HPC usage at BIOEMTECH: A case study on Nuclear Medicine Dosimetry

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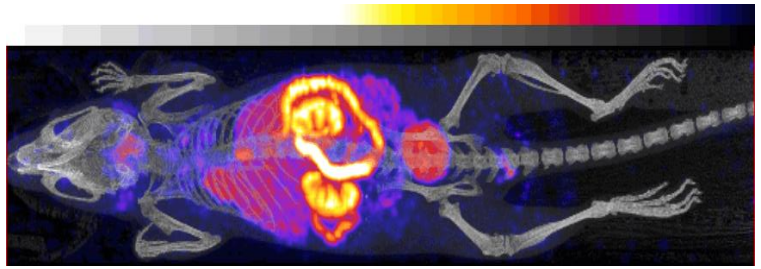
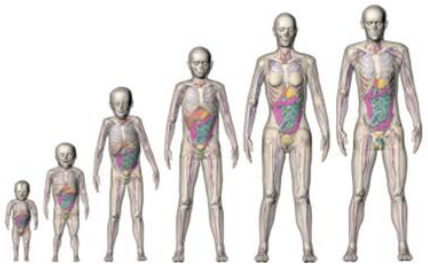
BIOEMTECH activities

BIOEMTECH develops and offers innovative solutions in pharmaceutical, medical physics and biotechnology research.

We focus on **molecular imaging, dosimetry & biomedical engineering**



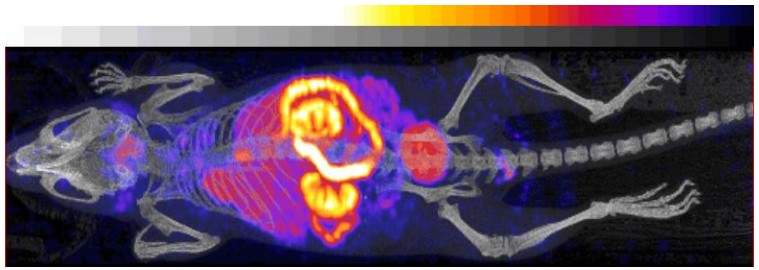


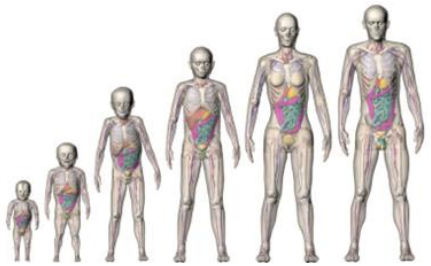
BIOEMTECH activities

BIOEMTECH develops and offers innovative solutions in pharmaceutical, medical physics and biotechnology research.

We focus on molecular imaging, dosimetry & biomedical engineering:

