# Influence of tube current modulation on noise statistics of reconstructed images in low-dose lung cancer CT screening

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August 30, 2017
AAPM Annual Meeting 2017

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Motivation

- Tube current modulation (TCM) is optimized for dose and noise reduction [1]

- Noise magnitude alone is not a predictor of task performance (e.g. [2])


Standard TCM Curves
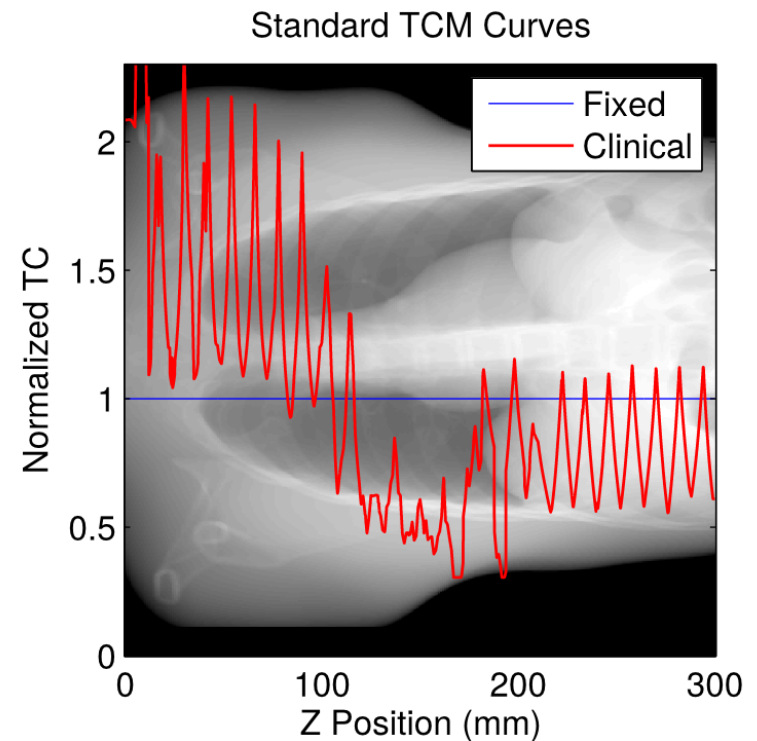
Motivation

- Previous work [3,4]

    - TCM impact on model observer performance

    - SKE/BKE

    - Found TCM has impact on detection of difficult, low-contrast lesions

- What about other tasks?

    - Does TCM improve/hinder performance?

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Methods

- The task

  - Estimate value of a voxel using 1,000 surrounding voxels

  - Clinically, might translate to estimating density of a tumor "core"
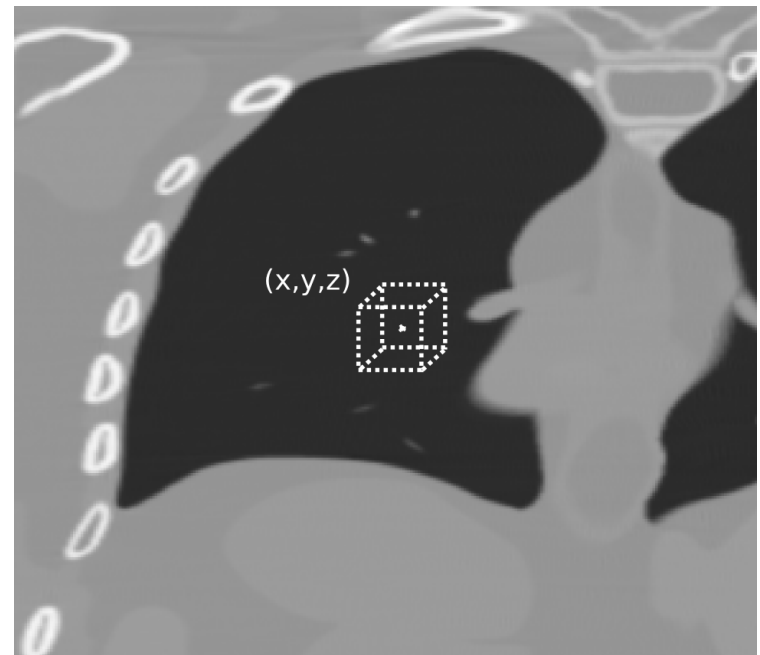
Methods

