Monte Carlo Methods in Electron Beam Treatment Planning

This presentation outlines recent advances in clinical implementation of the Monte Carlo method for electron beam radiotherapy dose calculation. The results presented are based, in part, on our experience at Stanford with Monte Carlo electron beam treatment planning. Systematic investigation of clinical electron beam characteristics have been carried out by various research groups using specially developed Monte Carlo programs such as the EGS4/BEAM code. As a result of this work, accurate and detailed electron beam phase space data are now available for patient dose calculation. Comparing results of Monte Carlo calculations and measurements of electron beam depth doses, lateral dose profiles and beam output factors for various electron energies, field shapes and sizes, and source to surface distances demonstrate excellent agreement (generally within 3%). Significant discrepancies (10% or more in dose or greater than 1 cm in the 70% isodose line) between the dose distributions calculated by Monte Carlo and by analytical algorithms are reported in the literature. The analytical algorithms, like those available in commercial treatment planning systems, show significant uncertainties when applied to clinical cases involving heterogeneities such as air cavities and bones. The Monte Carlo method is clinically implemented at Stanford for patient specific dose calculation. Electron beams of nominal energies 6 – 20 MeV from three Varian accelerators (Clinac 1800, 2100C and 2300C/D) were simulated using the EGS4/BEAM code. However, a full Monte Carlo phase space is not a realistic clinical tool for electron beam dose calculation. Thus, accurate models are being developed to represent the beam characteristics and reconstruct the beam phase space. This is required to: 1) improve the efficiency of accelerator simulation, 2) reduce data storage requirements and 3) allow for a quick commissioning procedure that can be routinely used by non-research oriented clinical departments. At this time, a model consisting of multiple sub-sources works well to satisfy these objectives. The source model parameters are derived from a reference accelerator's electron beam and are subsequently adjusted so that the simulation results match the measured results from the user's own beam. Additional focus of current research toward clinical implementation is that of calculation speed and the inclusion of all beam modifiers. An EGS4 user code, MCDOSE, is used to perform dose calculations in a 3D rectilinear phantom that can contain patient specific data from routine CT scans. Beam modifiers such as electron cutouts and bolus are also simulated using MCDOSE. By applying variance reduction techniques, the computation time for an electron beam plan have been reduced to 0.1 – 1.0 h on a Pentium II 400 MHz PC depending on the beam energy, field size and voxel size. Electron beam plans calculated using Monte Carlo for head and neck, breast/chestwall, and other treatment sites are presented and compared with those calculated by a commercial treatment planning system. Recent developments in Monte Carlo based inverse planning for electron beam IMRT are also discussed.