Analytical methods for computing the dose distribution in an inhomogeneous medium (i.e. the patient) from high-energy photon or electron beams involve approximations. For megavoltage x-ray beams, 3D convolution of the point-spread function is currently the most advanced method; however, these water-generated kernels must be "scaled" for inhomogeneities, involving crude approximations, especially for electron transport over different densities. For electron beams, pencil-beam algorithms can only accurately account for electron scatter if the inhomogeneities are layered perpendicular to the pencil direction. Monte-Carlo simulation avoids approximations in the transport of photons and electrons through arbitrary media. The CPU time on affordable hardware (e.g. a dozen or so Pentium 400 MHz PCs) to generate the required number of histories ($\approx 2 \times 10^8$ for a *photon* beam plan, for ±1-2% in 1-2 mm voxels) is around 1 hour.

Input data for MC are no longer measured dose distributions in water, but instead a full description of the incident particles i.e. type, energy, position and direction. This is obtained from an initial MC simulation starting at the vacuum window of the linear accelerator. The individual patient simulation starts just above the beam-defining devices, using a cartesian, voxelised geometry "filled" by the data from CT.

Within 2 to 3 years the first commercial MCTP system can be expected. This will open up a number of exciting possibilities. Of particular interest is the interaction between MCTP, DVHs and so-called biological models (TCP, NTCP). Dose-volume histograms (DVHs) summarize 3D dose information at the expense of spatial information; one can therefore expect that MC-generated DVHs will show less statistical noise than the dose distributions themselves. For the target volume, these statistical fluctuations are equivalent to hot and cold spots and could yield underestimates of the Tumour Control Probability if very small scoring volumes are chosen; on the other hand, choosing relatively large MC scoring volumes will yield very precise estimates of the mean tumour dose. There will thus be a fascinating interplay between voxel size, number of histories and TCP. Models for both TCP and Normal-tissue complication probability (NTCP) for the tumour and organs at risk respectively can be used to evaluate the likely clinical impact of the differences between dose distributions generated by MC and by the various analytical algorithms. It will be possible to compute not just doses but also (electron and photon) fluence spectra at all positions of interest in the phantom/patient, making possible the computation of dosimetric quantities such as water/air stopping-power ratios or (μ_{en}/ρ) ratios for the user's actual clinical beam quality. Additionally the visualization of particle tracks overlayed onto the patient anatomy will have considerable pedagogical value as well as verifying that the beams are in the right place.

The research described in this abstract was supported by a grant from the DOSIGRAY corporation.

1. To summarize the limitations of analytical dose calculation algorithms.
2. To summarize the advantages of Monte-Carlo based treatment planning (MCTP)
3. To predict interesting developments flowing from the use of MCTP