MAYO CLINIC

CT Clinical Innovation Center

# Implementation of low dose CT strategies: How low is too low

Cynthia H. McCollough, PhD, DABR, FAAPM, FACR, FAIMBE
Director, CT Clinical Innovation Center
Professor of Medical Physics and Biomedical Engineering
Mayo Clinic, Rochester, MN

MAYO CLINIC

## DISCLOSURES

<u>Research Support:</u>

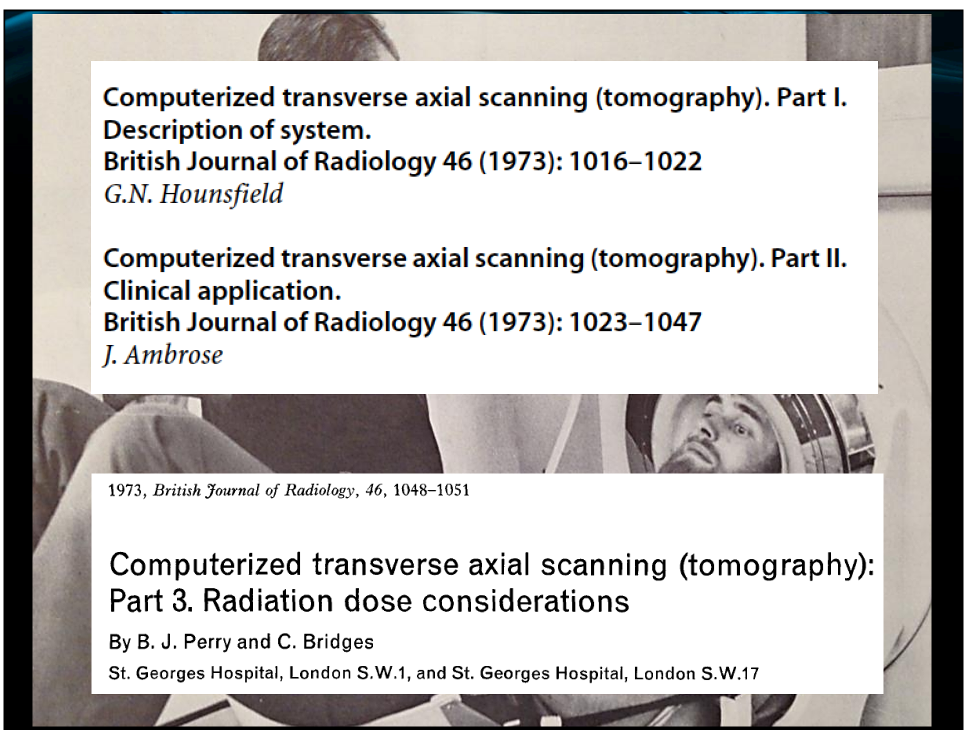
| NIH | Other |
|---|---|
| EB 017095 | Siemens Healthcare |
| EB 017185 | Mayo Center for Individualized Medicine Award |
| EB 016966 | |
| DK 100227 | |
| RR 018898 | |

<u>Off Label Usage</u>

None

MAYO CLINIC

*Radiation dose reduction over 4 decades of CT*



**Computerized transverse axial scanning (tomography). Part I. Description of system.**
**British Journal of Radiology 46 (1973): 1016–1022**
*G.N. Hounsfield*

**Computerized transverse axial scanning (tomography). Part II. Clinical application.**
**British Journal of Radiology 46 (1973): 1023–1047**
*J. Ambrose*

1973, *British Journal of Radiology*, *46*, 1048–1051

Computerized transverse axial scanning (tomography): Part 3. Radiation dose considerations

By B. J. Perry and C. Bridges

St. Georges Hospital, London S.W.1, and St. Georges Hospital, London S.W.17

MAYO CLINIC

[Reprinted from RADIOLOGY, Vol. 129, No. 2, Pages 457–463, November, 1978.]


