A Comparison of Noise Properties between Statistical-based Hybrid and Model-based Iterative Reconstruction Algorithms in CT

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

Colin Schaeffer MS, Stephanie Leon Ph.D., Edmond Olguin Ph.D., Manuel Arreola Ph.D.
Department of Radiology, College of Medicine , University of Florida

UF Medical Physics
COLLEGE of MEDICINE

INTRODUCTION

Iterative Reconstruction (IR) takes advantage of recent computer advances to employ a more computationally expensive reconstruction method resulting in reduced noise. IR algorithms vary in complexity of the modelling of the physical system. This study compares Canon's statistical hybrid IR algorithm, AIDR 3D, and their new full model-based IR algorithm FIRST.

AIM

To quantify and compare noise and noise properties between a statistical-based hybrid IR algorithm, AIDR 3D, and a new model-based IR algorithm, FIRST, for dose levels and processing kernels appropriate for three clinical exams: lung screening, abdomen, and brain imaging.

METHOD

The ACR phantom was scanned on a Canon Aquilion Genesis CT scanner with $CTDI_{Vol}$ of 2.8 mGy, 19.7 mGy, and 29.4 mGy (reported in the 32 cm phantom). These values are clinically appropriate for lung screening, abdomen, and head studies respectively (with the 29.4 mGy scan equivalent to ~70 mGy when reported with the 16 cm phantom). Ten scans were performed at each dose level. Each scan was reconstructed using six reconstruction methods: AIDR 3D with kernels FC18, FC56, and FC64 and FIRST with Body, Lung, and Brain settings. NPS curves were then generated for each reconstruction method and dose level for 18 curves in total using the following method:[1,2]

1. The central 10 slices were extracted from module 3 from each of the ten scans of the ACR phantom for a total of 100 images
2. Images were split into two groups of 50 and a pixel-by-pixel subtraction between the two sets was applied to get 50 purely stochastic images
3. Ten 32x32 pixel ROIs were placed in a radius of 6 cm around each image for a total of 500 ROIs
4. The FFT of each ROI was taken and the magnitude of the FFT was averaged over all ROIs and normalized by pixel size and the number of pixels in each ROI to create the 2D NPS (Equation 1)
5. The 1D NPS was created by rebinning each pixel of the 2D NPS according to its radial frequency

Area under the curve was recorded for each NPS curve to quantify total noise. The frequency at which the NPS curve peaked was also recorded to quantify noise texture in the image. Both quantifications of noise properties were compared between AIDR and FIRST.

$$NPS(f) = \frac{v_x v_y}{N_x N_y} \langle |DFT\{I - \bar{I}\}|^2 \rangle \qquad Equation\ 1$$

RESULTS

Though NPS curves were generated for each reconstruction method at each dose level (18 total curves), only a subset that shows the NPS of each reconstruction method at the appropriate $CTDI_{vol}$ for a typical exam that would use that filter is presented below in Fig 1-3.

- FIRST significantly (p<0.05) reduced image noise (AUC) in every kernel / dose combination except Body at 2.8 mGy and Lung at 29.4 mGy which are not clinically relevant dose / kernel combinations.
- FIRST significantly reduced the frequency at which the NPS curve peaked, indicating a different noise texture in the image (shown in Fig 4 and 5)

