A Phantom-Based Assessment of Low-Contrast Performance Comparing Iterative Reconstruction Algorithms in CT

S. LEON[1], C. SCHAEFFER[1], E. OLGUIN[1], and M. ARREOLA[1]
[1]University of Florida, Gainesville, FL

JULY 12–16 2020 VIRTUAL
JOINT AAPM | COMP MEETING
EASTERN TIME [GMT-4]

INTRODUCTION

FIRST is a model-based iterative reconstruction (MBIR) algorithm recently released by Canon Medical Systems. This phantom study compares the low-contrast performance of FIRST with Canon's default iterative reconstruction algorithm, AIDR 3D, for the detection of two differently-sized low-contrast objects. The traditional CNR metric is used since it is the most widely recognized and cited in literature; however, low-contrast detection depends on the noise frequency distribution rather than the total noise in the image, so it is not really the most appropriate metric to compare algorithms with different noise textures.[1] For this reason, the low-contrast object specific CNR, CNR_{LO}, was also calculated.

AIM

- This study compares the contrast between two Canon iterative reconstruction algorithms: AIDR 3D and FIRST.
- Two metrics are used: the traditional contrast-to-noise ratio (CNR), and the low-contrast object specific CNR (CNR_{LO}). CNR_{LO} evaluates the impact of noise texture on size-specific object detectability.
- Dose levels and reconstruction settings appropriate for lung screening, abdomen, and brain studies were investigated.

METHOD

- A Canon Aquilion Genesis scanner was used to scan the ACR image quality phantom at dose levels appropriate for lung screening, abdomen, and brain exams (Table 1). Each scan was repeated 10 times.
- Scans were reconstructed using AIDR 3D and FIRST with kernel settings appropriate for lung, body, and brain exams (Table 1).
- The NPS for each dose/algorithm/kernel combination was calculated as described in Schaeffer et al.[2]
- CNR (Eq. 1) and CNR_{LO} (Eq. 2) were calculated for the 25-mm and 6-mm low-contrast disks from ten 1-mm slices on each of the ten scans, for a total of 100 measurements per dose/algorithm/kernel combination.
- A two-tailed *t*-test was used to assess significant differences between FIRST and AIDR 3D using each metric.

$$CNR = \frac{S_{disk} - S_{bg}}{\sigma_{bg}} \quad \text{Eq. 1}$$

$$CNR_{LO}(\bar{u}) = \frac{S_{disk} - S_{bg}}{\sqrt{NPS(\bar{u})}} \quad \text{Eq. 2}$$

S is the signal, σ is the standard deviation, $\bar{u}$ is the spatial frequency corresponding to the diameter of the disk, and $NPS(\bar{u})$ is the noise power spectrum at that frequency.

Exam type	$CTDI_{vol}$ (mGy)*	AIDR 3D Kernel	FIRST Setting
Head	29.4	FC64	Head
Abdomen	19.7	FC56	Body
Lung Screening	2.8	FC18	Lung

* $CTDI_{vol}$ reported in the 32-cm phantom

Table 1: Scanner-indicated $CTDI_{vol}$ and reconstruction settings used

RESULTS

- FIRST and AIDR 3D produce different noise textures that are clearly apparent on phantom images (Figure 1).
- Using the traditional CNR metric, FIRST outperformed AIDR 3D for all scans (Figure 2).
- Using the CNR_{LO} metric, however, FIRST performed significantly better than AIDR 3D only for abdomen scans with the 6-mm contrast disk (Figure 3).
- Results from the abdomen scan with 25-mm disk were not significantly different between FIRST and AIDR 3D. FIRST produced a significantly lower CNR_{LO} than AIDR 3D for lung and brain scans with both contrast disks (Table 2).

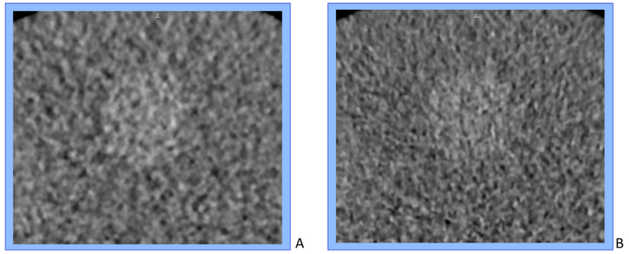

Figure 1. Images of the ACR phantom zoomed into the 25-mm disk, showing the differing noise patterns from a) FIRST and b) AIDR 3D. These images were processing using dose levels and reconstruction settings appropriate for a brain study.

