# Tailoring TCM schemes to a task: Evaluating the impact of customized TCM profiles on detection of lung nodules in simulated CT lung cancer screening

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AAPM Annual Meeting 2016

# Disclosures

- John Hoffman:
  - Part-time intern, Toshiba Medical Research Institute, USA, Inc.
- Frederic Noo:
  - Insitutional research agreement, Siemens Healthcare
  - Receives research funding from Siemens Healthcare
- Michael McNitt-Gray:
  - Institutional research agreement, Siemens Healthcare
  - Past recipient, research grant support, Siemens Healthcare
  - Consultant, Toshiba America Medical Systems
  - Consultant, Samsung Electronics

# Outline



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# Motivation

- Tube current modulation (TCM) is optimized for **dose and noise reduction** [1]
- Noise magnitude alone does not fully predict task-performance [2]

[1] **[Gies et al., 1999]**

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# Aims

- How to **optimize TCM schemes for detectability** (task performance)?
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- Detectability in **fixed tube current** vs. **clinical TCM** scheme[3]
- Detection of low contrast (ground glass) nodules in simulated lung screening
  - 6mm, 25 HU contrast, 131 Z locations
- Realistic phantom (XCAT[4]), scanner geometry (Sensation 64), finite focal spot, bowtie, reconstruction algorithm (FreeCT wFBP)

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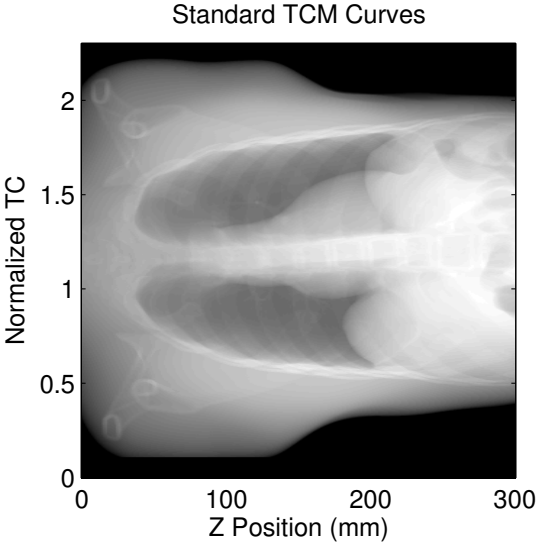
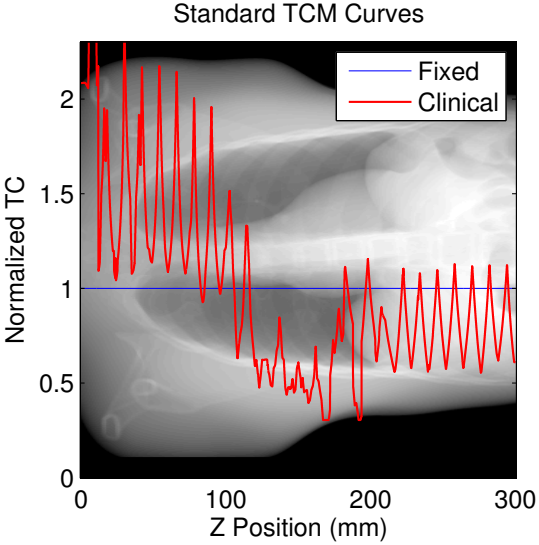
# Geometry


Standard TCM Curves
Normalized TC
2
1.5
1
0.5
0
0
100
200
300
Z Position (mm)

# Geometry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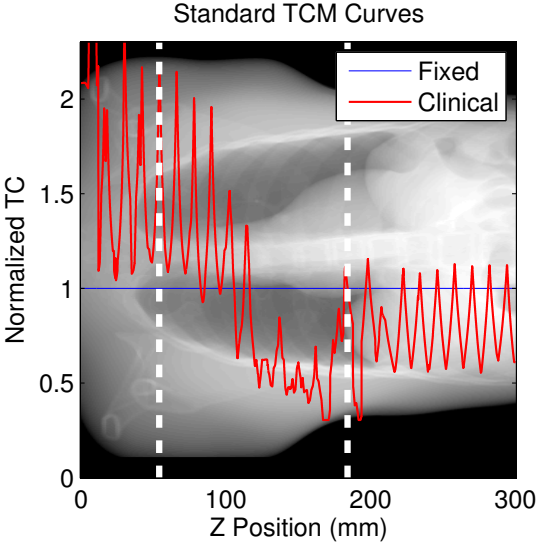
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# Lung Cancer Screening

