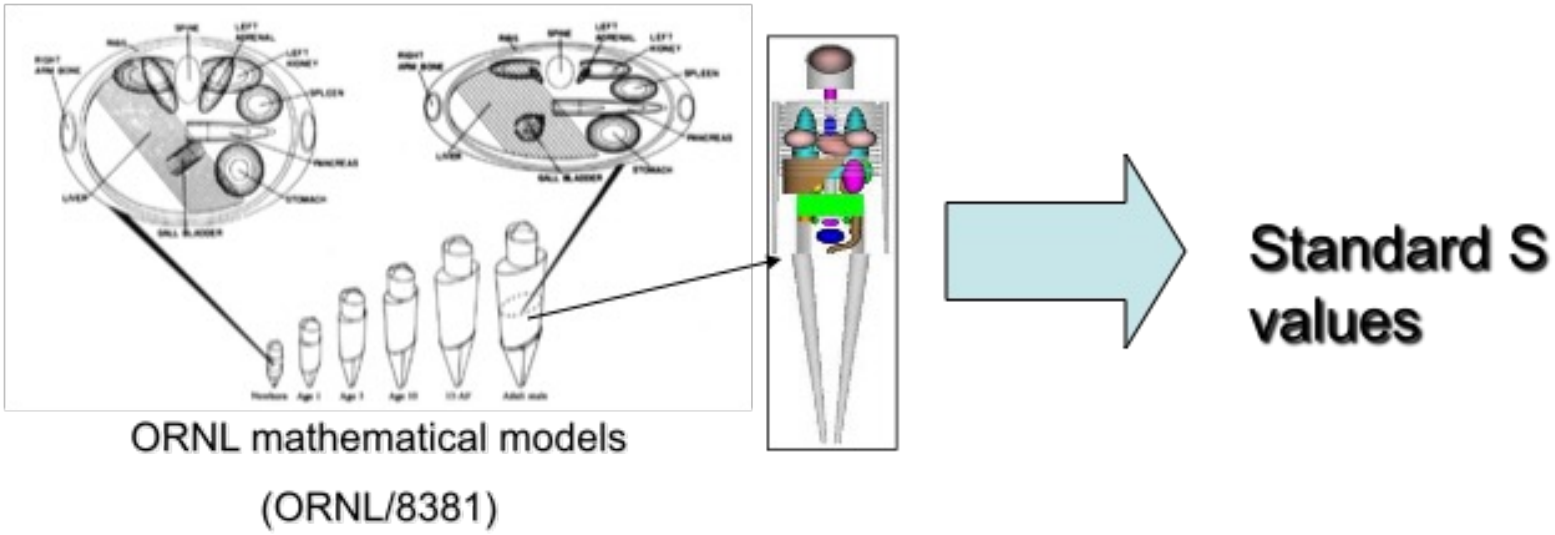
Model-based dosimetry software

First software to have been proposed:

- MIRDOSE:
  Stabin MG J Nucl Med. 1996 37(3):538-46
- OLINDA V1:
  Stabin et al. J Nucl Med. 2005 46(6):1023-7
- IDAC-DOSE 2.1:
  Andersson et al. EJNMMI Research 2017
- OLINDA V2:
  Stabin Health Phys. 2023 124(5):397-406.
- MIRDcalc:
  Kesner *et al*. J Nucl Med. 2023 64(10):1668



