Longitudinal quantitative assessment of 40 keV photon-counting CT artifacts for system stability and detector performance evaluation

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ABSTRACT

Currently there is no specific QC requirement for photon-counting CT (PCCT), which is different than conventional energy integrating detector CT. Ring artifacts were observed on our PCCT daily quality control images, with 40 keV VMIs exhibiting the most pronounced artifacts. Because these artifacts may reflect degraded system stability and detector performance, longitudinal monitoring is essential. However, visual assessment alone is challenging for consistent and objective artifact tracking. This study aims to perform a longitudinal quantitative assessment of artifacts on 40 keV images. The artifact index, defined as the mean value within the ROI, showed a strong correlation with artifact severity. The artifact index serves as an effective metric for quantifying global artifact severity and may serve as a valuable tool for longitudinal monitoring of detector stability and system performance.

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INTRODUCTION

Daily quality control for diagnostic CT include water CT number and its standard deviation, and visual artifact evaluations[1]. ACR also requires these two tasks if the scanner is accredited. Currently there is no specific QC requirement for photon-counting CT (PCCT), which is different than conventional energy integrating detector CT. At our institution, 70 keV virtual monoenergetic images (VMIs) are used for these evaluations on PCCT, because they are closer to the 120kV from the conventional CT. Ring artifacts were observed on our PCCT daily quality control images, with 40 keV VMIs exhibiting the most pronounced artifacts[2]. Because these artifacts may reflect degraded system stability and detector performance, longitudinal monitoring is essential. However, visual assessment alone is challenging for consistent and objective artifact tracking. This study aims to perform a longitudinal quantitative assessment of artifacts on 40 keV images.

METHODS AND MATERIALS

An ACR phantom was scanned daily on a PCCT (NAEOTOM Alpha, Siemens) as an established QC program. Both helical and axial acquisitions were performed at 120 kV and a fixed dose (CTDIvol: 20 mGy). The images were reconstructed with 1 mm thickness, 0.5 mm increment, Qr44 kernel, QIR-3. Since 09/23/2024, both 40 keV VMI and low-energy images (T3D) have been reconstructed for artifact quantification. Twenty slices from the uniformity module (Figure 1) were used to generate a maximum intensity projection (MIP) image after calculating the absolute Hounsfield Unit value for each pixel. A large ROI covering 80% of the phantom cross-section was placed on the MIP to compute the artifact index, defined as the mean value within the ROI. Artifact indices and corresponding images acquired before and after a major system software upgrade (VA50A_sp1 to VB10_sp1) were compared.

$$Artifact\ Index = \frac{1}{N}\sum_{i=1}^{N}|I_i|$$

I_i: HU value of the i^{th} pixel inside ROI.
N: total number of pixels in the ROI.