- Low-dose CT (LDCT) lung cancer screening has been shown to reduce lung cancer mortality and has recently been approved for use in the US
- Screening scans are performed using low-dose protocols that include the use of tube current modulation (TCM)
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# Detectability Maps

- Plot of **AUC as a function of nodule location**
- AUC was calculated using **model observers** assuming Gaussian statistics
  - Hotelling observer
  - Channelized Hotelling observer with 40 Gabor channels
  - Multislice channelized Hotelling observer
- 2500 unique noise realizations per TCM scheme (SNR error: $\approxeq 3\%$)

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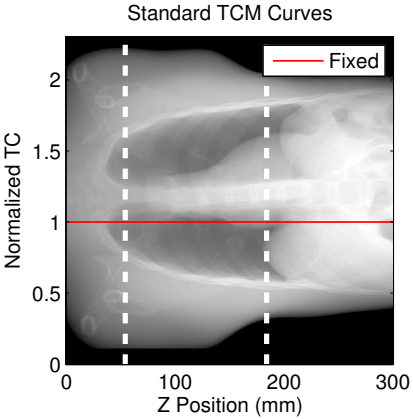
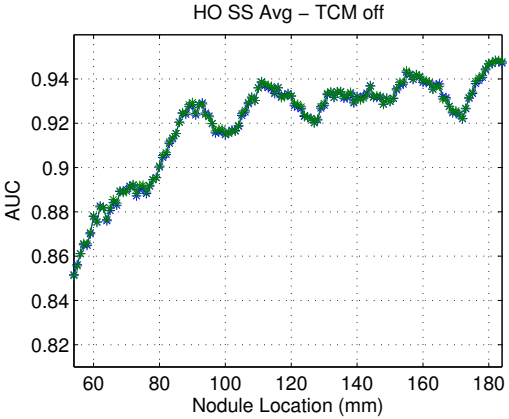
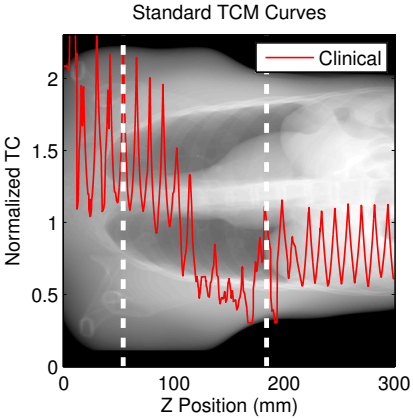
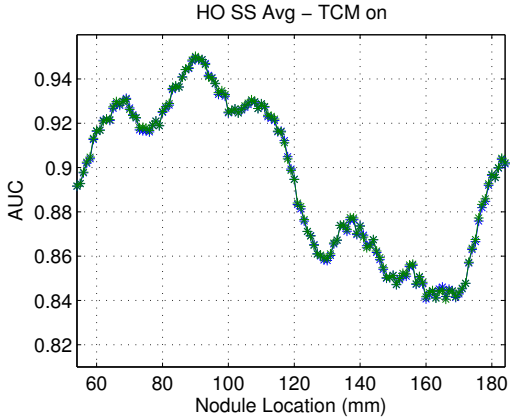



TCM **OFF**

# Results of Hoffman et al. 2016



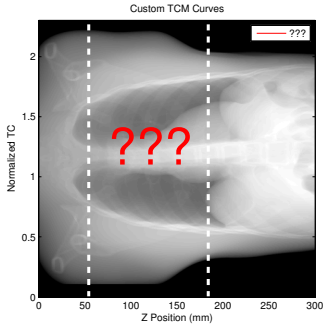

TCM **ON**

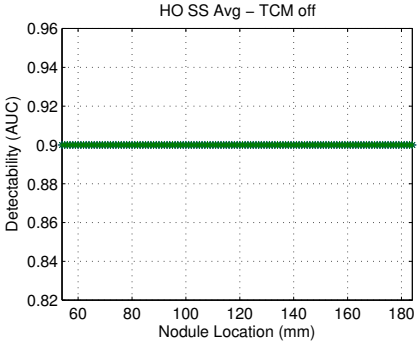
# Outline



# Purpose

- Building off of initial work, explore
  - **New TCM design schemes** with **uniform detectability**