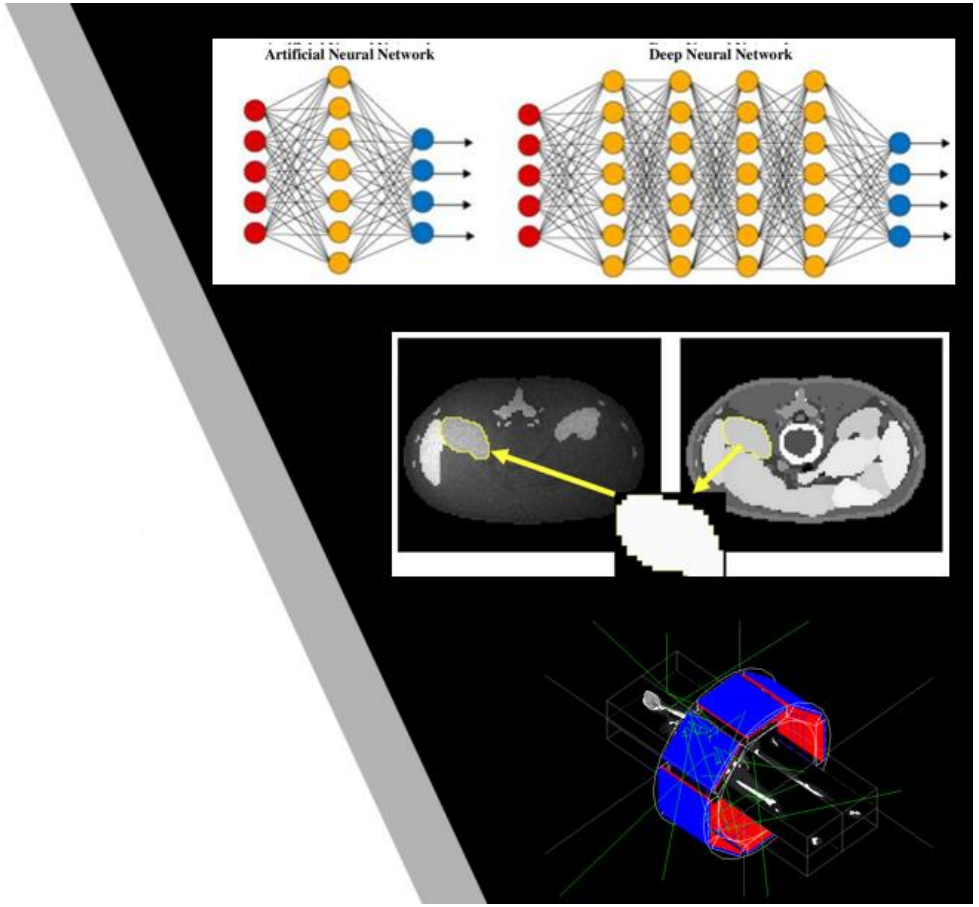
- ✓Design and construction of benchtop **imaging devices** for screening applications
- ✓Performance of preclinical **imaging services** in our imaging platform
- ✓**Computational solutions** using MC simulations & AI techniques





SW unit activities

- Monte Carlo Simulations
  - Dosimetry – Medical Imaging PET/SPECT/CT
- Artificial Intelligence
  - Develop prediction models (clinical and preclinical apps)
  - Decision Support Systems (DSS for clinicians)
- Image Processing/Analysis
  - Radiomics – Segmentation – Reconstruction
- Anthropomorphic & Animal 3D computational models
  - Synthetic Data (artificial realistic clinical data)



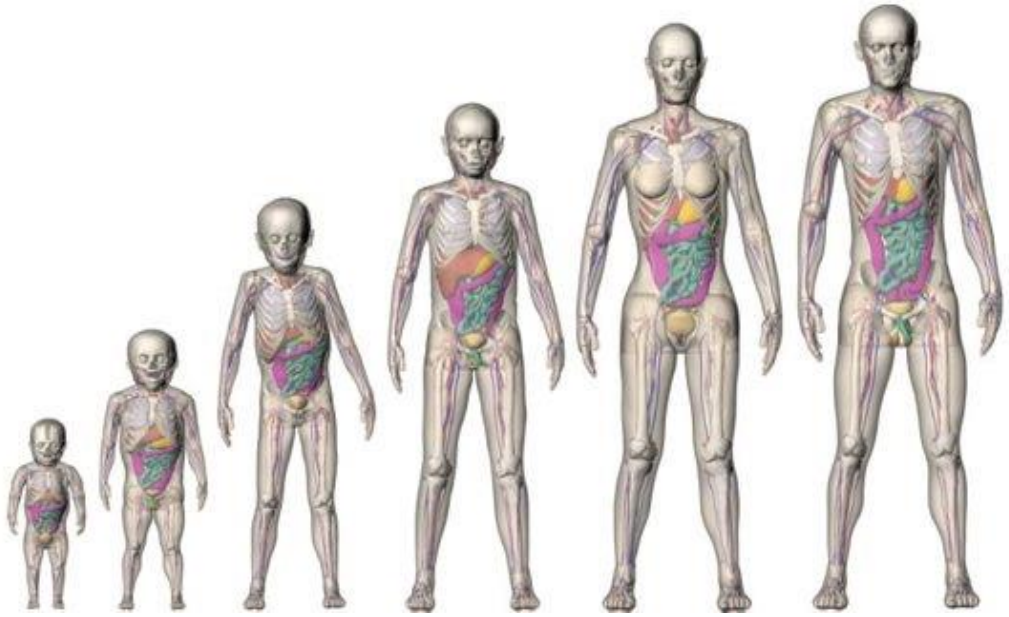
Current HPC usage at BIOEMTECH

✓2021-2022 – FF4EuroHPC
(**PediDose** project at YOTTA – 11000 unit hours)