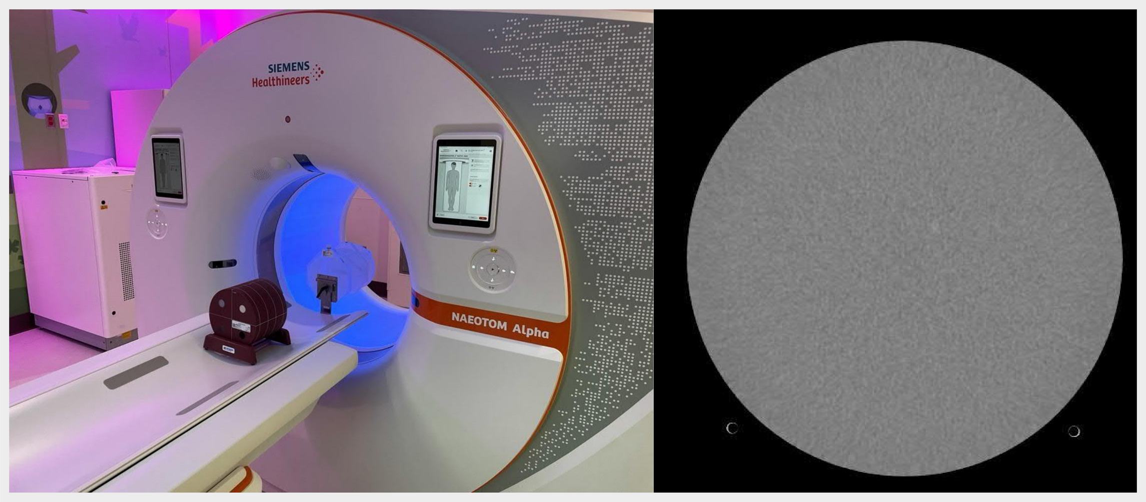

Figure 1: ACR phantom in the PCCT and the uniformity module of ACR phantom.

RESULTS

The artifact index showed a strong correlation with artifact severity. Artifact index for T3D images remained stable over 15 months (minimum: 8.3; maximum: 9.5 HU). In contrast, 40 keV images showed a gradual increase in artifact index from 25.2 HU (mean of first 30 measurements) to 36.0 HU (mean of the last 30 measurements) before the software upgrade, after which the artifact index decreased to approximately 16.2 HU and remained stable. (Figures 2, 3 and 4)

