PhD Thesis Title: 'Evaluation of Diagnostic, Therapeutic and Dosimetric Applications in Nuclear Medicine, with the Development of Computational Models and the Use of Monte Carlo Simulations**'**

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ABSTRACT:

In this thesis the state of art techniques applied in Nuclear Medicine field are investigated. By exploiting modern tools such as Monte Carlo simulations anthropomorphic computational models and high performance computing clusters, as well as using clinical data, we are assessing several parameters for the optimization and the evaluation of the applied clinical protocols in Nuclear Medicine. Initially, we have performed an extensive literature research for all the topics which are investigated in this thesis. More specifically, the bibliographic investigation includes the history and the description of the emission based imaging techniques (single photon and positron emission - SPECT and PET), as well as the state of the art on the most recent approaches for the creation of realistic Monte Carlo imaging databases. The methods used in modeling clinical and preclinical detection systems are also reviewed. Alongside, the evolution of anthropomorphic computational models development, used in Nuclear Medicine field, is presented. The literature investigation is completed with the study of the dosimetric protocols that are used in clinical practice. There is a detailed analysis and historical review on the calculation of dose point kernels (DPKs) that are commonly used in the diagnostic and therapeutic dosimetry. The theoretical background on dosimetry is completed with the study of the personalized dosimetric factors, such as the calculation of S-values.
In the present thesis, the evaluation of the clinical protocols is performed in two main directions. Based on the Monte Carlo simulations "ground truth" we try to optimize:

i. diagnostic / imaging techniques,
ii. dosimetry / therapeutic protocols.

Analytically, these two main axis are described in Chapters 2 and 3, respectively. In Chapter 2 the description and the results of the modelled imaging systems are presented. Moreover, a comparison study of the realistic intra-tumor heterogeneity PET modeling is performed, based on real clinical data. Finally, a full description of the created simulated imaging database is given, including clinical and preclinical PET and SPECT data.

In Chapter 3, we provide for the first time the entire calculation procedure of the DPKs, for three different materials (soft tissue/water, lung and bone) for a set of 13

commonly used radioisotopes. The DPKs were extracted using the GATE Monte Carlo toolkit, which was initially validated for the dosimetry calculation using monoenergetic i) photon (γ), ii) electron (e-) and iii) betta (b-) particles. We continue our internal dose assessment study by calculating the S-values in preclinical applications. The S-values were calculated using whole body biodistributions as a source, while the procedure was validated with previously published data. Accordingly, the whole-body (heterogeneous source) S-values were extracted for the optimization of pediatric nuclear medical applications, so as to accurate calculate the absorbed dose per critical organ of interest. The biodistributions used in the pediatric studies were based on clinical data.

The thesis is completed with the discussion and the analysis of the results obtained in each separate section. Future steps are suggested, so as to better exploit the presented results towards their application in clinical practice.

References to author publications that relate specifically to the dissertation:

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