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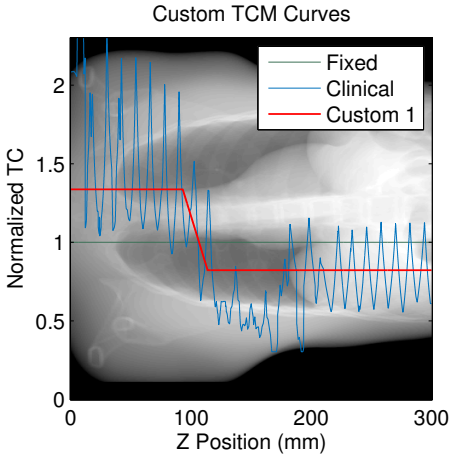
# Methods

- Same experiment as Hoffman et al. 2016 however
  - **Three custom TCM schemes**

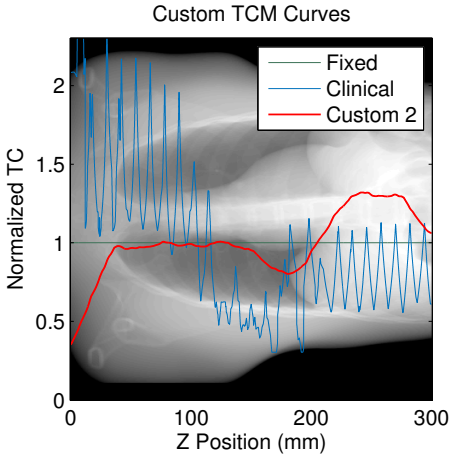
# Custom TCM Scheme 1

- **"Initial (Educated) Guess"** - General trends in clinical TCM, [Hoffman et al., 2016]