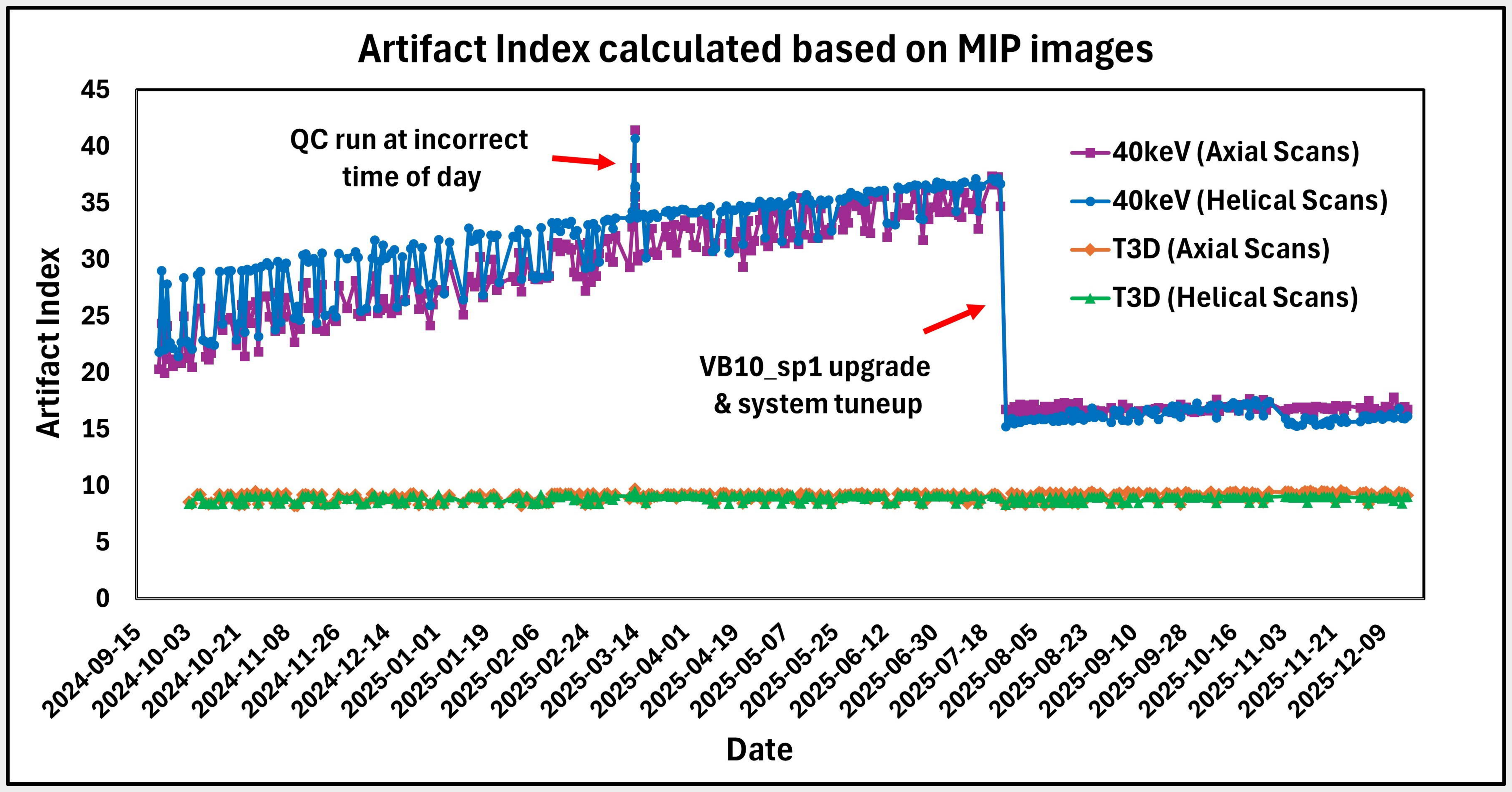

Figure 2: Artifact index quantified for 40 keV VMIs and T3D images over 15 months. Artifact index based on 40 keV gradually increased before software upgrade and system tune up, and it decreased and remained stable thereafter. T3D images had stable artifact index over time.

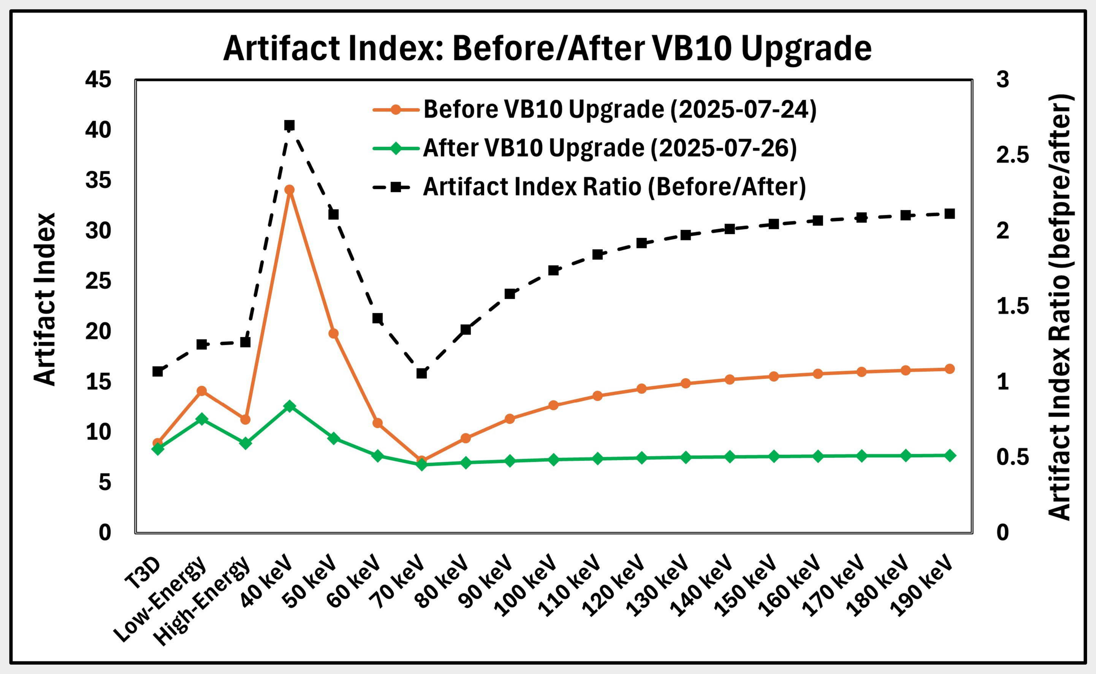

Figure 3: Artifact Index before and after software upgrade from all image types with 40 keV image exhibiting the largest changes.