# Patient Dosage in Computed Tomography[1]

**Edwin C. McCullough, Ph.D., and J. Thomas Payne, Ph.D.**

The maximum surface dosage in most clinical CT scans seems to range from 2–10 rads/study but much larger dose per study values seem possible with both rotate-translate and rotary geometry designs. The CT scanner type in itself does not significantly reduce doses. Secondary radiation dose values were measured for critical organs and indicate that dosage from secondary radiations may be reduced significantly by external shielding. Dose values in the vicinity of most CT scanners are typically 1–2 mrad/scan at 1 meter at the parameters of a typical clinical scan.

INDEX TERMS: Computed tomography, dosimetry • Computed tomography, instrumentation • Computed tomography, radiation dose

**Radiology 129:**457–463, November 1978

TABLE I, A: SINGLE-SCAN PATIENT DOSES IN CT SCANNING (ROTATE-TRANSLATE)

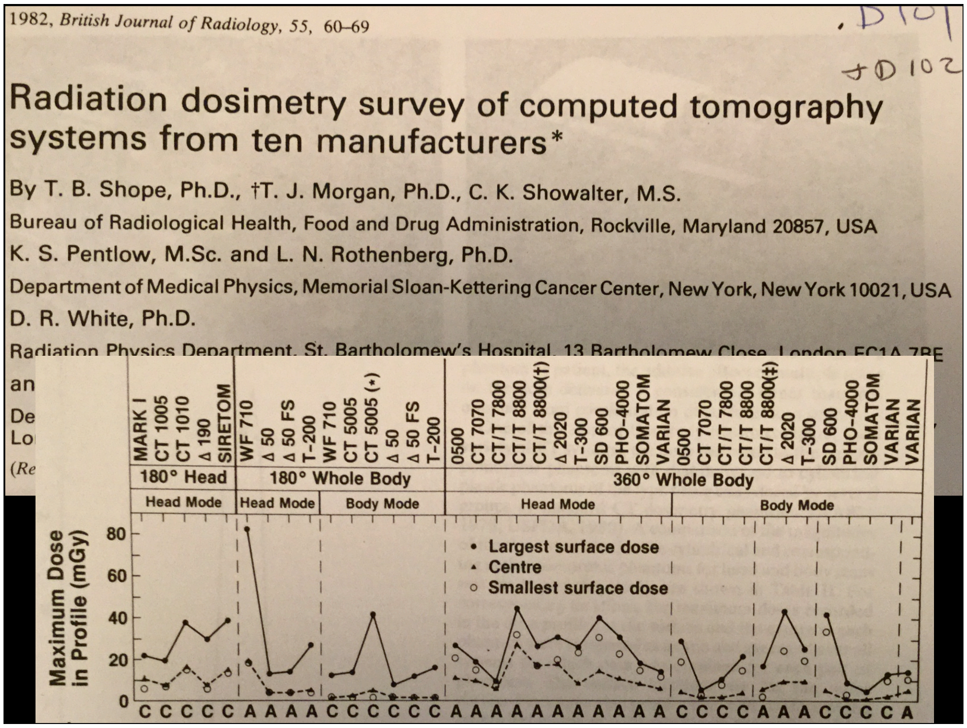
| CT Unit | Study | Technique: kVp | mA | Scan Time(s) (secs.) | Scan Angle | Max. Surface Dose, in Rads, Single Scan |
|---|---|---|---|---|---|---|
| EMI Mark I | head* | 120 | 33 | 240 | 180° | 2.7 |
| EMI CT-1005 | head | 120 | 33 | 60/240 | 180° | 3.6/12‡ |
| EMI CT-5005 | head | 140 | 28 | 26/73 | 180° | 2.4/9.6‡ |
| | body | 140 | 28 | 25/73 | 180° | 3.0/12‡ |
| Pfizer 0100 | head | [illegible] | [illegible] | [illegible] | 180° | 2.2 |
| | body | [illegible] | [illegible] | [illegible] | 180° | 3.4 |
| Pfizer 0200 | head | [illegible] | [illegible] | [illegible] | 180° | 2.0/4.0 |
| | body | [illegible] | [illegible] | 27 | 180° | 2.4 |
| Delta 25 | head | 130 | 30 | 130/185 | 192° | 5.8/11.6§ |
| Delta 50 | head | 120 | 30 | 120 | 180° | 1.8 |
| | body | 120** | 30 | 150 | 180° | 1.4 |
| Delta 50FS | head | 140 | 35 | 17/27 | 180° | 2.3/4.7 |
| | body | 140 | 35 | 20/36 | 180° | 2.4/4.8 |
| Siemens Siretom 2000 | head | 133 | 30 | 60/120/180 | 201° | 6.5/13/19.5 |