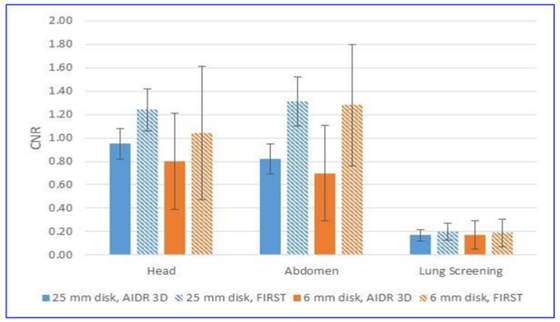

Figure 2. Calculated values of CNR for the three phantom-simulated exam types

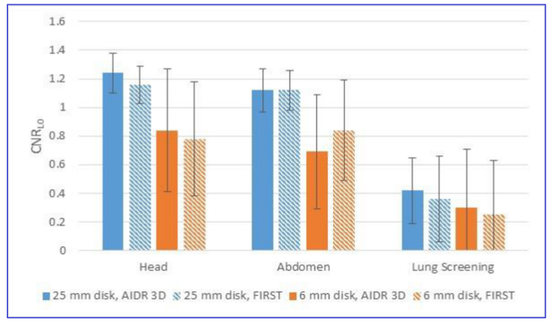

Figure 3. Calculated values of CNR_{LO} for the three phantom-simulated exam types

	25-mm Disk		6-mm Disk	
Exam Type	CNR	CNR_{LO}	CNR	CNR_{LO}
Head	FIRST ($p < 0.01$)	AIDR 3D ($p < 0.01$)	FIRST ($p < 0.01$)	AIDR 3D ($p < 0.01$)
Abdomen	FIRST ($p < 0.01$)	Equivalent ($p = 0.85$)	FIRST ($p < 0.01$)	FIRST ($p < 0.01$)
Lung Screening	FIRST ($p < 0.01$)	AIDR 3D ($p < 0.01$)	FIRST ($p = 0.047$)	AIDR 3D ($p < 0.01$)

Table 2. Results of the t-test comparisons for each dose/algorithm/kernel combination ("Exam Type"), contrast disk size, and metric. The algorithm producing the higher value of CNR or CNR_{LO} is given, with p-values in parentheses.

CONCLUSIONS

This phantom study considered the low-contrast performance of the FIRST and AIDR 3D reconstruction algorithms for 3 simulated exam types: lung screening, abdomen, and brain. If CNR is used to compare the algorithms, FIRST would clearly dominate for all scenarios tested (Figure 2, Table 2). However, use of CNR_{LO} suggests that low-contrast detectability using FIRST would be superior only for abdomen scans (Figure 3, Table 2). AIDR 3D outperforms FIRST on lung scans and head scans. Noise texture clearly differs between FIRST and AIDR 3D (Figure 1), suggesting that CNR_{LO} is likely the more appropriate metric to use.

This phantom study suggests that FIRST may be beneficial for abdomen protocols, since the low-contrast performance is better than AIDR 3D for smaller objects and equivalent for larger objects. AIDR 3D may be the algorithm of choice for low-contrast detectability in brain and lung screening exams.

DISCLOSURES

Research funded by Canon Medical Systems USA, Inc.

REFERENCES

1 **Urikura A et al.** Objective assessment of low-contrast computed tomography images with iterative reconstruction. *Phys Med* 2016; 32; 992-8.

2 **Schaeffer C et al**. A Comparison of Noise Properties Between Statistical-Based Hybrid and Model-Base Iterative Reconstruction Algorithms in CT (Poster). *Joint AAPM/COMP Annual Meeting*. 2020.

CONTACT INFORMATION

leons@radiology.ufl.edu

UF Medical Physics College of Medicine