EXPLOITATION OF HPC FOR REALISTIC PEDIATRIC DOSIMETRY SIMULATIONS USING GATE

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INTRODUCTION

The objective of this research concerns the development of a realistic dosimetry database based on the estimation of absorbed dose rate at different organs using Monte Carlo (MC) simulations. Several radiopharmaceuticals with clinically specified biodistributions and pediatric applications in Nuclear Medicine (NM) procedures were studied in the context of this project[1]. High Performance Computing (HPC) resources utilized to achieve low statistical uncertainties.

MATERIALS AND METHODS

- GATE v9.1 MC toolkit[2] was used for the absorbed dose rate assessment at this study.
- 20 computational phantom (15 XCAT[3] and 5 IT'IS[4]) with different anatomical characteristics and varying age, gender, mass and height were simulated.
- $5x10^8$ primary events were simulated.
- Four different radiopharmaceuticals together with their specified activity distribution[5] were considered.
  - ^{99m}Tc-MDP
  - ^{123}I-mIBG
  - ^{131}I-MIBG
  - ^{153}Sm-EDTMP
- The activity distributions derived from clinical data, at 4 different time points and used for the calculation of dose rate at the respective time points.
- Simulations were executed on YOTTA HPC center, to accelerate their execution, having 112 parallel jobs running.
- The "Dose actor" concept was utilized to measure the deposited energy per voxel, producing 112 dose maps for each case.
- All produced dose maps were merged to a single file for minimizing uncertainty, during the calculation of the absorbed dose rate per organ (Figure 1) .

RESULTS

- Dose rate for 31 different organs of each pediatric phantom were calculated (case of Tc-99m MDP at Figure 1).
- The relative percentage uncertainty in the dose values per organ fluctuating between 0.05% and 2.7%, with a median value of 0.11%.
- The very low standard deviation values indicate that our MC environment reduces the statistical uncertainty.
- There are fluctuations at the dose rate, for the same organ on different phantoms (up to 71% difference at male phantoms and up to 65% at female phantoms.
- Figure 2 illustrates the results at the case of Tc-99m MDP , while we have already completed the 123I-mIBG and 131I-MIBG cases.

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YOTTA HPC CHARACTERISTICS

- All simulations were performed in YOTTA HPC reducing significantly the time needed for their execution.
- It consists of compute nodes that each one includes 28-Core Intel Broadwell CPUs and 512 GB of memory.
- Simulations performed more than 80 times faster than a regular PC.

