Current status and future directions of Monte Carlo methods in radiation treatment planning, an overview

With the use of Monte Carlo methods imminent in routine clinical practice, it is important for the radiation oncology community to be aware of current developments in the field. Over the last several decades, considerable effort has been expended in the development of approximate empirical and semi-empirical dose computation models. In the evolution of these models approximate correction factors and patches were applied continually to account for observed discrepancies between measurements and calculations or to incorporate new treatment methods and accessories. Monte Carlo methods, being based on basic principles of physics, are universally accurate, i.e., apply equally well to photons, electrons, brachytherapy, protons, neutrons and all devices and accessories. Their introduction will obviate the need for incessant refinement of models. In addition to accuracy, there are numerous other advantages of Monte Carlo methods. For instance, they should require considerably less effort to commission and implement. Monte Carlo methods can provide monitor unit settings directly regardless of the modality, device or accessory being used, and will eliminate this source of treatment errors. In the long run, clinical dose-response data accumulated based on accurate dose distributions will allow improvements in treatment designs.

Current heightened interest in Monte Carlo is a result of the demonstration by the group at Lawrence Livermore National Laboratory of the feasibility of Monte Carlo methods in routine clinical work. This group is the creator of the Monte Carlo code known as Peregrine. Other institutions involved in Monte Carlo efforts include Stanford, NRCC, UCLA, Institute of Cancer Research in UK, Medical College of Virginia and Memorial-Sloan Kettering Cancer Center. Stanford is already using Monte Carlo for electron beam treatment planning. Others are likely to follow suit in the near future. Widespread use may take some time, the main impediments being integrating Monte Carlo codes with existing treatment planning systems, generating and commissioning phase space data for various models of treatment machines, validating results, and complying with FDA regulations. Initially, the add-on cost of Monte Carlo dose computation systems may be another factor.

While a limited use of Monte Carlo in clinical setting has begun, many areas need to be investigated. For example, it is necessary to compare Monte Carlo generated dose distributions with those produced using empirical and semi-empirical methods and estimate whether such differences are clinically significant. Further, assuming that Monte Carlo methods reveal deficiencies in treatment plans which were not apparent in conventional dose distributions, it is important to develop means to rectify such deficiencies, perhaps with intensity-modulated radiotherapy. A related issue is to explore ways of utilizing Monte Carlo dose distributions for optimizing intensity-modulated treatment plans. Monte Carlo methods may also be used for predicting accurate dose images for dosimetric verification of dynamic IMRT.

Educational objectives of this symposium are to (1) update the audience on the current status of Monte Carlo methods, (2) describe potential advantages of Monte Carlo, and (3) identify areas of further research.