Purpose: Recently introduced compressed sensing theory has enabled accurate, low-dose CBCT reconstruction of anatomic information with fewer and noisier projections data. However, the reconstruction time remains a significant challenge for practical implementation in a busy clinic. We propose a novel gradient projection algorithm, based on Barzilai and Borwein formulation (GP-BB), that handles the total variation (TV)-norm regularization-based least squares problem for CBCT reconstruction in an extremely efficient manner, with speed acceptable for use in on-line IGRT.

Methods: CBCT is reconstructed by minimizing the energy function consisting of 1) data fidelity term, and 2) TV-norm regularization term. Both terms are simultaneously minimized by calculating the gradient projection of the energy function with the step size determined using an approximate second-order Hessian calculation at each iteration, based on Barzilai and Borwein formulation. To speed up the process, a multi-resolution optimization is used. In addition, the entire algorithm was designed to run with a single GPU card. To evaluate the performance, the CBCT projection data of a clinically-treated head-and-neck patient was acquired from the Varian TrueBeam system.

Results: The proposed GP-BB algorithm was shown to be extremely efficient that a clinically reasonable patient image, using 120 CBCT projections, was reconstructed in 12 iterations for a total time of < 34 seconds. The image quality was visually equivalent to the commercial Feldkamp-Davis-Kress (FDK) algorithm using 364 CBCT projections. This represents dose reduction of one-third (= 120/364) all at while maintaining the speed needed for clinical use.

Conclusions: In this work, we developed a novel low-dose CBCT reconstruction algorithm that is able to generate a clinically reasonable patient image in 12 iterations, using 120 CBCT projections, in total of < 34 seconds, with a single GPU card. This makes our GP-BB algorithm entirely practical for daily clinical use.