✓2022-2023 – Extended access at YOTTA
(Internal usage of HPC – 8500 unit hours)

✓2024 – EuroHPC JU Development Access
(**SynthesizeCare** project at MeluXina – 3000 node hours)

Precision Medicine



Personalized Medicine

A medical model **that aims to provide tailor-made Prevention, Diagnosis & Treatment strategies** of a disease for defined individuals (group of individuals)

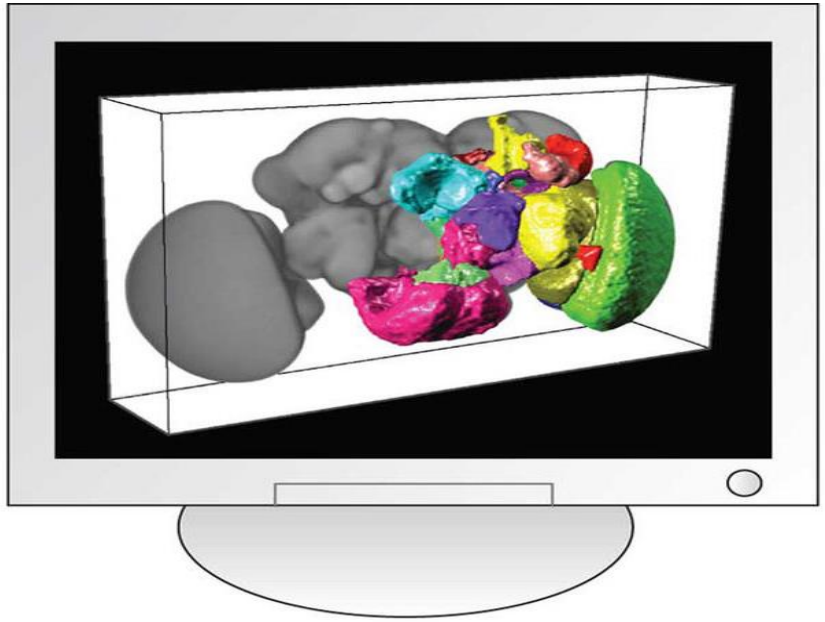
PRECISION MEDICINE

Big Data / AI / Digital Twins

Reconsider clinical protocols → Individualized

AI in Precision Medicine

Prevention	**Delayed** diagnosis
Diagnosis	**All fits one** clinical protocols
Therapy	**Non-individualized** approaches
Management	No common **expertise**
Cost Effectiveness	**Lack of personnel**
Productivity	**Unsure** diagnosis
	Non-effective **management** of the patients
	Non-effective therapies
	Non effective **follow up processes**
	Reduce the no required clinical examinations
	Lack of DSS

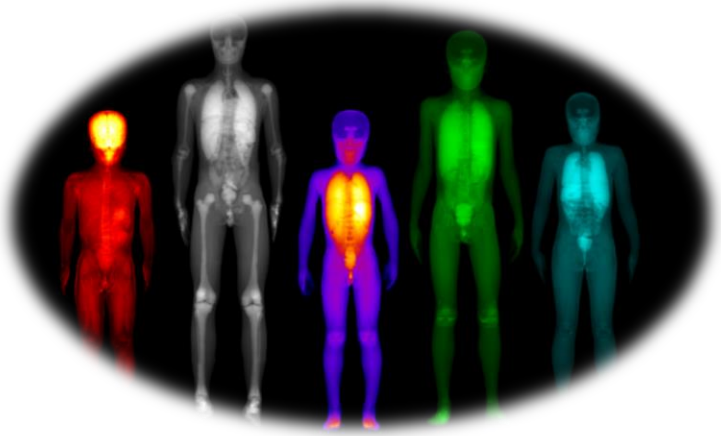


PediDose: Overview

Call: FF4EuroHPC Call-1

Duration: 15 months (2021)

