Overview of Monte Carlo Studies for Treatment Device Modeling in Radiation Therapy

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This study aims to overview studies on the Monte Carlo (MC) simulation for radiation treatment devices with the brief history and commonly-used simulation codes.

The MC simulations have taken important role in medical physics as an alternative method to the radiation measurements since the suggestion made by Metropolis and Ulam in 1949. Originally, it was used in simple calculation of physical constants such as reflection probabilities, particle range and energy loss of particle in matters. The MC simulation became more widespread in various research areas as more powerful computation was available and lots of simulation codes were developed. Especially, EGS, MCNP, FLUKA, Geant4, etc. is the representative codes that are the most commonly used for medical physics researches. The EGS and MCNP series were started from 1960s. The FLUKA was given its name in 1970, and the Geant4 was released in late 1990s. These codes underwent improvements with advanced physical models and accurate cross-section data.

With the developments and revisions of various simulation tools, studies on the medical physics were started with early works from 1960s to 1980s. The high energy gamma unit was firstly modeled in 1970s with an encapsulated ^{60}Co sources and the results were reported by the ICRU. First MC-based model of linear accelerator was reported in 1978 by using the EGS version 3. Despite the early model was simplified with target, collimator, and flattening filter, recently the more sophisticated modeling was implemented for complex geometries such as multi-leaf collimators to be available for four-dimensional simulations on time-dependent treatment techniques. For the charged particle therapy, early model of the proton beam nozzle for passive scattering was developed in 1986. Full model of the proton treatment head was reported from late 2000s. With modern simulation technique, time-dependent proton treatment can be currently simulated for the patient dose evaluation. Studies on modeling the heavy ion treatment devices were started from early 2010s.

Increased employment of the MC simulation on radiation treatment study was reported; that is, the number of papers published in *Physics in Medicine and Biology* and *Medical Physics* was five times higher in 2000-2019 than in 1968-1999. In addition, MC simulation is now employed to the studies on various research areas such as high resolution computational phantom and 4D simulation, which could contribute to predict accurate dose distribution in the patient.

Keywords: Monte Carlo simulation, Radiation Treatment, Device Modeling