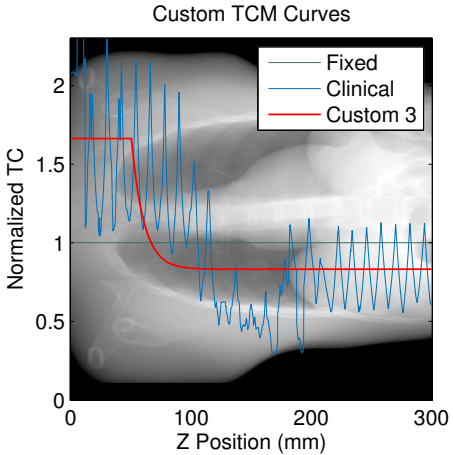
# Custom TCM Scheme 2

- **"The Water Equivalent Diameter"** - Based on WED



# Custom TCM Scheme 3

- **"The Exponential"** - Heuristic based on observations of custom TCM 1 and 2



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# Simulation Methods

- 2500 noise realization per scheme
- 6mm, 25 HU ground-glass nodules in simulated lung screening
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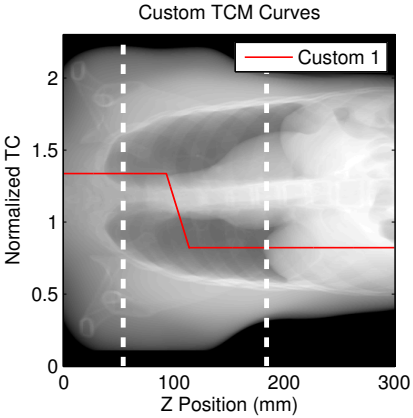
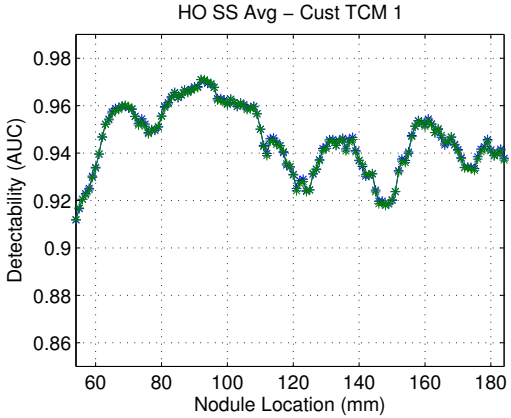
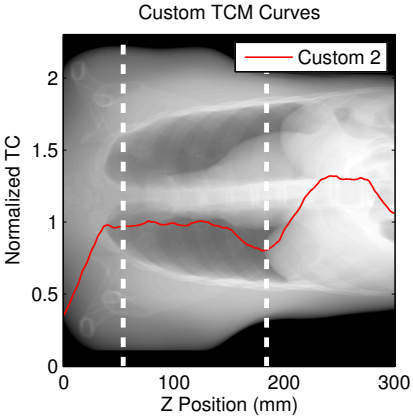
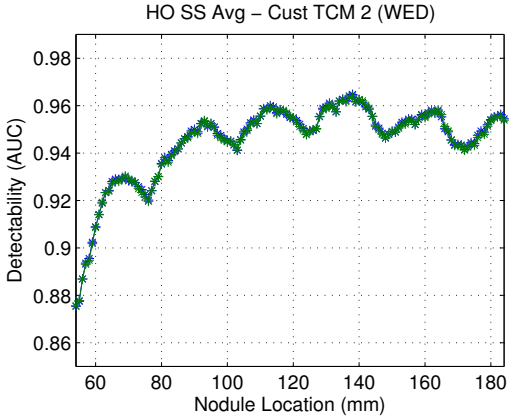



- "Leveled" in lower lung, but failed to lever upper lung

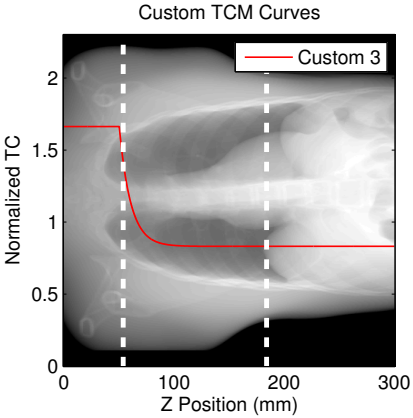
# (2) The W.E.D. - HO

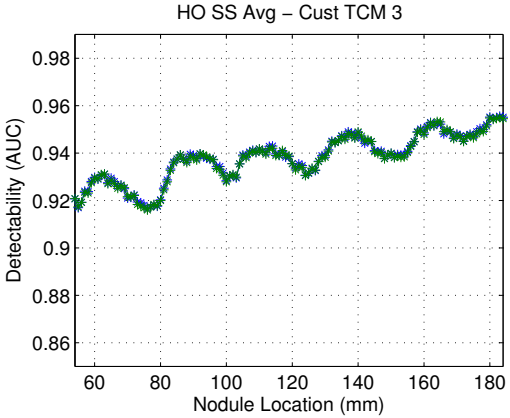



- Too similar to fixed TC case through the region of interest

# (3) The Exponential - HO




- While not level, is at least linear with smallest range

# Summary

- In custom modulated TC scans
  - **"The Exponential"** was closest to our goal of **uniform detectability**
    - ★ Smallest detectability range
    - ★ most linear performance
  - "The WED" showed that WED was not sufficient for the prediction of detectability
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# Limitations

- Theoretical, idealized study
- Phantom does not have arms
- MOs tend to "over-perform"
  - Requires very difficult task
  - Perhaps too difficult to be relevant human readers
  - Still probably relevant to CAD, quantitative imaging

# Future work

- Correlate detectability to physical metrics
  - WED (other attenuation-based measure?)
  - Eccentricity
  - Slice heterogeneity
- Generalized approach for prospective TCM optimization based on "planning" scan or topogram?
- Dose impacts of detectability-optimized TCM schemes
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# Finally...

Thank you for your interest and any questions!

# References I


Beutel, J., Kundel, H., and Van Metter, R. (2000). *Handbook of Medical Imaging: Physics and Psychophysics*. SPIE Press, 1 edition.

