COMPUTED TOMOGRAPHY DOSIMETRY AND OPTIMIZATION FOR PAEDIATRIC PATIENTS

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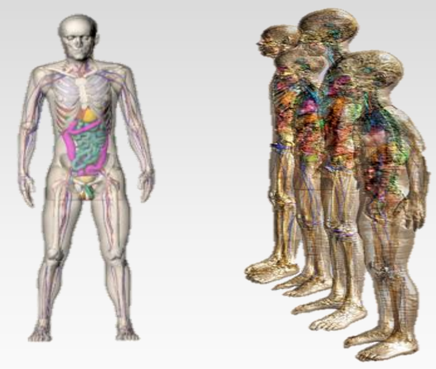
Overview

Realistic paediatric CT simulations were performed in the present study. A computational anthropomorphic phantom, in combination with well validated Monte Carlo simulations was used to model common clinical protocols. Our **goal** is the creation of a framework, freely available to the scientific community for the dose calculation on specific organs of interest in pediatric computed tomography towards:

- the standardization of the protocols that are used in the various examinations,
- the use of flexible / validated models and
- the realistic CT simulation procedure using anthropomorphic computational data.

- **GATE** Monte Carlo simulation toolkit was used for modeling the Toshiba Aquilion™ PRIME scanner
- The source energy spectrum was calculated using the software Spektr
- System validation was performed with CTDI phantom experiment
- A Monte Carlo normalization factor was calculated for validation purposes
- Dose maps and Initial dosimetric data are provided in the present study for chest and head helical scans
- Pediatric models from XCAT and ITIS series will be used for the database



XCAT (right) and ITIS series (left) representations

Introduction

Continuing improvements in CT technology, including faster scanning times and improved resolution, have dramatically increased the accuracy and usefulness of CT scanning and reduced the dose, which may partially account for increased use in medical diagnosis. However, the trend for increased numbers of procedures using this imaging modality may increase the overall doses.

Radiation sensitivity in pediatric population is noteworthy higher compared to adults. Children have a higher risk of developing cancer compared to adults receiving the equivalent dose. In addition, exposure to ionizing radiation in children has a longer period in which it may cause developing of radiation-induced complications that may include cancer or as future parents risk for passing on radiation-induced genetic defects in the next generations.

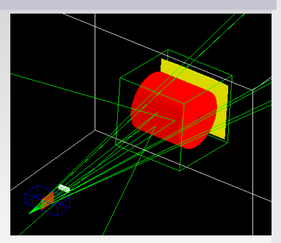
The dose in each organ during CT scans can be obtained using Monte Carlo (MC) simulations and computational phantoms. GATE is a Monte Carlo simulation toolkit based on the precise modeling of the physical processes of the Geant4 code. It is dedicated for Nuclear Imaging applications and Radiotherapy with large flexibility in using voxelized phantoms and complex geometries with movement incorporation. GATE is extensively validated, although realistic simulations are highly demanding in computational resources.

Materials / Methods

In the present study, the GATE open-source MC toolkit (v7.2) [1] was used for modeling AquilionTM PRIME multislice helical CT system.
The energy spectrum was calculated using the software Spektr.
The energy photon spectrum was defined in GATE as a gamma-particle point source with certain fan and cone angles.
The X-ray source-to-detector distance and the source-to-isocenter distance were also defined and an almost continuous movement of the source was achieved.

In order to validate our results, the absorbed dose in PMMA digital phantom was compared with measured data in corresponding PMMA physical phantom at 1 position.
A thin-walled ionization chamber was constructed from manufacturer specifications and a Monte Carlo normalization factor was also described.

An XCAT anthropomorphic phantom [2] was used as reference model for the dosimetric simulations.
Helical CT trajectories were modeled by rotating and translating the voxel phantom with respect to a fixed source position in order to simulate a chest protocol.



Simulation of the PMMA phantom

Results

Normalization factors were derived to convert the dose simulated to absolute absorbed dose for the particular beam collimation.

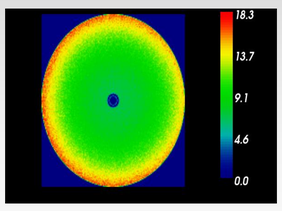
The measured and simulated $CTDI_{100}$ in air at isocenter are presented.

Energy (kVp)	Measured (mGy x mAs-1)	Simulated (mGy x particle-1)	NF (particle x mAs-1)
120	34.6 x 10-2	7.52 x 10-11	4.59 x 109

Table 1. Measured and simulated CTDI100 in air

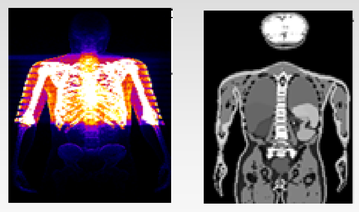
Phantom	Measured	Simulated	Diff. %
32-cm	35.0	31.96	8.69

Table 2. Comparison of CTDI in mGy between simulated and published data for the center position

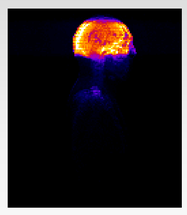


CTDI Dose maps for PMMA phantom

Results of XCAT dose maps indicate the **chest** and **head** helical movements.



a) Simulated chest scan and b) the corresponding slice of the attenuation phantom



Simulated head scan

Discussion and Conclusion

The verification of the CT scanner was completed, with high accuracy comparing experimental and simulated results. Initial dosimetric simulations were applied using standard pediatric phantoms.

This is an ongoing study for optimization of pediatric dosimetry. The next step is to irradiate several children phantoms with different clinical scanners in order to extract the absorbed doses in the most critical organs.

Acknowledgments

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https://error.upatras.gr/

References

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