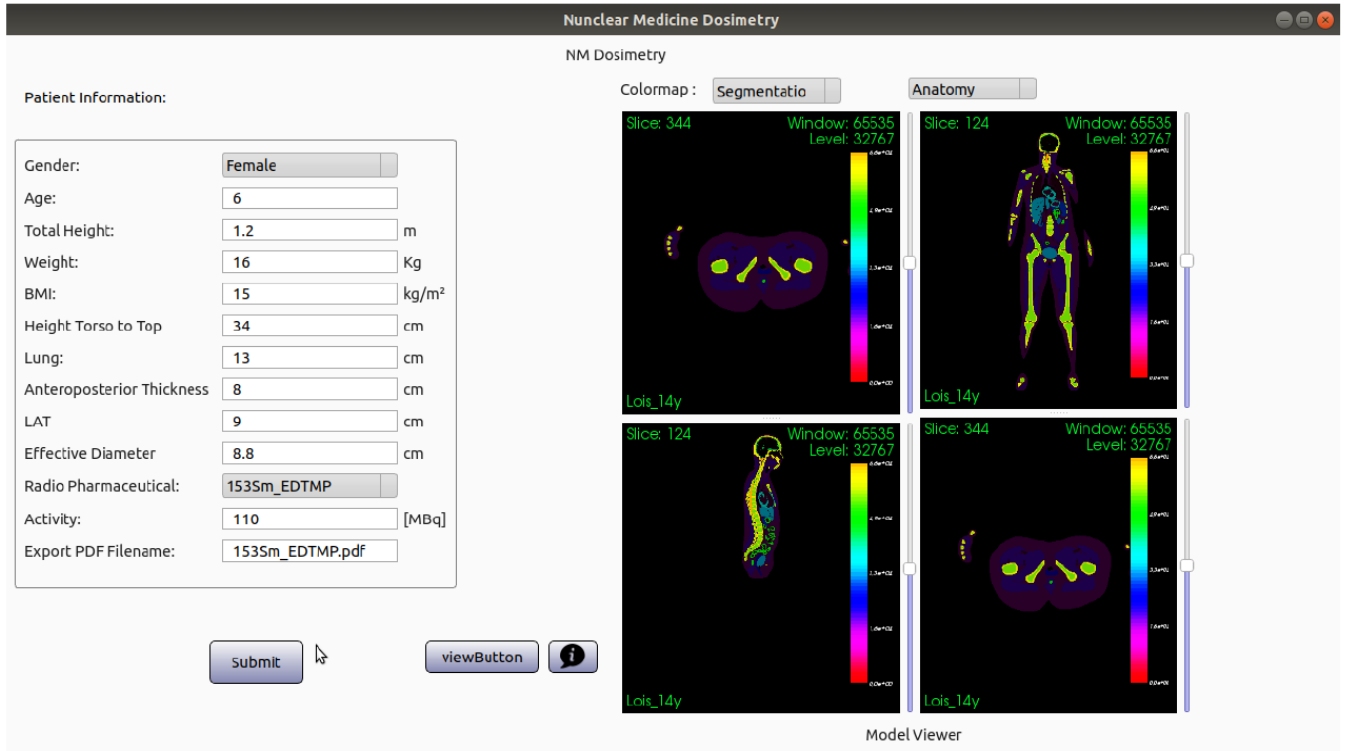
- **BIOEMTECH** (Domain expert & End-user) – Coordinator
  SME in the field of Biotechnology
- **IKNOWHOW** (End-user)
  SME in the field of Medical Software
- **GRNET** (HPC expert)
  Greek National Infrastructures for Research and Technology



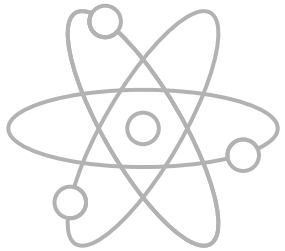
* **YOTTA** (HPC provider) – Subcontractor

PediDose: The idea

- Develop a new product – clinical software tool – assist clinicians (DSS)
- **Personalized pediatric dosimetry prediction** – prior the examination
- Based on a dosimetry methodology previously developed (H2020-MSCA-RISE ERROR project)