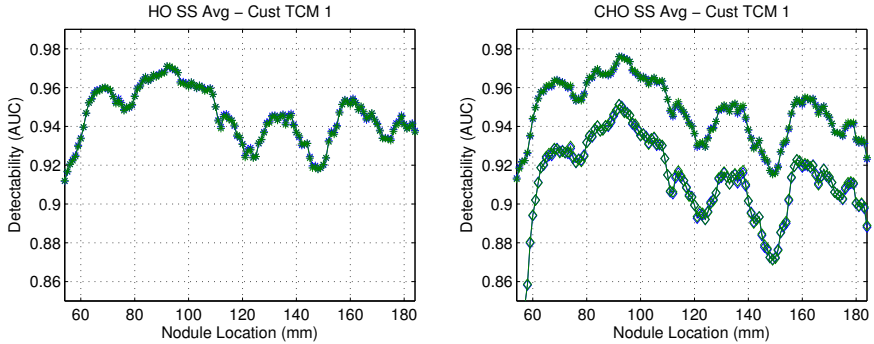
Boedeker, K. L., Cooper, V. N., and McNitt-Gray, M. F. (2007). Application of the noise power spectrum in modern diagnostic MDCT: part I. Measurement of noise power spectra and noise equivalent quanta. *Physics in medicine and biology*, 52(14):4047–61.

Gies, M., Kalender, W. a., Wolf, H., Suess, C., and Madsen, M. T. (1999). Dose reduction in CT by anatomically adapted tube current modulation. I. Simulation studies. *Medical physics*, 26(2235):2248–2253.

Hoffman, J. M., Noo, F., Mcmillan, K., Young, S., and McNitt-Gray, M. (2016). 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*.

Segars, W. P., Sturgeon, G., Mendonca, S., Grimes, J., and Tsui, B. M. W. (2010). 4D XCAT phantom for multimodality imaging research. *Medical physics*, 37(9):4902–4915.


# "Shot in the Dark" - CHO




- Trends are same between HO, CHO, and CHO with internal noise

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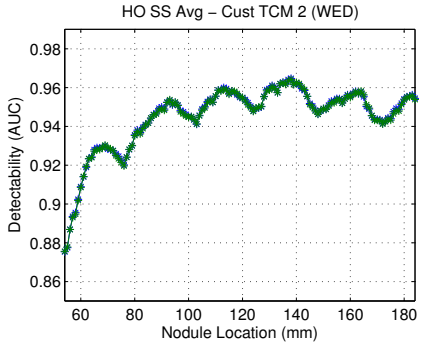


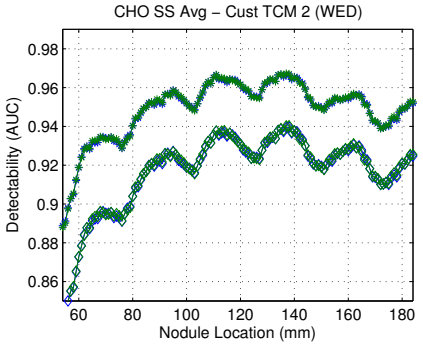


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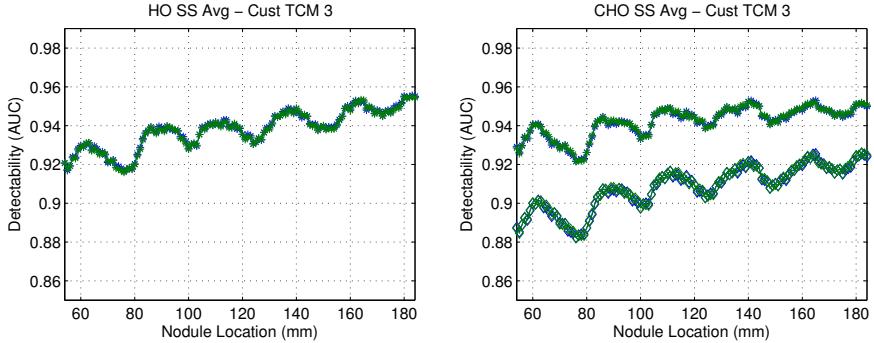


- Absence of high-frequency modulation very notable