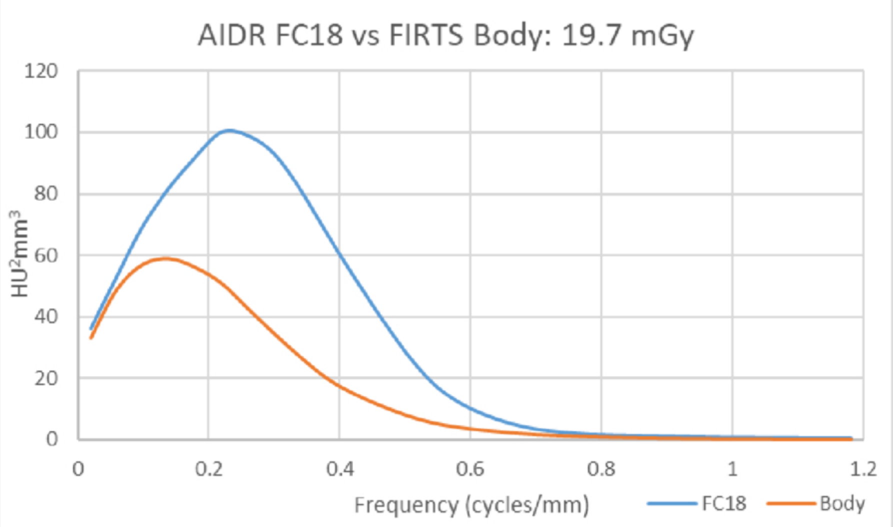

Fig 2. NPS curve generated from images reconstructed using AIDR 3D with kernel FC18 and FIRST with Body setting with a $CTDI_{vol}$ of 19.7 mGy

Table 1. Quantitative properties of the NPS Curves including AUC and frequency at which the curves peaked. The data shown is only for the clinically relevant $CTDI_{vol}$ of each kernel.

	mGy	AUC	f_{max}
FC 18	19.7	37.91	0.22
Body		19.27	0.14
FC 56	2.8	599.04	0.42
Lung		463.32	0.26
FC 64	29.4	22.48	0.22
Brain		19.19	0.14

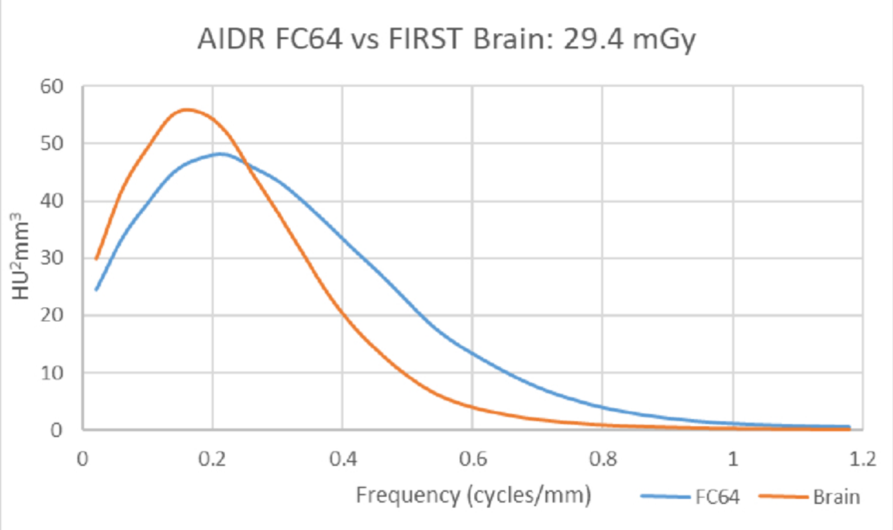

Fig 1. NPS curve generated from images reconstructed using AIDR 3D with kernel FC64 and FIRST with Brain setting with a $CTDI_{vol}$ of 29.4 mGy