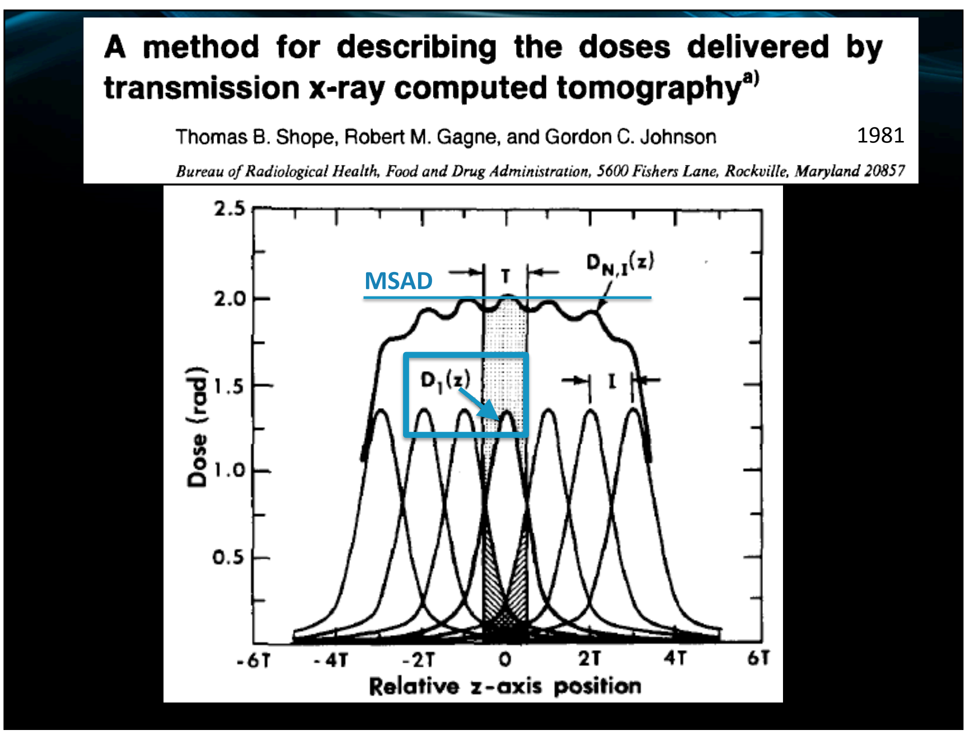
14 – 195 mGy

TABLE I, B: SINGLE-SCAN PATIENT DOSES IN CT SCANNING (ROTARY).

| CT Unit | Study | Technique: kVp | mAs* | Scan Time (secs) | Scan Angle | Max. Surface Dose in Rads Single Scan |
|---|---|---|---|---|---|---|
| Amer. Sci. and Eng. | head | 125† | 200-500(1000)‡ | 5(10) | 405° | 2.0–5.0(10.0) |
| | body | 125† | [illegible] | 5(10) | 405 | 2.2–6.0(12.0) |
| Artronix Torsoscanner | head | [illegible] | [illegible] | 6(6) | 360 | 2.6(5.2) |
| | body | [illegible] | [illegible] | 6(6) | 360 | 2.8(5.6) |
| Delta 2020-P | head | [illegible] | [illegible] | 2(16) | 392 | 5.6(56) |
| | body | 130§ | 40-200(1600) | 2(16) | 392 | 1.5–6.5(52) |
| GE CT/T-7800 | head | 120 | 100-300(1152) | 4.8(9.6) | 360 | 0.5–1.5(5.8) |
| | body | 120 | 100-300(1152) | 4.8(9.6) | 360 | 0.9–2.6(9.2) |
| GE CT/T-8800-P | head | 120 | 550(1152) | 4.8(9.6) | 360 | 2.8(5.8) |
| | body | 120 | 200-300(1152) | 4.8(9.6) | 360 | 1.7–2.6(9.2) |
| Siemens Somotom | head | 125 | 230(460) | 4(4) | 360 | 1.9(3.8) |
| | body | 125 | 230(460) | 4(4) | 360 | 1.6(3.6) |