Mass adjustment:
A means to go towards personalisation



ORNL mathematical models

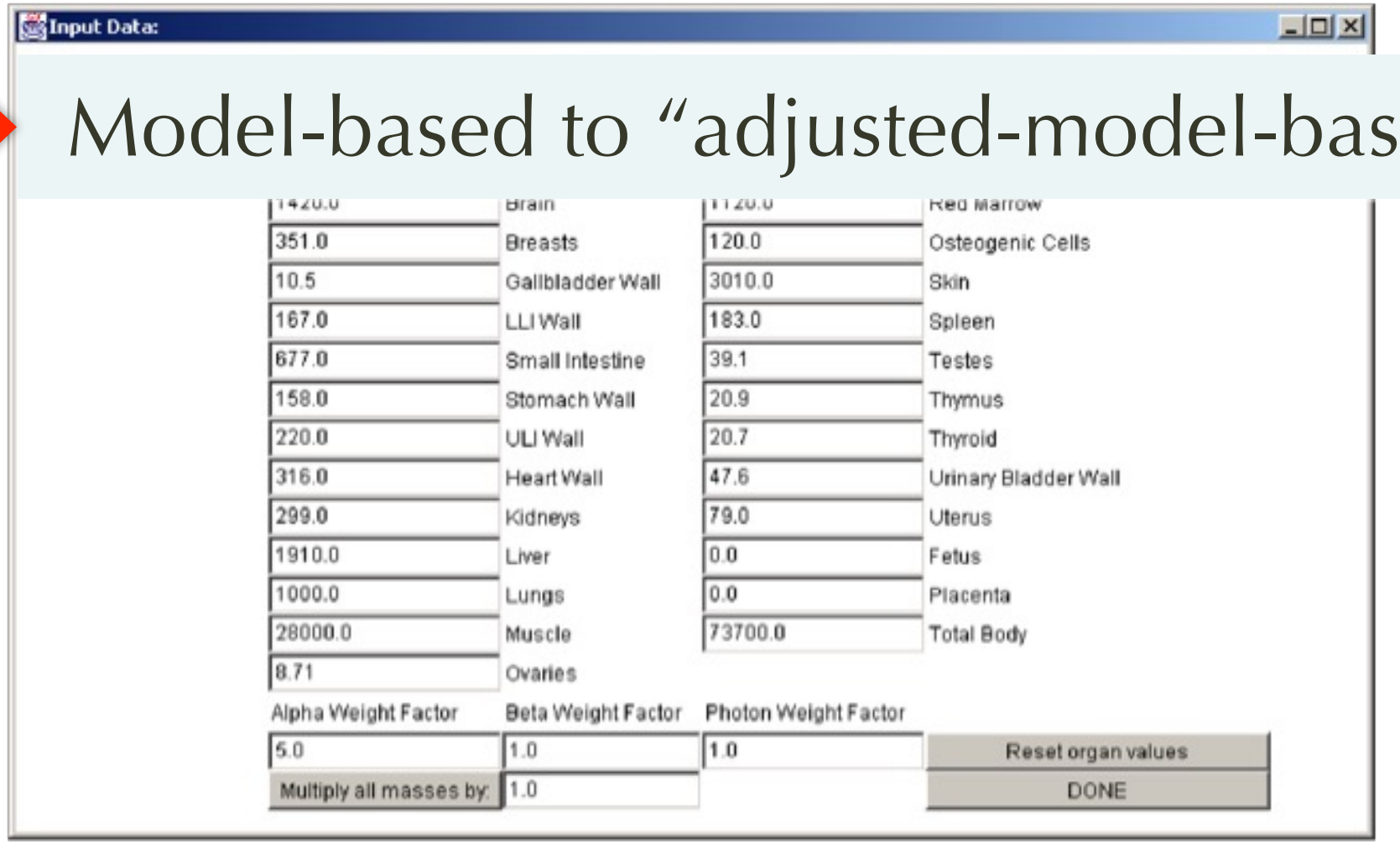
(ORNL/8381)

$$S_{Patient} = S_{Model} \times \frac{m_{Model}}{m_{Patient}}$$ (for α, ß, ē)