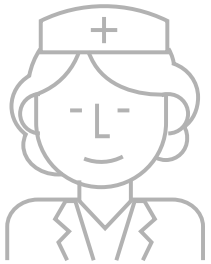


PediDose: The problem



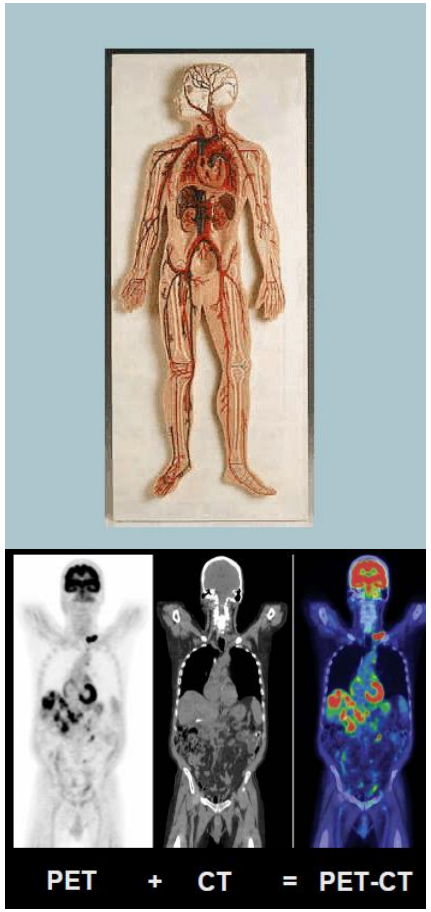
Problem based on theory

- Nuclear Medicine procedures involve **radioactivity**
- Ionizing radiation deposits energy in human body
- **Absorbed dose** from ionizing radiation can lead to cancer
- Pediatric patients are higher radiosensitive than adults



Daily clinical routine drawback

- Difficult to measure the absorbed dose in each organ of the body
- Rough estimations are currently applied in clinical practice
- Dosimetry is done after the radiopharmaceutical injection
- No estimation on the dose that a child will receive



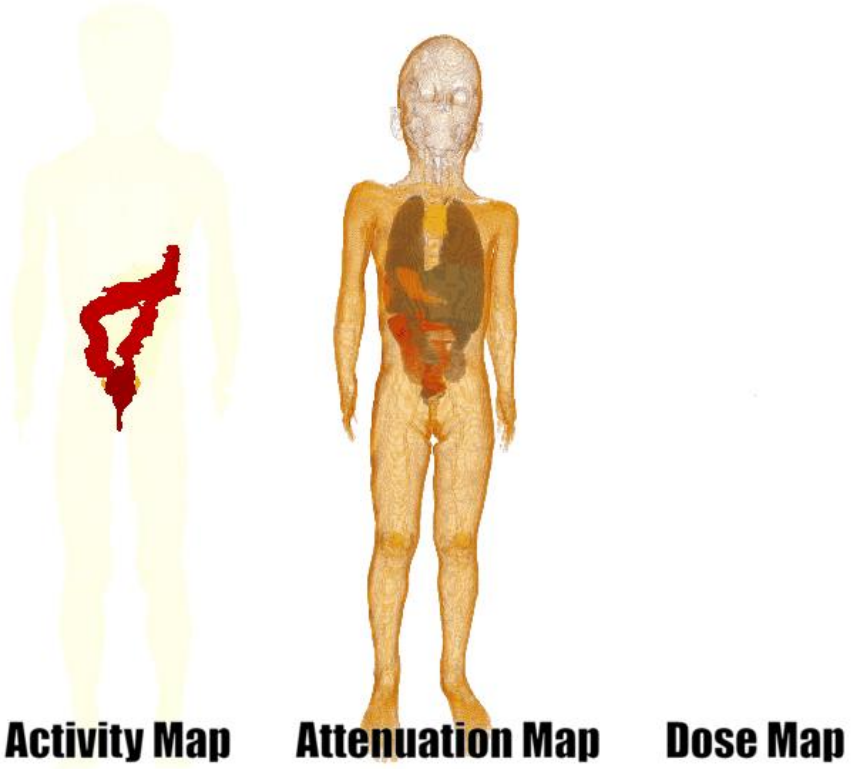
PediDose HPC: The need

- Many & Intensive dosimetry MC simulations:
  - ~30 pediatric models (2-15 years old)
  - for 5 most common radiopharmaceuticals
  - 4 time points after the injection