5 – 560 mGy


1982, British Journal of Radiology, 55, 60–69
Radiation dosimetry survey of computed tomography systems from ten manufacturers*
By T. B. Shope, Ph.D., †T. J. Morgan, Ph.D., C. K. Showalter, M.S.
Bureau of Radiological Health, Food and Drug Administration, Rockville, Maryland 20857, USA
K. S. Pentlow, M.Sc. and L. N. Rothenberg, Ph.D.
Department of Medical Physics, Memorial Sloan-Kettering Cancer Center, New York, New York 10021, USA
D. R. White, Ph.D.
180° Head
180° Whole Body
360° Whole Body
Head Mode
Body Mode
Maximum Dose in Profile (mGy)
Largest surface dose
Centre
Smallest surface dose

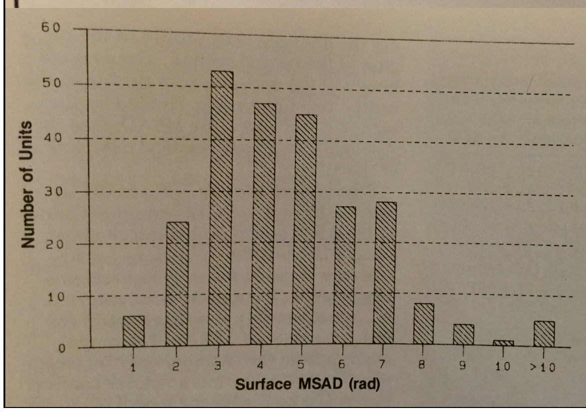

A method for describing the doses delivered by transmission x-ray computed tomography[a)]
Thomas B. Shope, Robert M. Gagne, and Gordon C. Johnson
1981
Bureau of Radiological Health, Food and Drug Administration, 5600 Fishers Lane, Rockville, Maryland 20857
MSAD
T
$D_{N,I}(z)$
$D_1(z)$
I
Dose (rad)
Relative z-axis position

Medical Physics

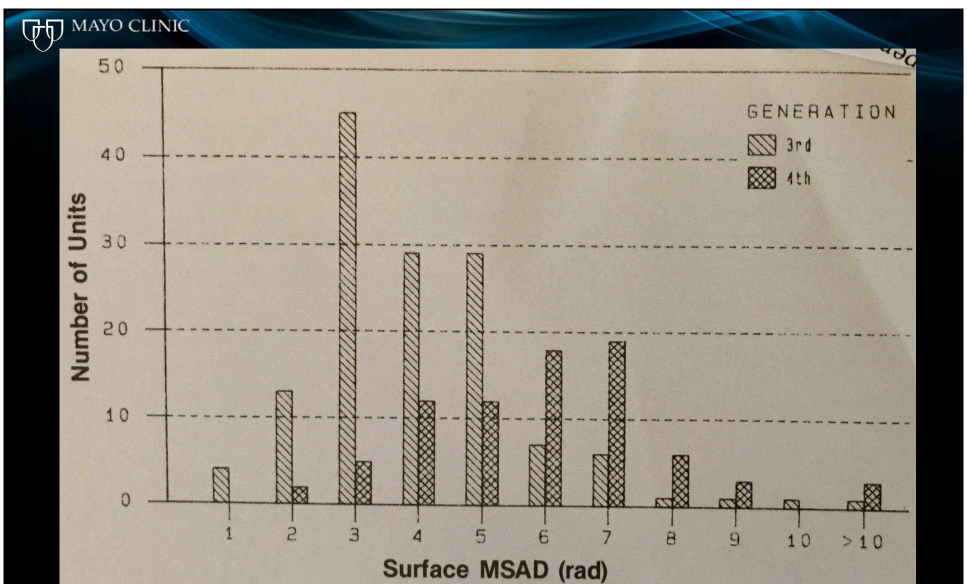
John L. McCrohan, MS • Jack F. Patterson, BS
• Robert M. Gagne, PhD • Howard A. Goldstein, MS

