Purpose: To evaluate the accuracy of a new, deterministic linear Boltzmann transport equation solver, AcurosXB, for radiotherapy dose calculations in the presence of high-density materials by comparison with Monte Carlo.

Methods: AcurosXB, EGSnrc-based Monte Carlo and Analytic Anisotropic Algorithm (AAA) were used to model 6MV and 18MV photon beams incident on phantom and patient geometries containing stainless steel and titanium high-density objects. Monte Carlo was used as the evaluation benchmark while AAA was included as a representative of the convolution-based clinical modeling algorithms currently used for radiotherapy treatment planning. Calculation geometries include a virtual cubic phantom created in MatLab, a cubic water phantom containing stainless steel rods and prosthetic hips and patient CT images with associated clinical treatment plans. Dose distributions were processed and analyzed in MatLab.

Results: Agreement between AcurosXB and Monte Carlo is within 5% and 2mm. There is a backscatter peak position offset of up to one pixel (2mm) between AcurosXB and Monte Carlo which can be accounted for by differences in voxel coordinate definition, contour definition and interpolation effects. Additional differences between AcurosXB and Monte Carlo fall within statistical variance associated with Monte Carlo. Disagreement between AAA and Monte Carlo was far more dramatic; AAA was unable to model the sharp backscatter peak associated with photon transport across low- to high-density boundaries resulting in inaccurate dose distribution through and past high density regions.

Conclusions: AcurosXB has shown to be an improvement on existing algorithms for calculating dose distribution in the presence of high-density regions, nearly matching the current gold standard Monte Carlo method. Discrepancies between AcurosXB and Monte Carlo do not translate into clinically significant dose differences, while AAA has shown to under- or over-estimate dose by as much as 20%.

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Varian Medical Systems has provided AcurosXB hardware and software for research activities.