Different scaling for X and γ

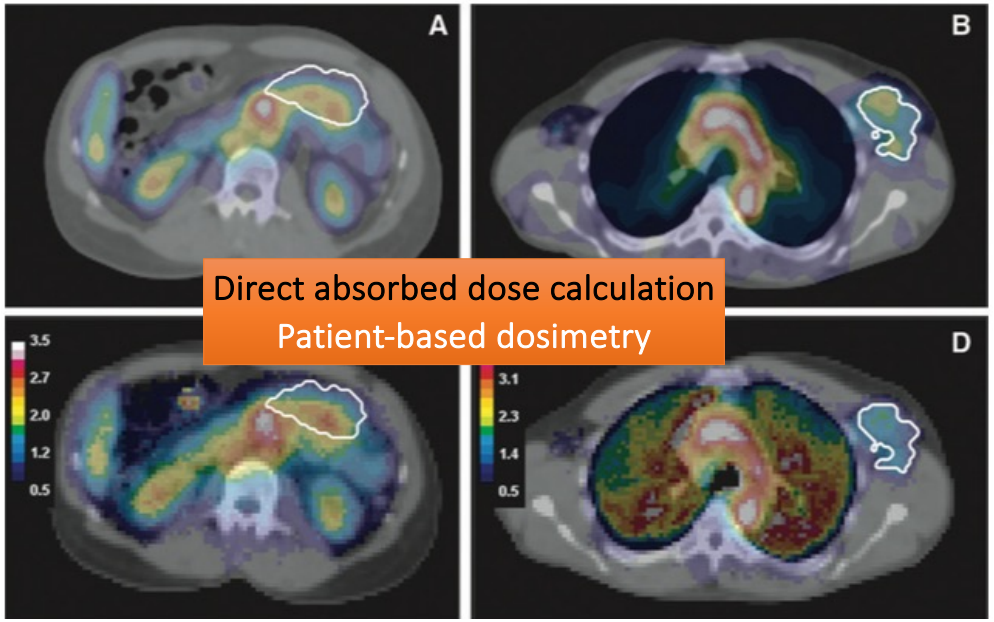
For self irradiation only!

Example: OLINDA mass adjustment



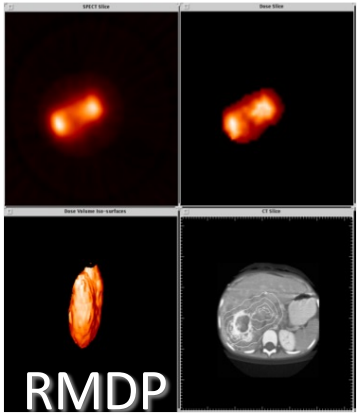
Patient-based dosimetry

- **Fully** based on patient images:
  - (Cumulated) activity maps (SPECT or PET)
  - Density maps (CT)
- No need for S but still MIRD formalism!
- One pass calculation!
  - ≠ algorithms (LED, Conv., Monte Carlo)
- Accuracy (vs. time)?
  - Debatable (rapidly changing panorama)
- Implemented in most commercial software



Patient-based dosimetry software

- Fully image-based
- Address “some” parts of the clinical dosimetry workflow
- **Academic** or commercial software



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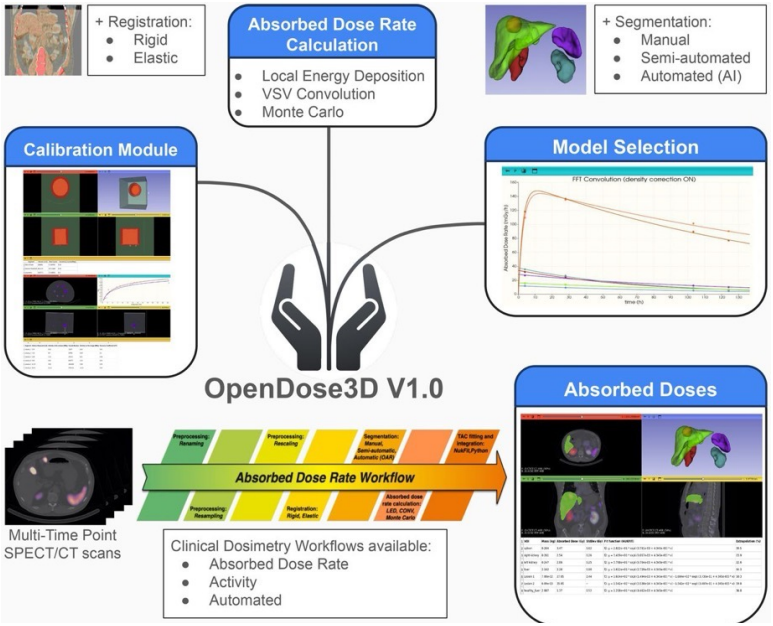

