Impact of iCBCT reconstruction on cone beam acquisitions

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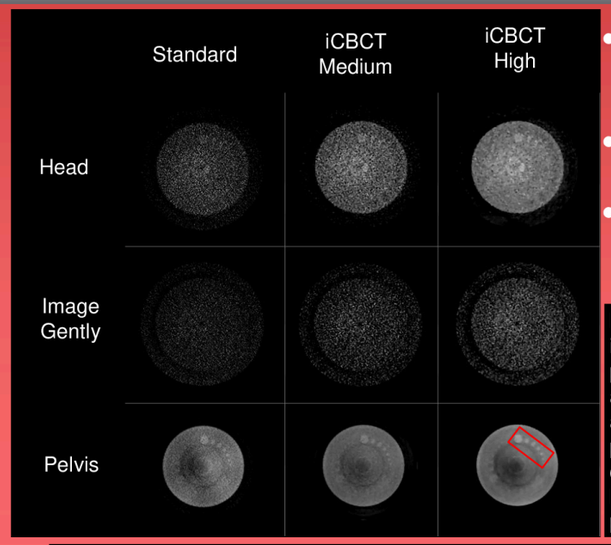
Introduction

Iterative reconstruction with noise suppression of cone beam CT (CBCT) images has been shown to improve the contrast to noise ratio (CNR). In version 2.7 of the TrueBeam software, Varian enabled their proprietary iterative reconstruction package called iCBCT that includes multiple options for noise suppression. Adoption of this tool in our clinic has been slowed by the lack of sufficient characterization of this technique in the literature. Here we characterize the impact of iCBCT reconstruction with medium, high, and very high noise suppression compared to the standard filtered back projection reconstruction technique and demonstrate the possibility of reducing kVp or tube current while preserving resolution and CNR.

Methods

CBCT images were acquired on a TrueBeam running console version 2.7. The included Head (full fan, 100kVp, 15mA), Image Gently (full fan, 80kVp, 10 mA), and Pelvis (half fan, 125kVp, 60mA) CBCT protocols were acquired of a Cathpan 504 centered on the interface of the low contrast and geometry modules. The default reconstruction using FDK with fASKS scatter correction was used as the standard for comparison to iCBCT reconstruction with medium or high noise reduction.
Further images using the Head protocol as a base with variations of kVp and mA settings with all other variables held static were acquired in triplicate. After acquisition and reconstruction with the standard algorithm, images were retrospectively reconstructed using the iCBCT algorithm with the medium, high, and very high noise suppression options. An in-house ImageJ plugin that calculates Modulation Transfer Function (MTF) of the Point Spread Function (PSF) and CNR was used to analyze the images. MTF PSF F50 is the spatial frequency that results in the MTF being reduced to 50% and is used as a partial representation of spatial resolution.

iCBCT impact on included protocols



- Reconstruction using iCBCT enables enhanced visualization of the 1% insert in the head protocol
- iCBCT had no effect on 1% insert visualization for Image Gently
- For Pelvis noise suppression is apparent, but visualization of 1% insert is unaffected

Figure 1: Reconstructions of Truebeam included Head, Image Gently and Pelvis protocols with standard, and iCBCT medium and high reconstructions. Three CBCTs were acquired and three reconstructions are pictured. The red box in Pelvis iCBCT High contains the 1% contrast supra-slice inserts. Further analysis done on 1% insert is performed on the largest insert.