- Simulations – XCAT Phantom [5]

  - Noise realizations

    - Poisson statistics

    - Realistic scanner bowtie

    - Realistic scanner TCM

  - 1,000 noise realizations

    - 500 Fixed TC

    - 500 TCM

    - Equivalent fluence cent. detector
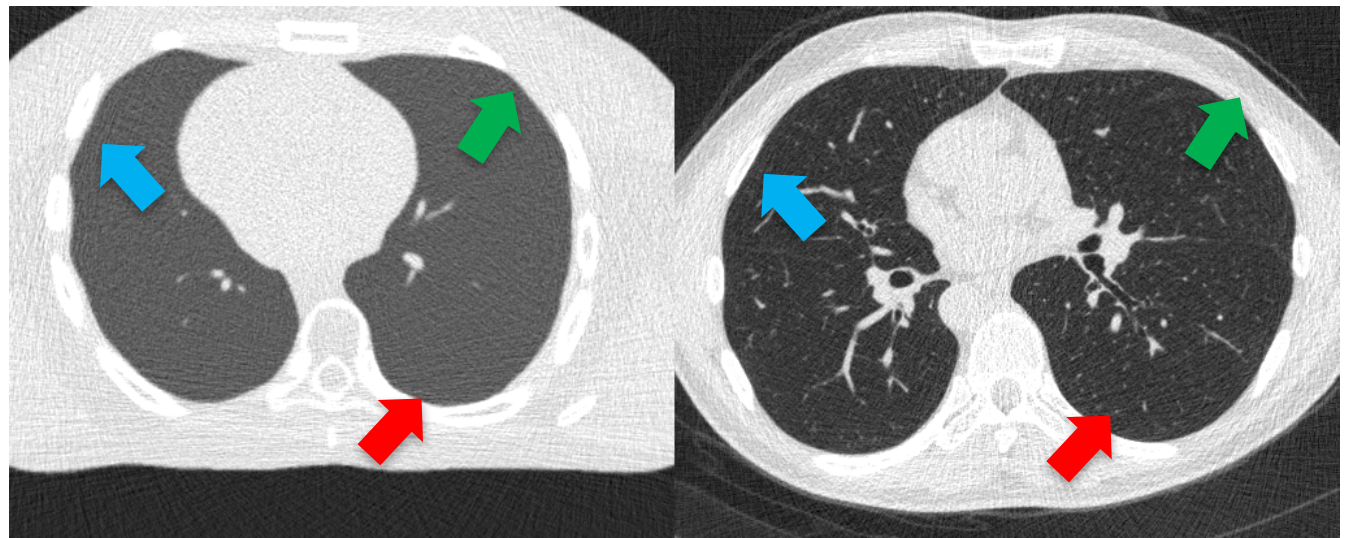

Standard TCM Curves
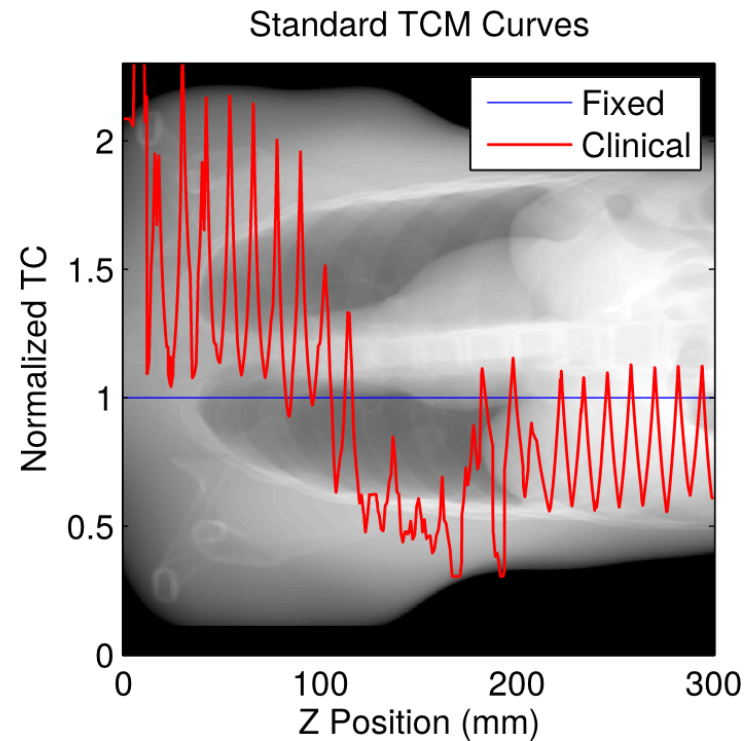
Methods

- Simulations – XCAT Phantom [5]