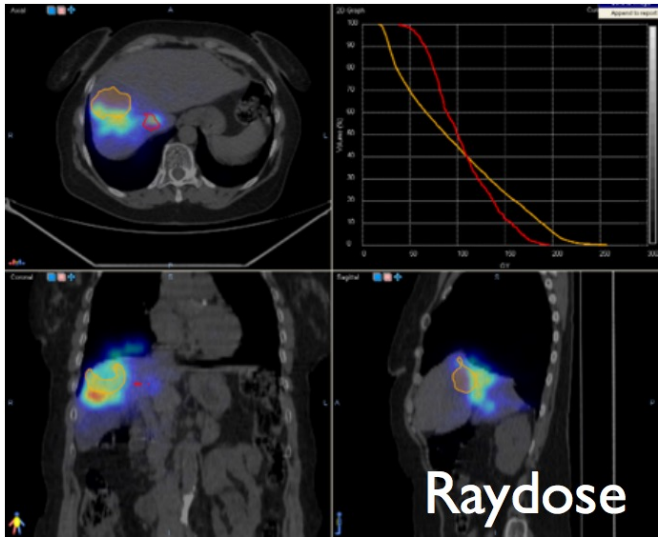

Patient-based dosimetry software

- Fully image-based
- Address “some” parts of the clinical dosimetry workflow
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VOXIMETRY

DOSIsoft

PLANET Dose

HERMES Dosimetry Software

HERMES

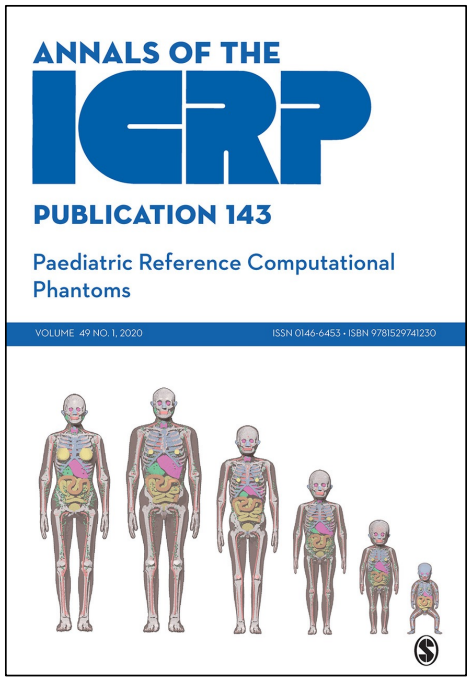
HERMES *Medical Solution*

mim SurePlan MRT

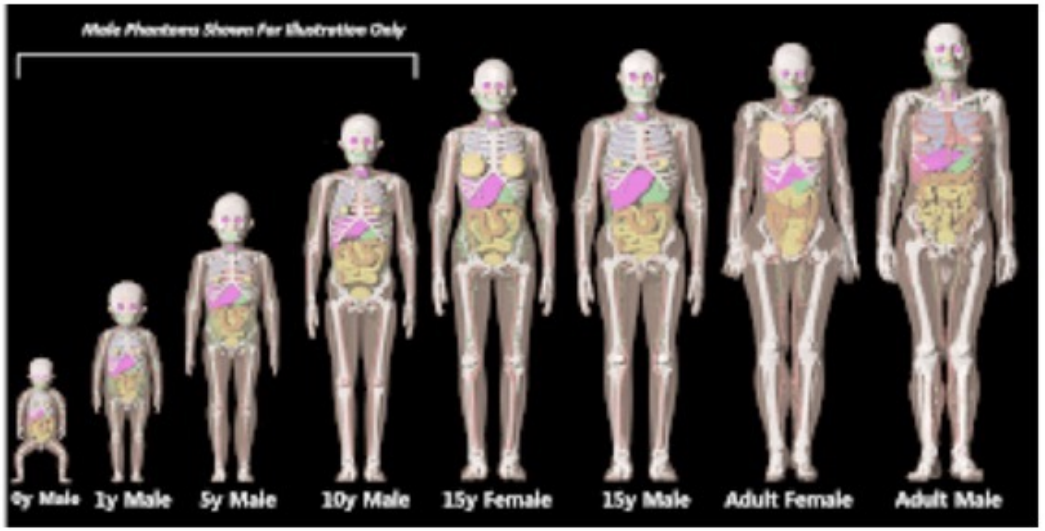
Organ vs. Voxel-based approaches?