Impact of energy and current on Head CBCT image quality

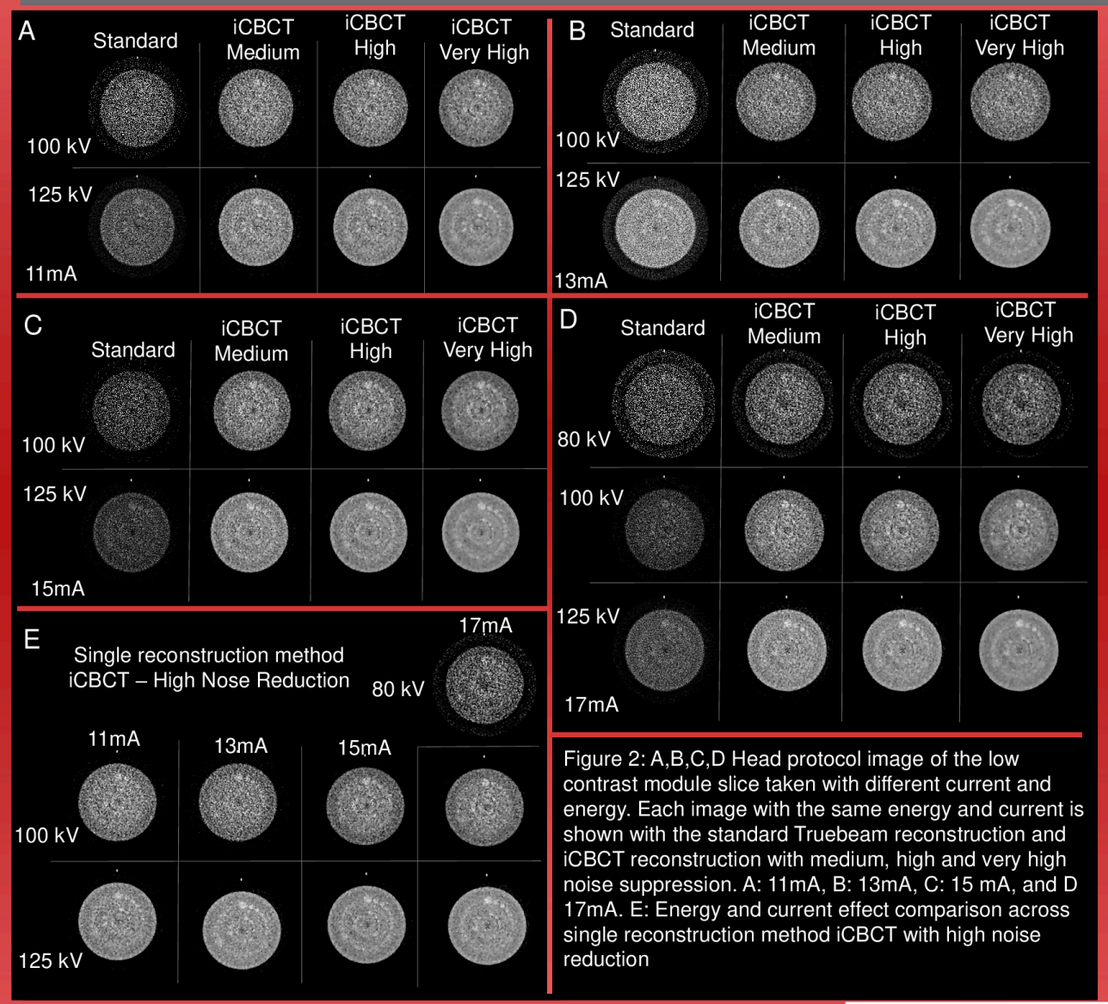
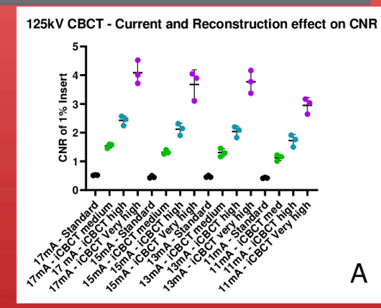
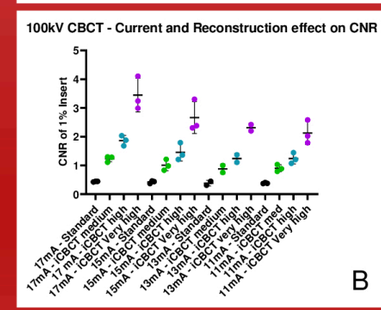
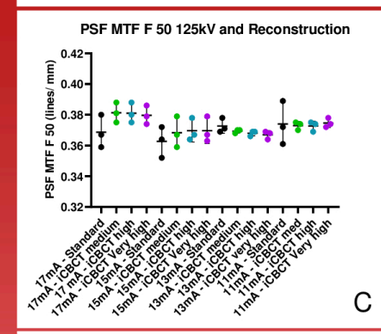
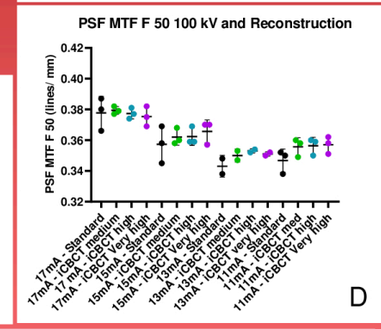


Figure 2: A,B,C,D Head protocol image of the low contrast module slice taken with different current and energy. Each image with the same energy and current is shown with the standard Truebeam reconstruction and iCBCT reconstruction with medium, high and very high noise suppression. A: 11mA, B: 13mA, C: 15 mA, and D 17mA. E: Energy and current effect comparison across single reconstruction method iCBCT with high noise reduction









- Images using 80kV results in very noisy images with low contrast even with iCBCT and 17mA
- Increasing noise suppression improves CNR with added variability
- Increasing noise suppression results in a slight reduction in spatial resolution
- iCBCT high at 100kV and 11mA has a 2X higher CNR than standard at 125kVp and 17mA

Figure 3: A,B,C,D Quantitative analysis of images taken in triplicate including those in figure 2. Black data points are standard reconstruction, green – iCBCT medium, blue – iCBCT high, and purple – iCBCT very high.

Conclusions

This work demonstrates that iCBCT's iterative reconstruction with variable noise suppression provides opportunities for image CNR improvement with no additional dose and little sacrifice in resolution. This indicates the opportunity to reduce dose from imaging with protocol optimization. Further work characterizing dose via CBDI is necessary for optimization of kV and mA for establishing dose reduction while keeping image quality comparable to that currently used in clinic.