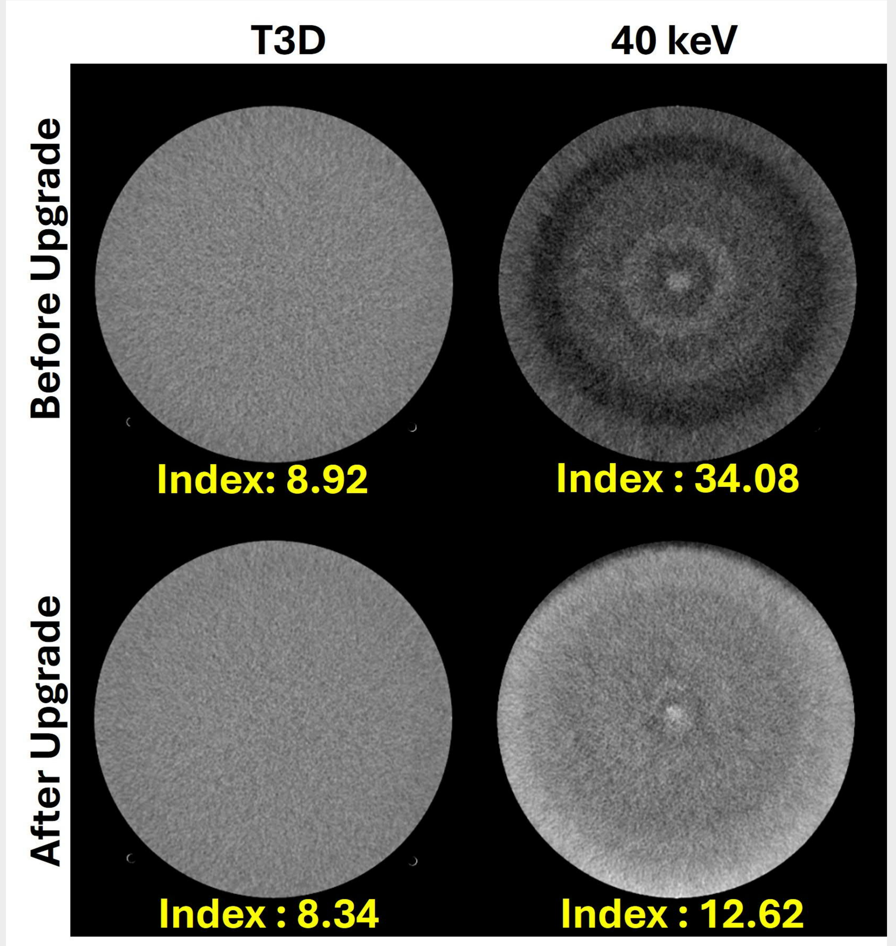

Figure 4: The 3rd module of ACR phantom images from T3D and 40 keV VMIs before and after the upgrade (Level/Window = 0/200 HU).

DISCUSSION

Ring artifacts were observed on virtual monoenergetic images acquired with clinical photon-counting CT using an ACR phantom, with 40-keV images exhibiting more pronounced artifacts on visual assessment. To address the limitations of subjective evaluation, a quantitative artifact index was developed to characterize the global artifact level in uniform images. Longitudinal tracking of this index enables objective monitoring of artifact evolution over time and may provide a practical tool for assessing system stability and detector performance in clinical photon-counting CT.

CONCLUSIONS

The artifact index serves as an effective metric for quantifying global artifact severity and may serve as a valuable tool for longitudinal monitoring of detector stability and system performance.

REFERENCES

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