~500 simulations!
1 simulation run: ~3days locally ⟹ ~1h on HPC

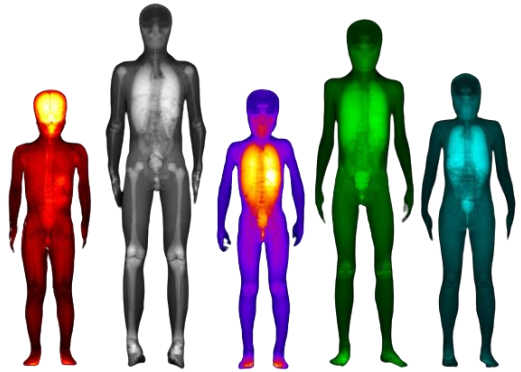
→ Absorbed dose database

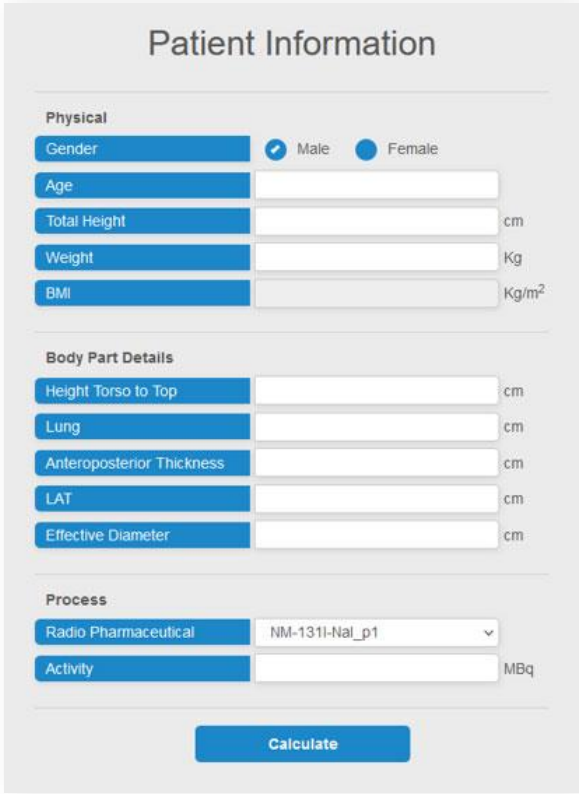
→ Training of Machine Learning models to predict dose per organ for a pediatric patient according to his/her anatomical characteristics

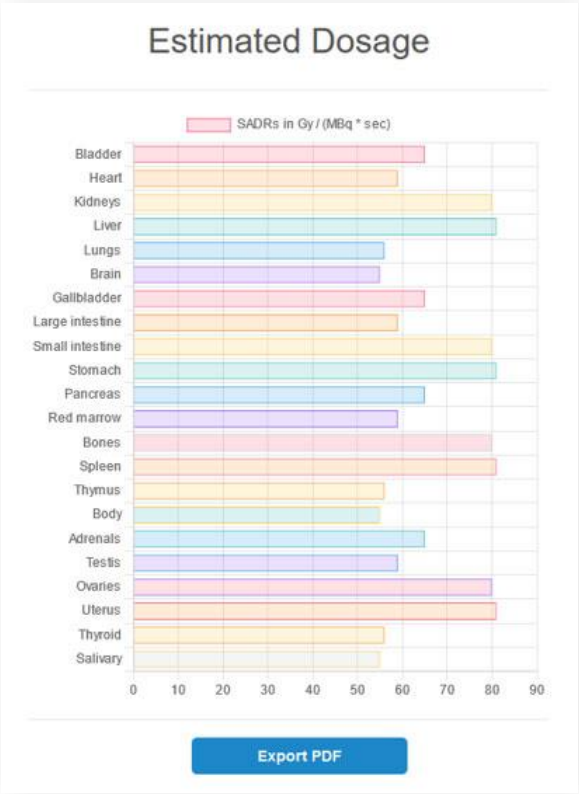


PediDose: Solution

"A novel software product (decision support) that offers clinicians the possibility to assess internal dosimetry and optimize Nuclear Medical (NM) imaging clinical protocols in terms of personalized dosimetry"