Radiology 1987; 163:263-268

**Average Radiation Doses in a Standard Head Examination for 250 CT Systems[1]**




≈ 50% of values between 22 and 68 mGy




Mean MSAD = 38 ± 16 mGy (3rd generation)
Mean MSAD = 58 ± 22 mGy (4th generation)

MAYO CLINIC

Burton J. Conway, MS • John L. McCrohan, MS • Robert G. Antonsen, BS • Fred G. Rueter, DSc
Robert J. Slayton, MS • Orhan H. Suleiman, PhD

Radiology 1992; 184:135–140

**Average Radiation Dose in Standard CT Examinations of the Head: Results of the 1990 NEXT Survey[1]**

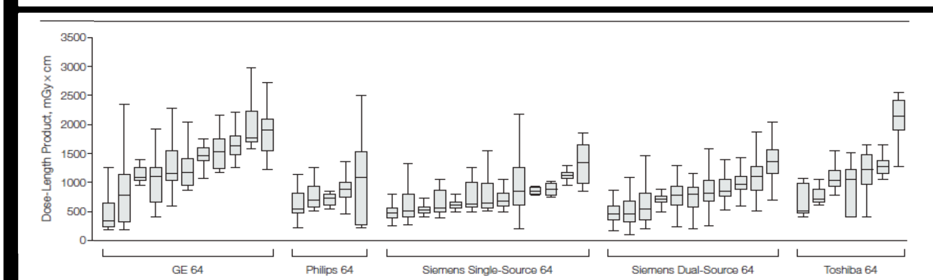
- 252 scanners, sampled nationwide
- Again used MSAD as dose descriptor
- Typical head exam was 34 – 55 mGy
  - Distribution of doses more narrow than in prior survey (22-68 mGy)
- Doses up to 140 mGy observed
- Variations in factor of 2 or more observed for identical units

MAYO CLINIC

# Variability across models and practices

**Table 2.** Patient and CT Scan Characteristics for 64-Slice Coronary CT Angiography[a]

| | No. (%) of Patients or Median (Interquartile Range) | | | | |
|---|---|---|---|---|---|
| | GE 64 (n = 384) | Philips 64 (n = 123) | Siemens 64 Single-Source (n = 380) | Siemens 64 Dual-Source (n = 521) | Toshiba 64 (n = 138) |
| Body mass index | 25.9 (23.2-29.4) | 27.5 (25.4-29.7) | 25.8 (23.4-28.4) | 26.3 (24.1-28.7) | 26.0 (24.3-29.4) |
| $CTDI_{vol}$, mGy | 77.3 (51.3-89.6) | 47.0 (42.0-52.9) | 39.6 (35.5-65.8) | 47.8 (35.8-60.8) | 88.0 (60.3-121.1) |