	Time for 1 simulation
PC (single CPU)	~110 h
HPC (112 CPUs)	~0.85 h

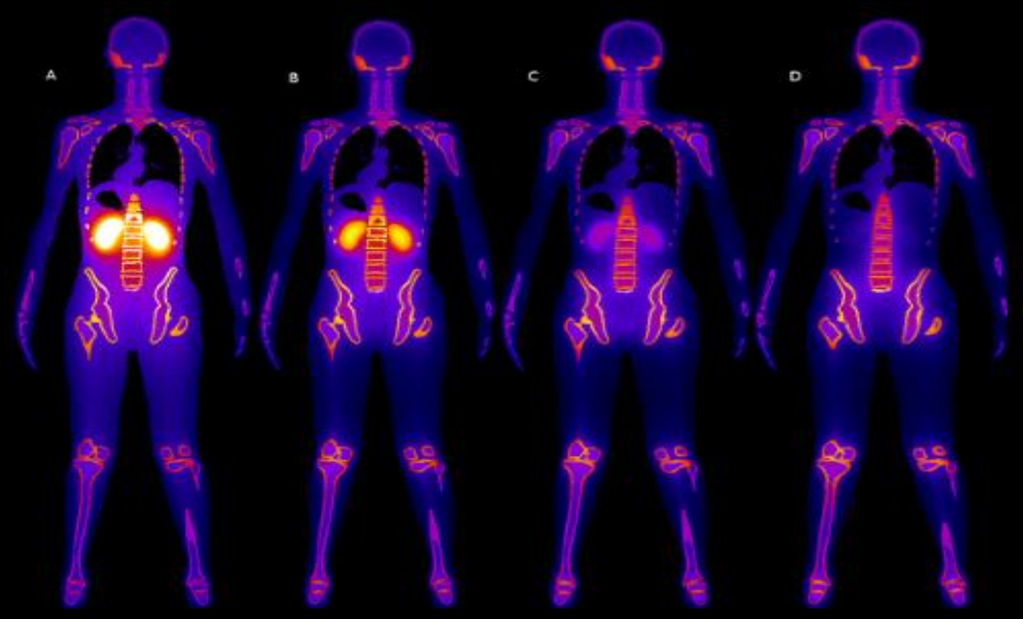

***Figure 1**: Dose maps of Tc-99m MDP radiopharmaceutical at the same pediatric phantom at 4 different time points. A -> T=0h, B-> 1.42h, C-> 4.11h, D-> T=20.2h.*

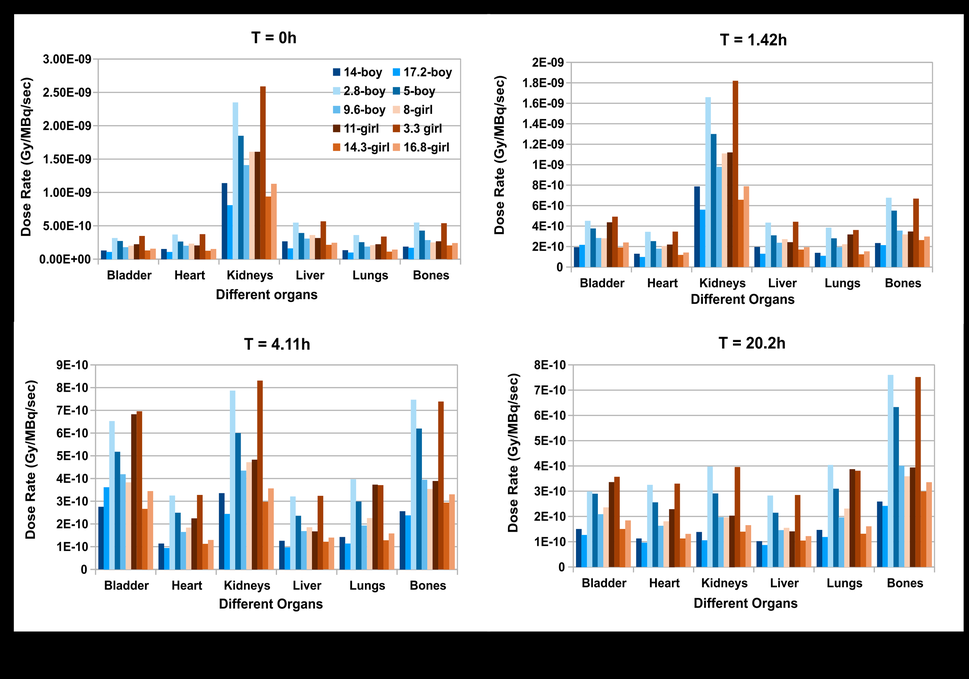

***Figure 2**: Indicative values of dose rate in several organs for the case of Tc-99m MDP, for ten different pediatric phantoms at ages between 2.8 and 17.2 years old at 4 different times.*

DISCUSSION & CONCLUSIONS

- In this poster the case of ^{99m}Tc-MDP is presented, and indicative values of dose rates are presented.
- The main goal of our study concerns the implementation of simulations for a variety of commonly used radiopharmaceuticals in NM applications.
- The development of a large database for internal dosimetry in pediatric examinations will be the outcome of our study.
- More computational pediatric models are expected to be utilized for the enhancement of the dosimetry database
- At next steps, Artificial Intelligence techniques will be used, utilizing ML/DL algorithms, trained on our simulated database, to predict the internal absorbed dose for any new pediatric patient.

References

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