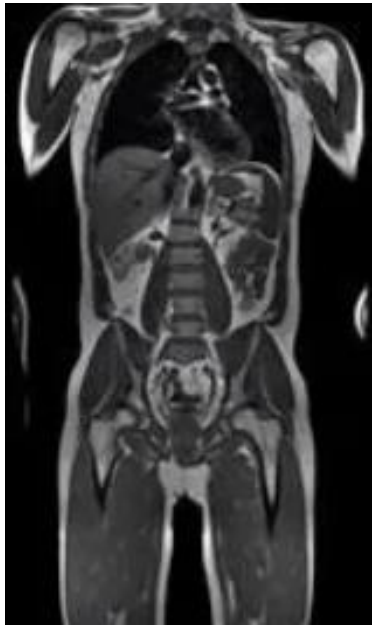




SynthesizeCare: Tool

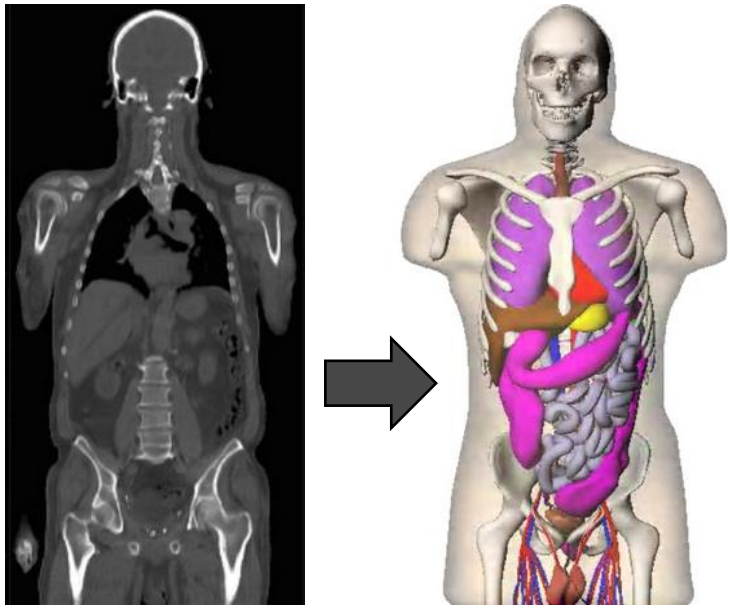
*Development of a tool for auto-creation of a **computational anatomical model for each patient** who undergoes CT/MRI examination*

(e.g., for personalized radiotherapy treatment plan)



SynthesizeCare: Methodology

- Collection of clinical datasets (>2000 clinical CT and/or MRI images)
- Access HPC (MeluXina) for organs' segmentation
- Creation of anatomical phantoms for the acquired dataset.
- Evaluation of the anatomical models
- **Train AI models on HPC to provide synthetic anatomical map for each new patient**



HPC use → Output

*Applicability in hospitals and clinics → data to be stored in Patients' Medical Record

(e.g., for personalized radiotherapy treatment plan)

BIOEMTECH: HPC opportunities

- New collaborations (2 SMEs collaborated for a new product).
- HPC provided resources to develop **novel products.**
- Combination of **MC, AI and HPC** → Innovative solutions for **personalized medicine**.
- Extension and grow in medical SW market.
- Be more competitive in the market.
- Staff was trained on HPC procedures.

Benefits of HPC @ BIOEMTECH

- ✓ **Gain speed in execution time** of MC simulations and AI training models.
- ✓ Manage to have robust results in couple of hours with **low statistical uncertainty** (High Statistics)
- ✓ **Extension of HPC access** beyond PediDose for MC simulations in our HW department
- ✓ Learned to use **HPC for other applications** (HPC usage to become **daily routine**)
  Use of HPC for **AI** applications: training models for ML/DL with large imaging datasets
- ✓ **Submission of other proposals** with the prior expertise of HPC

Limitations | Challenges

EURO

Personalized Medicine / AI / HPC / Industry

1895 X-rays 2023 AI

AI in Medicine is real.
HPC can bring AI in clinical routine!

- **Ethical Issues** (data processing, GDPR, mechanical decisions)
- **Clinical acceptability** (trustworthiness, robustness)
- **Explainability** (Black box → Grey/white box, useful tools for clinicians)
- **Data Harmonization** (multicenter, multiscale data)
- **Standardization of data** (collection & storage)
- **Change clinical protocols** (personalized protocols – clinical trials need)
- **Computational resources** (HPC, clusters, GPU infrastructures)
- **Training personnel in new techniques**
- **New regulations** are required (EU regulations, legislations)
- **Involve several stakeholders** (researchers, clinicians, patients, legislators, regulators, industry)

…the end

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Thank you!

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