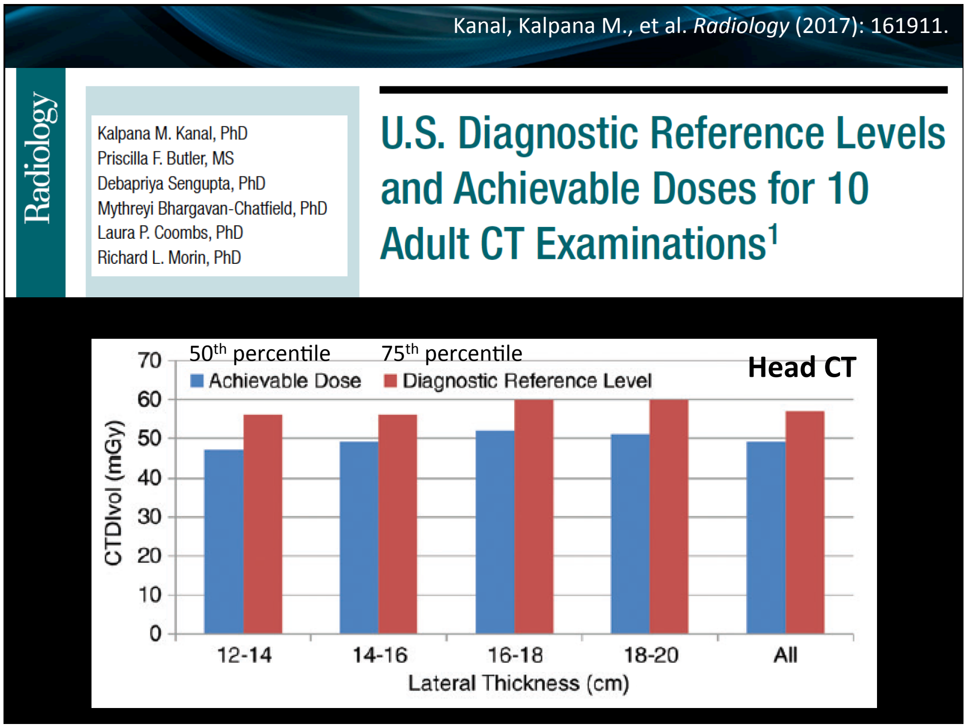

Hausleiter et al, *Estimated Radiation Dose Associated With Cardiac CT Angiography. JAMA 2009*

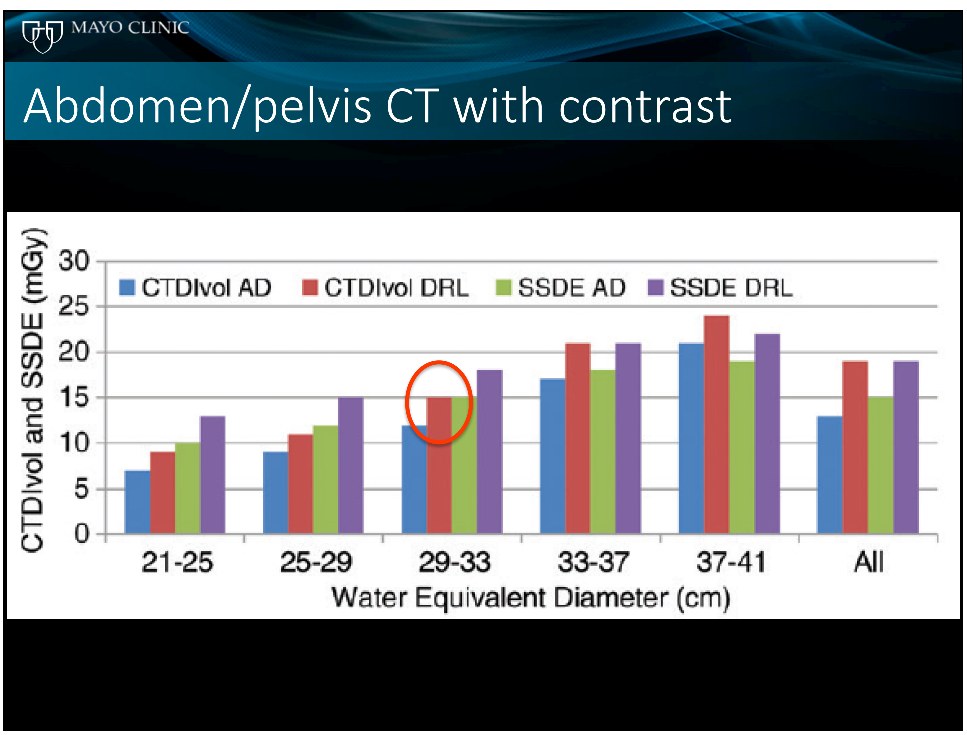
# ACR CT Accreditation Program Diagnostic Reference Levels (CTDIvol)

- Reference doses 2002
  - Adult Head 60 mGy
  - Adult Abdomen 35 mGy
  - Pediatric (5 yr old) Abdomen 25 mGy