  - Noise realizations
    - Poisson statistics
    - Realistic scanner bowtie
    - Realistic scanner TCM
  - 1,000 noise realizations
    - 500 Fixed TC
    - 500 TCM
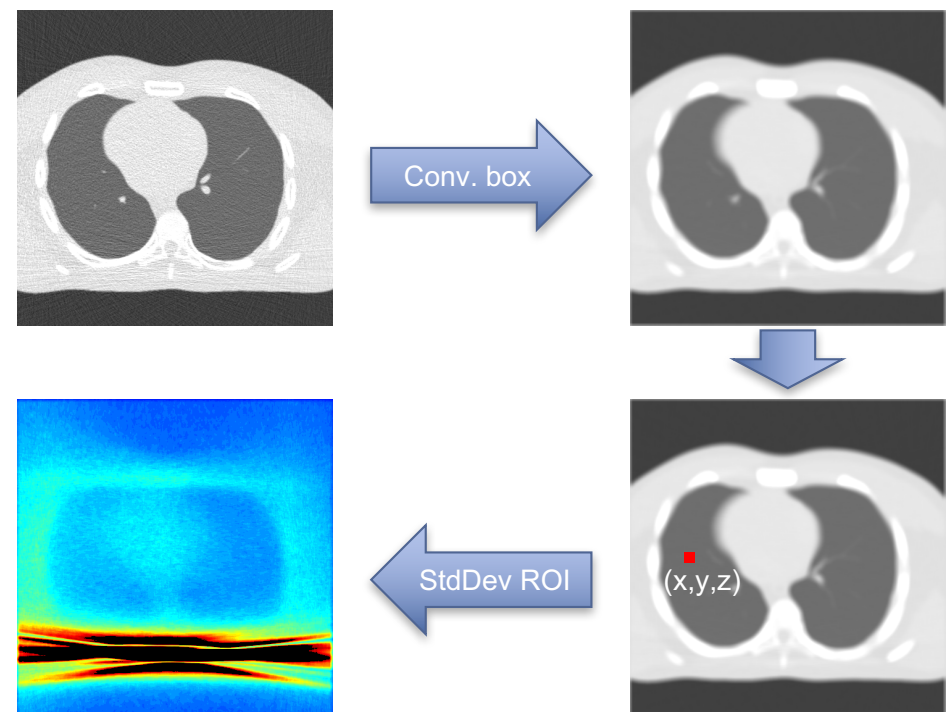   - Equivalent fluence cent. detector

Methods

- Reconstructions
  - FreeCT_wFBP [6]
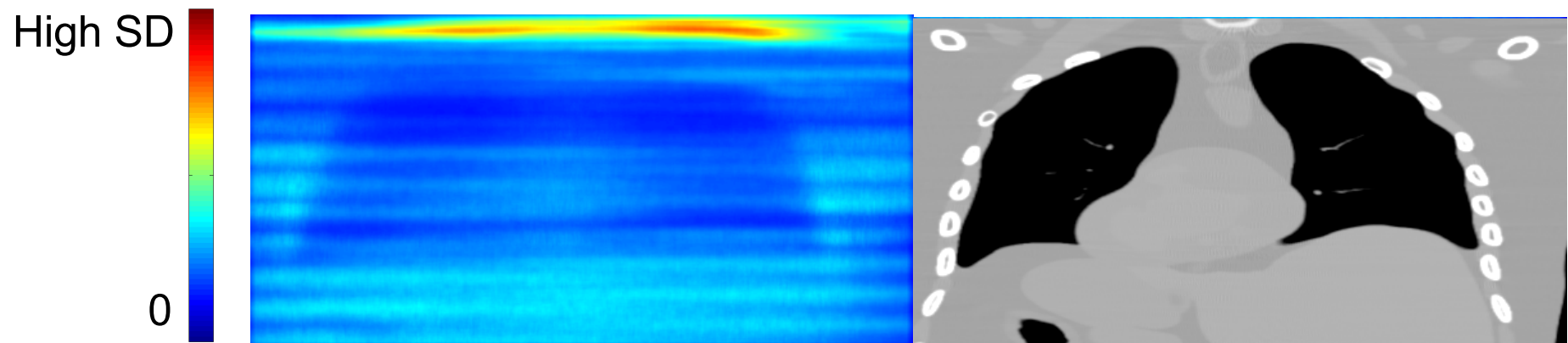   - Clinically-similar weighted filtered backprojection
    - http://cvib.ucla.edu/freect