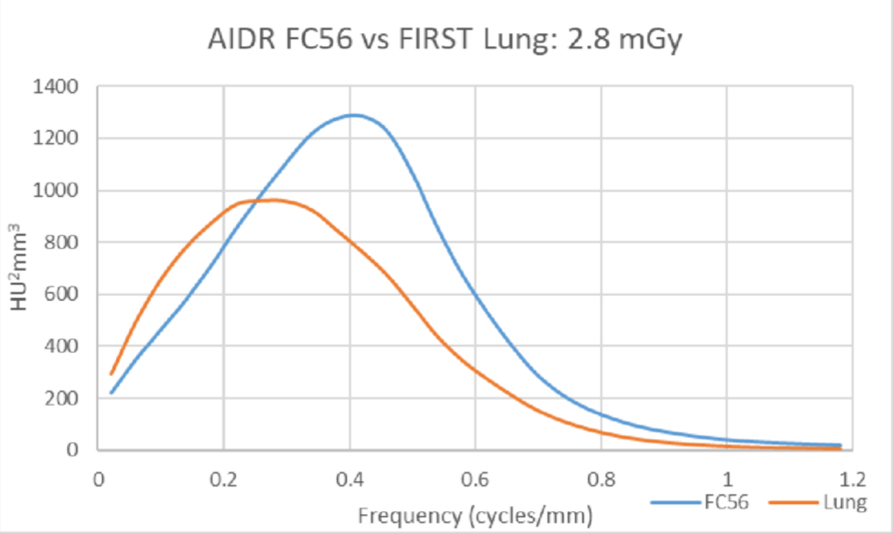

Fig 3. NPS curve generated from images reconstructed using AIDR 3D with kernel FC56 and FIRST with Lung setting with a $CTDI_{vol}$ of 2.8 mGy

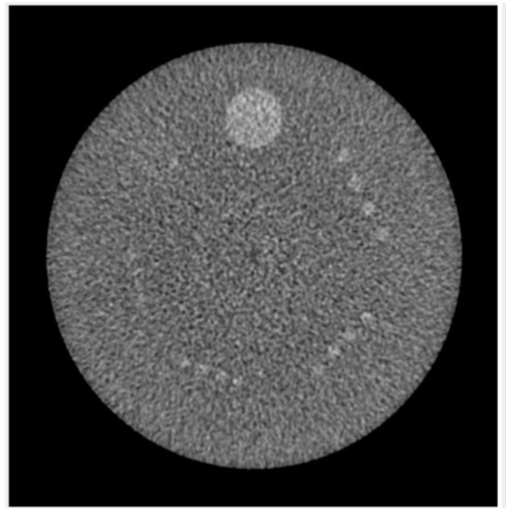

Fig 4. Average of ten slices reconstructed using ADR 3D and the FC 18 kernel

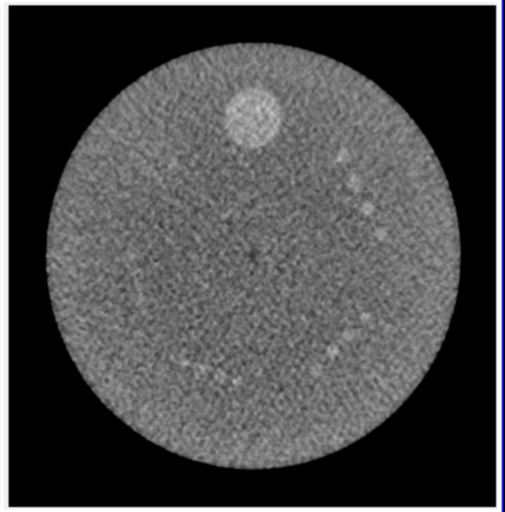

Fig 5. Average of ten slices reconstructed using FIRST Body setting

CONCLUSIONS

- Canon Medical Systems' new model-based iterative reconstruction algorithm significantly reduces noise when compared to the older, statistical- based AIDR 3D
- The noise texture of images reconstructed with FIRST and AIDR 3D are significantly different with FIRST showing a lower frequency of max noise

REFERENCES

1. Dolly S, Chen HC, Anastasio M, Mutic S, Li H. Practical considerations for noise power spectra estimation for clinical CT scanners. *J Appl Clin Med Phys.* 2016;17(3):392-407.
2. Friedman SN, Fung GS, Siewerdsen JH, Tsui BM. A simple approach to measure computed tomography (CT) modulation transfer function (MTF) and noise-power spectrum (NPS) using the American College of Radiology (ACR) accreditation phantom. *Med Phys.* 2013;40(5):051907.

DISCLOSURES

Research Funded by Canon Medical Systems USA

CONTACT INFORMATION

schaefferc14@ufl.edu