# ACR CT Accreditation Program Diagnostic Reference Levels (CTDIvol)

- Reference doses 2002 2005
  - Adult Head 60 → 75 mGy
  - Adult Abdomen 35 → 25 mGy
  - Pediatric (5 yr old) Abdomen 25 → 20 mGy


Kanal, Kalpana M., et al. Radiology (2017): 161911.
Radiology
Kalpana M. Kanal, PhD
Priscilla F. Butler, MS
Debapriya Sengupta, PhD
Mythreyi Bhargavan-Chatfield, PhD
Laura P. Coombs, PhD
Richard L. Morin, PhD
U.S. Diagnostic Reference Levels and Achievable Doses for 10 Adult CT Examinations1
50th percentile
75th percentile
Achievable Dose
Diagnostic Reference Level
Head CT
CTDIvol (mGy)
0
10
20
30
40
50
60
70
12-14
14-16
16-18
18-20
All
Lateral Thickness (cm)

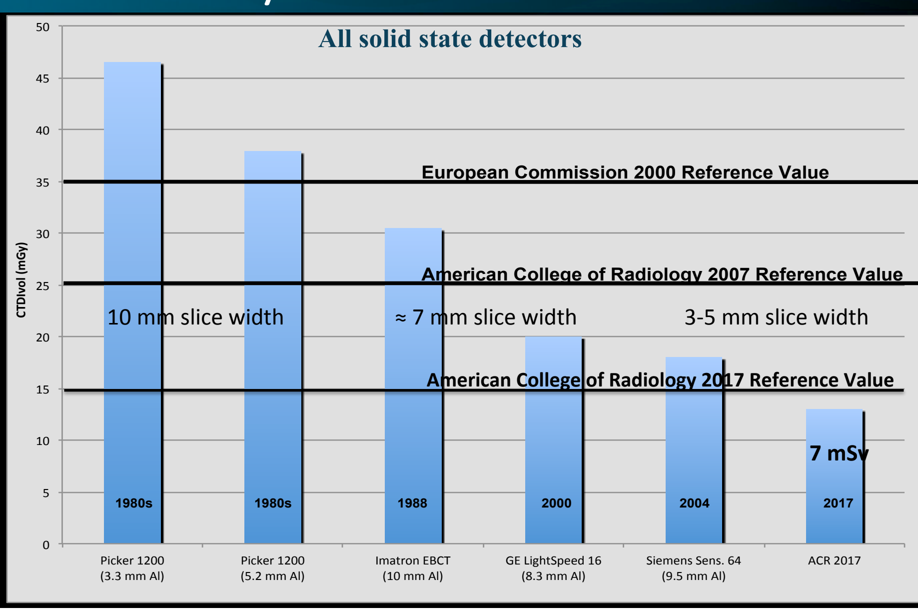

MAYO CLINIC
Abdomen/pelvis CT with contrast
CTDIvol AD
CTDIvol DRL
SSDE AD
SSDE DRL
CTDIvol and SSDE (mGy)
0
5
10
15
20
25
30
21-25
25-29
29-33
33-37
37-41
All
Water Equivalent Diameter (cm)

# ACR CT Accreditation Program Diagnostic Reference Levels (CTDIvol)

| Reference doses | 2002 | 2005 | 2017 |
|---|---|---|---|
| – Adult Head | 60 → | 75 mGy | → ≈ *60 mGy* |
| – Adult Abdomen | 35 → | 25 mGy | → ≈ *15 mGy* |
| – Pediatric (5 yr old) Abdomen | 25 → | 20 mGy | |

MAYO CLINIC

# Routine Body CT Doses over 3.7 Decades



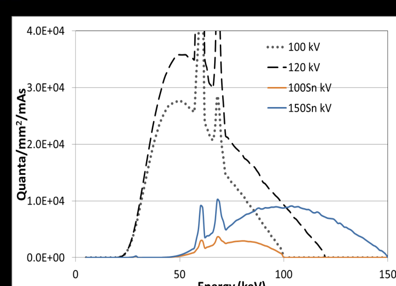
MAYO CLINIC

# What technology has reduced dose?

MAYO CLINIC

## Beam filtration

- Added beam filtration, such as the addition of a tin filter, may improve dose efficiency.*
  - More powerful x-ray tubes allow increased beam filtration, which reduces dose
  - Low-energy photons that do not contribute to image formation are removed by the tin filter
  - Examples: 100kV Sn and 150 kV Sn modes on Siemens Flash and Force scanners