Methods

- ## Analysis

  - Convolve 10x10x10 window

  - Variance maps of phantom

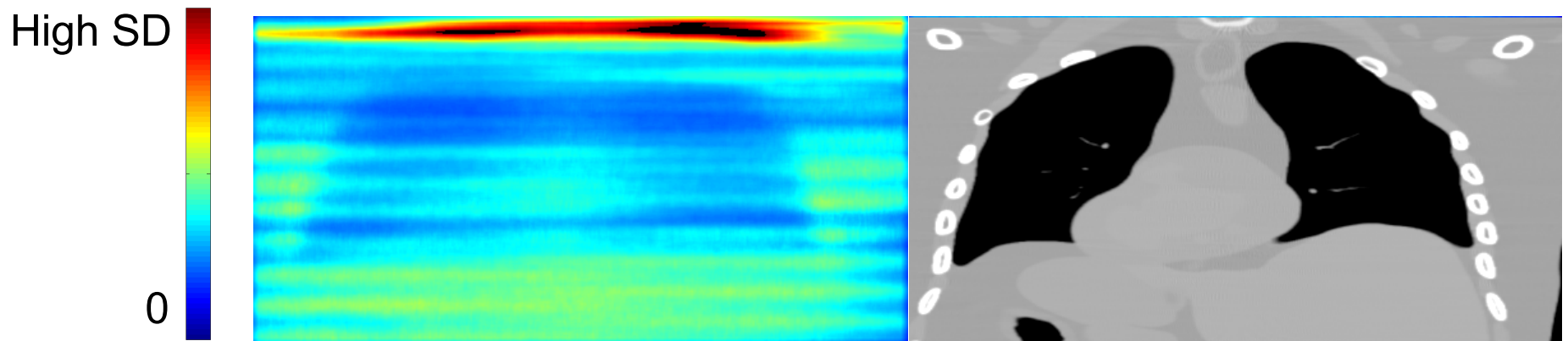 - Figure of merit: standard deviation of estimated voxel value, σ

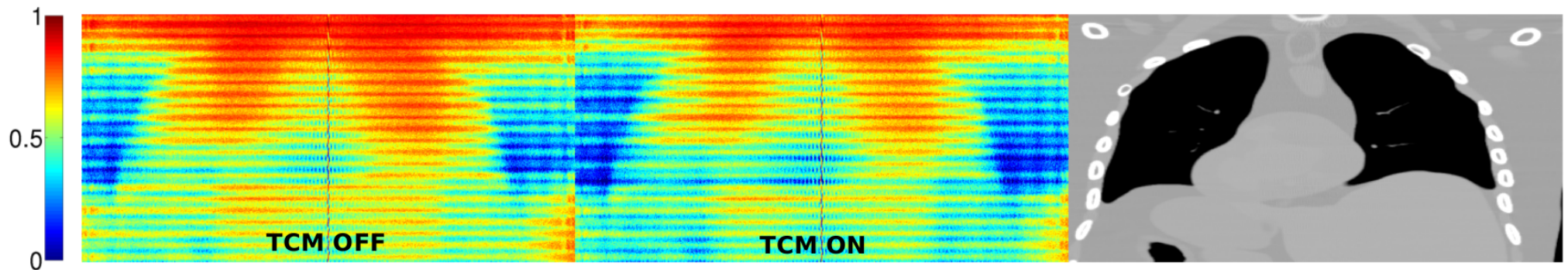# Some intuition…

- **Good** task performance:

Some intuition…

- **Poor** task performance:
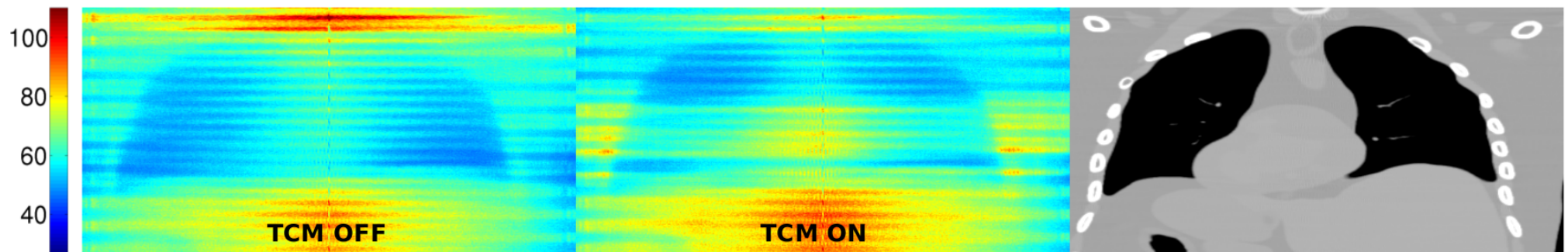
Results

- First, correlations

- TCM does have impact on fundamental noise characteristics

Results

- Variance maps (no task)

