Monte Carlo for Nuclear Medicine: vision and future requirements

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Background: Monte Carlo simulation has a long tradition of application in nuclear medicine. In fact, the internal dosimetry calculations of radionuclides used in diagnostic and therapeutic tracers, the radiation protection calculations in the exposure of radioactive sources and the design of new detectors for nuclear medicine, have benefited from the power and versatility of the Monte Carlo (MC) simulation.

Methods: Firstly, an historical prespective and a current status on the several applications of MC simulation in nuclear medicine will be reported: the calculation of dose point-kernels (DPK) and Voxel S-Values (VSV) for radionuclides, the evaluation of organ-level S factors in anthropomorphic computational phantoms, the introduction of models for clinical internal dosimetry, the direct MC dosimetry from SPECT-CT and PET-CT imaging, the development of calculation approaches for radiation protection estimations for external and internal exposure to radionuclides employed in diagnostics and therapy, the implementaion of attenuation, scatter and resolution correction in emission tomography, the design and optimization of novel detectors and scanners. An overview of models for small-scale and micro-dosimetry of radionuclides will be provided as well.
Then, a personal perspective on the possible future priorities and requirements, based upon the ongoing implementation in the clinical practice of the optimization of nuclear medicine therapies, on the novel scanner architectures and on the demands of the present directives on radiation protection, will be presented.

Conclusion: The most recent GEANT4 packages and interfaces, implemented on stand-alone scientific workstations or HPC resources, provide a tool of unprecedented power and versatility to address problems of medical radiation physics applied in nuclear medicine. To fully exploit these potentialities, a comprehensive knowledge of the past and present pathways of the research in each given application, together with a tight connection with the clinical and professional priorities, is woth to be achieved.