MIRDcalc organ level dosimetry

- 333 isotopes (ICRP Publication 107),
- Family of 12 ICRP phantoms with 79 source organs and 43 target organs each



ICRP voxelized phantoms used in MIRDcalc software

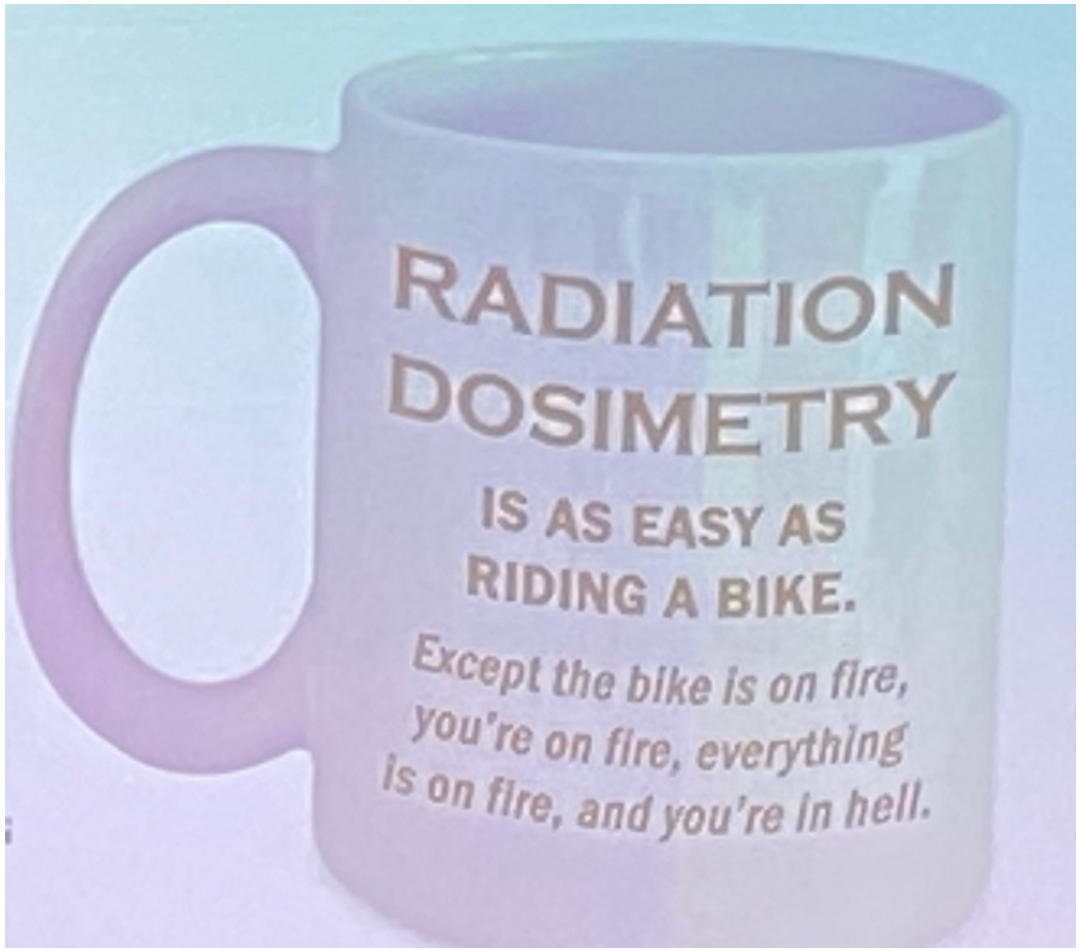


- www.mirdsoft.org (MIRD pamphlets 28a and 28b 2023)

Conclusions

- Traceability means documenting all steps of patient dosimetry
  - Individual Building Blocks
  - Clinical Dosimetry Workflows
  - Approaches
- Store ALL relevant data (patient dosimetry may require a lot!)
  - Need of a specific DICOM format for MRT dosimetry
  - Ongoing Joint EFOMP/AAPM/EANM/SNMMI Workgroup on QSPECT and MRT dosimetry standards (Jaroslav Ptacek)
- Document, document, document…
  - Lassmann *et al.* EANM Dosimetry Committee guidance document: good practice of clinical dosimetry reporting. *Eur J Nucl Med Mol Imaging* **38**, 192–200 (2011)

Thank you


RADIATION
DOSIMETRY
IS AS EASY AS
RIDING A BIKE.
Except the bike is on fire,
you're on fire, everything
is on fire, and you're in hell.