TCM OFF   TCM ON

Results

- Variance maps - **ROI estimation task**

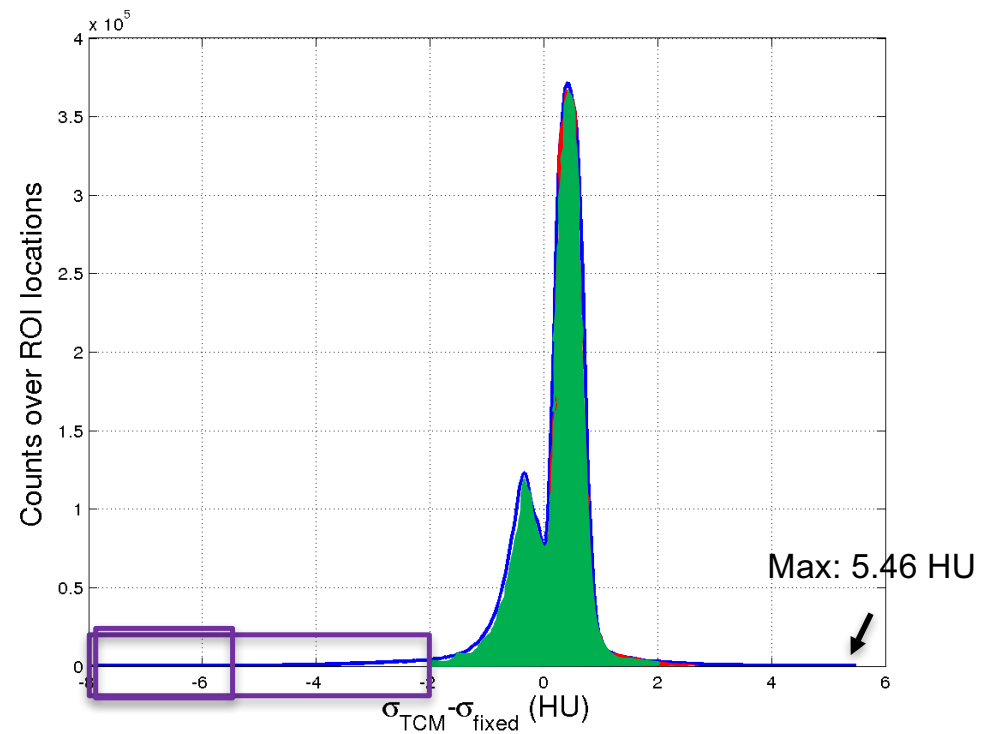TCM OFF   TCM ON

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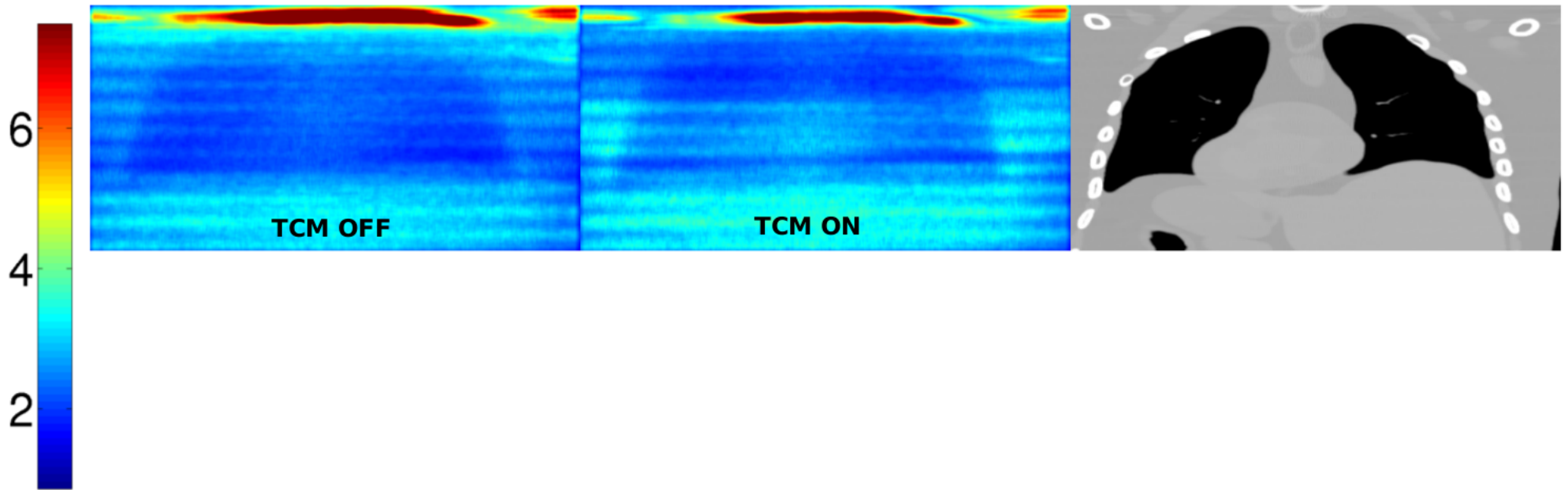
Results

- Voxel by voxel comparison

  - TCM less-favorable in 70.8% of locations

  - 97.51% of all differences <2HU

  - 1.72% of locations where unfavorable fixed TC differences > 2HU

  - Least favorable fixed TC locations were worse than TCM (0.06%)

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Conclusions

- From this data alone

  - Fixed is perhaps *slightly* preferential to TCM

- However

  - More voxels (1.72%) with 2-8 HU difference w/ fixed

    - Concentrated around posterior apices of lungs

  - Clinical significance of 0.06% of voxels

    - ~1cm nodule if all clumped together

Limitations

- Simulation

  - Monochromatic beam

  - Normalized fluence vs. normalized dose

  - Standard -size patient

- Task

  - More complex task could result in different conclusions

Thank you! Questions?

References:

[1] M. Gies, W. a. Kalender, H. Wolf, C. Suess, and M. T. Madsen, "Dose reduction in CT by anatomically adapted tube current modulation. I. Simulation studies," Med. Phys., vol. 26, no. 2235, pp. 2248–2253, 1999.

[2] K. L. Boedeker, V. N. Cooper, and M. F. Mcnitt-Gray, "Application of the noise power spectrum in modern diagnostic MDCT: part I. Measurement of noise power spectra and noise equivalent quanta," Phys. Med. Biol. Phys. Med. Biol, vol. 52, no. 52, pp. 4027–4046, 2007.

[3] J. M. Hoffman, F. Noo, K. Mcmillan, S. Young, and M. McNitt-Gray, "Assessing nodule detection on lung cancer screening CT: the effects of tube current modulation and model observer selection on detectability maps," in Proc. SPIE Medical Imaging, 2016.

[4] J. M. Hoffman, F. Noo, S. Young, and M. F. Mcnitt-gray, "TH-AB-207A-9: Tailoring TCM Schemes to a Task: Evaluating the Impact of Customized TCM Profiles On Detection of Lung Nodules in Simulated CT Lung Cancer Screening Biomedical Physics and Radiology , David Geffen School of Medicine at UCLA , Los Angeles , C," in AAPM Annual Meeting, 2016.

[5] W. P. Segars, G. Sturgeon, S. Mendonca, J. Grimes, and B. M. W. Tsui, "4D XCAT phantom for multimodality imaging research.," Med. Phys., vol. 37, no. 9, pp. 4902–4915, 2010.

[6] J. Hoffman, S. Young, F. Noo, and M. McNitt-Gray, "Technical Note : FreeCT _ wFBP : A robust , efficient , open-source implementation of weighted filtered backprojection for helical , fan-beam CT," Med. Phys., vol. 43, no. 3, p. 10 pp., 2016.

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