Hybrid Scatter Correction for CT Imaging

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Purpose:

The purpose of this study was to develop and evaluate the hybrid scatter correction algorithm (HSC) for CT imaging. Therefore two established ways to perform scatter correction, physical scatter correction based on Monte Carlo simulations and convolution-based scatter correction, were combined in order to perform an object-dependent, fast and accurate scatter removal.

Based on a reconstructed CT volume, patient-specific scatter intensity is estimated by a coarse Monte Carlo simulation that uses a reduced amount of simulated photons in order to reduce simulation time. To further speed-up the Monte Carlo scatter estimation, scatter intensities are simulated only for a fraction of all projections. In a second step the high noise estimate of the scatter intensity is used to calibrate the open parameters in a convolution-based algorithm which is then used to correct measured intensities for scatter. Further the scatter-corrected intensities are used to reconstruct a scatter-corrected CT volume.

Materials and Methods:

Monte Carlo-based scatter correction is considered to be very accurate since the real physics of photon transport are incorporated in the model. However, currently clinical applicability is hindered by the high computational complexity of the Monte Carlo scatter reduction methods.

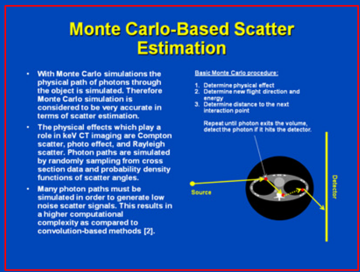
Convolution-based scatter correction on the other hand has far less computational needs since scatter intensity is estimated by scaling and low-pass filtering measured intensities. Their drawback is that the semi empirical models used have open parameters which must be calibrated in advance based on reference objects which also causes them to be not patient-specific.

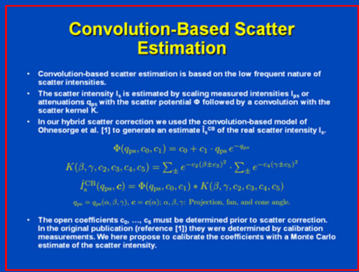
With HSC the Monte Carlo simulation is accelerated by reducing the number of simulated photons and by reducing the number of projections for which the Monte Carlo simulation is done. This reduced number of photon histories comes at the cost of a higher noise level in the scatter estimate. Therefore instead of using the high noise estimate directly, we aim at using it only for the determination of the open parameters in the convolution-based algorithm which is then used for scatter correction.

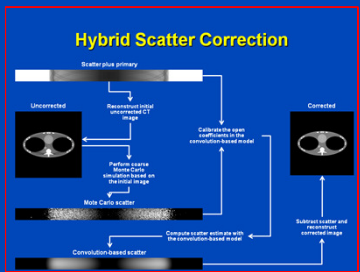
We evaluated the scatter correction potential of HSC in simulations and measurements. For the simulation study we simulated primary and scatter intensities for the Forbild thorax phantom.

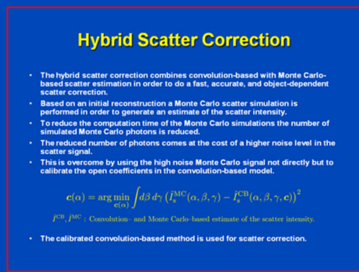
Measurements were done for a head phantom on the Varian OBI CBCT scanner (Varian Medical Systems, Palo Alto, USA).

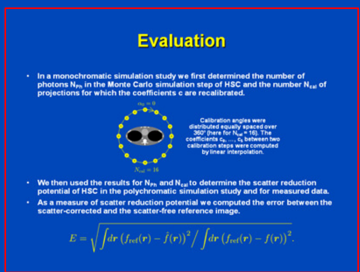
In both cases we applied the empirical cuppping correction (ECC) algorithm [3] and the empirical beam hardening correction (EBHC) algorithm [4] to correct for artifacts caused by the polychromatic x-ray spectrum.

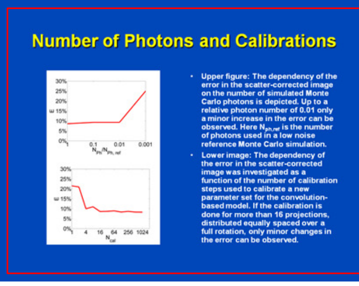


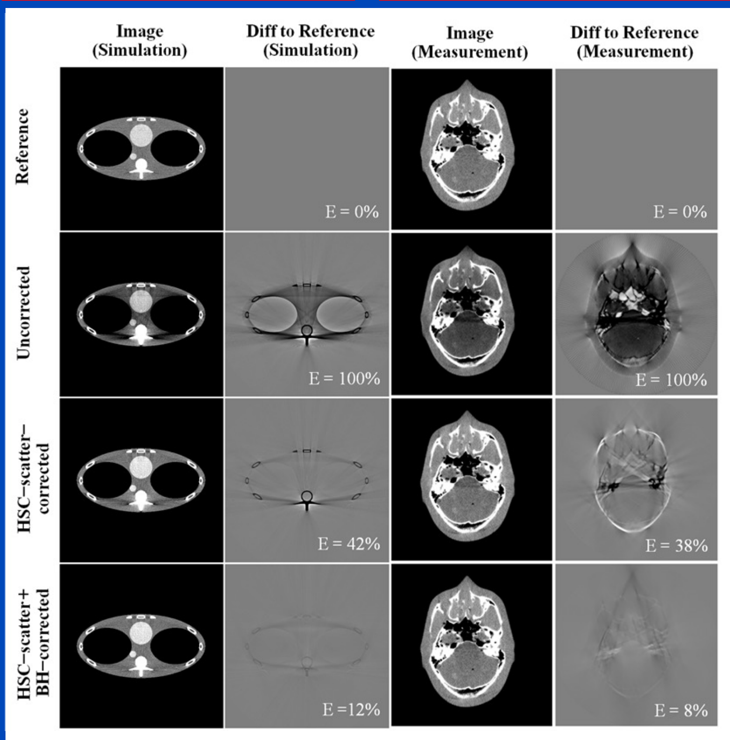












Results for the scatter correction potential of HSC in case of polychromatic data. For the simulations the reference image is a beam hardening–corrected image reconstructed from primary radiation only. For the measurements the reference is corrected for scatter with a low noise Monte Carlo simulation. On top of the scatter correction a beam hardening correction (EBHC, reference [4]) is performed.

Results:

Using our hybrid approach for scatter correction the number of Monte Carlo photons may be reduced by a factor of 50 to 100 as compared to a pure Monte Carlo simulation while still achieving accurate results for the scatter correction. Further, it turned out to be sufficient to recalibrate the parameters of the convolution-based model at an angular increment of 22.5°, i.e. to do the calibration only for 16 projections equally spaced over 360 degree.

Conclusion:

HSC allows to do a Monte Carlo-based, object-dependent scatter correction with highly reduced computational needs as compared to pure Monte Carlo-based scatter correction while still achieving a good scatter artifact correction.

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References:

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