Purpose:
To design and validate a tool for routine verifications of clinical treatment plans using Monte Carlo (MC) simulations.

Methods:
We focus on the clinical implementation for patient dose calculations using TOPAS (TOol for PArticle Simulation), a user-friendly interface to the Geant4 MC toolkit. Gantry and patient positioning follow guidelines of the IEC and phase-space output is compliant with the IAEA format. Different parameterization schemes for voxel navigation have been tested to improve computing speed. Patient geometry and alignment are controlled by text files. CT slice input is currently supported for DICOM and XiO data files. Delivered doses, particle fluxes, energy deposits and many other properties can be scored. This new tool is now available for routine proton treatment planning at MGH. In many instances MC studies are preferred over pencil-beam algorithms.

Results:
We present results from a cohort of MGH patients. A reduction in CPU time of up to 30% in patient dose calculations has been achieved with a specialized voxel navigation for CT volumes with 30 million voxels. Clinically required accuracy has been reached and verified in a water phantom with uncertainties of +1/-1.5mm in range, 3mm in modulation width and 2% for the flatness of spread-out Bragg-peaks with a variance comparable to measurements. For patient dose calculations, up to 8% of the voxels in patients were found to have larger than 2% and 2mm difference when comparing MC and a pencil-beam algorithm.

Conclusions:
Monte Carlo simulations are still an exception in treatment planning, requiring detailed work by medical physicists who are also MC software experts. TOPAS supports an easy-to-use interface to set up nozzle and patient simulations without programming knowledge. This study demonstrates routine patient simulations with the MC method and supports the value and feasibility of using MC simulation as a standard in proton treatment planning.

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