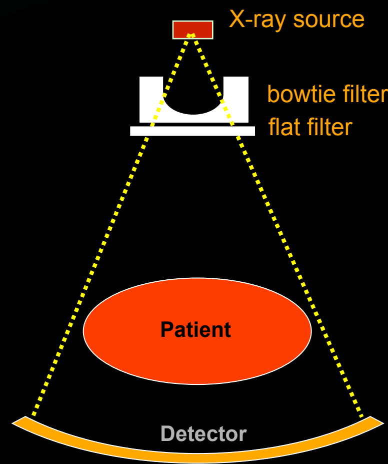



* Gordic et al. Invest. Rad. 2014

MAYO CLINIC

## Beam shaping

- Beam shaping
  - "Bow-tie" filters used to reduce unneeded surface dose
  - More powerful tubes allow more aggressive filters
  - Research into "adaptive" beam shaping is ongoing



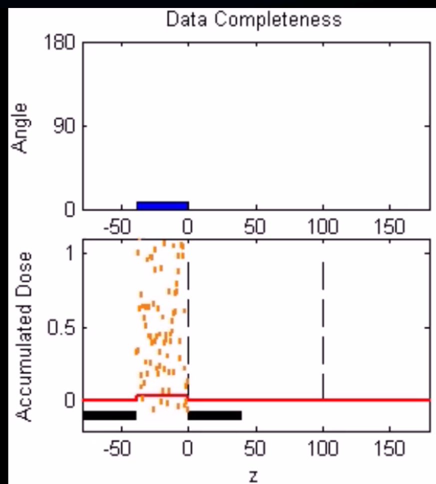

MAYO CLINIC

## Collimation

- Collimation
  - Early scanners had post-patient collimation to define slice width, reduce scatter, and improve spatial resolution
    - Current scanners rarely use post-patient collimation (very high resolution modes are an exception)
  - Multi-slice CT
    - 4 slice MSCT scanners use of narrow z collimations (e.g. 4 x 1 mm) required a larger penumbral region and "wasted" more dose
    - Adaptive z collimation addresses spiral overranging

MAYO CLINIC

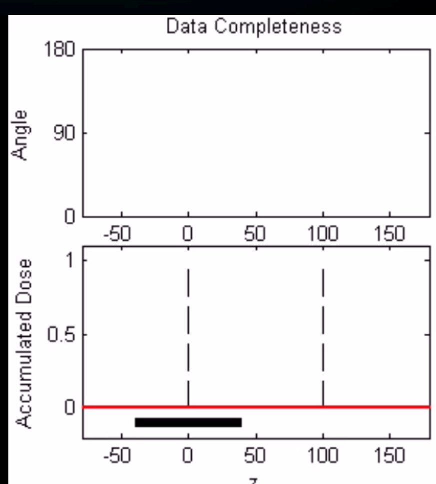
# Adaptive collimation: Off




23

MAYO CLINIC

# Adaptive collimation: On




24

MAYO CLINIC

# Right sizing

- Global size adaptation (e.g. child vs. adult)
  - Image Gently campaign has helped to make "right-sizing" the dose the standard of care (e.g. protocols for children)

Table I: mAs Reduction Factors for the Pediatric Body

| Abdomen/ Pelvis: | Abdomen/ Pelvis: | Abdomen/ Pelvis: | kVp | mA | Time (sec) | Pitch During Measured CTDIvol | Pitch During Clinical Exam | Adult SSDE |
|---|---|---|---|---|---|---|---|---|
| | | | 120 | 200 | 1 | 1.0 | 1.0 | 23 |

| AP Thickness (cm) | LAT Thickness (cm) | Effective Diameter (cm) | Mass (kg) | Age | *Limited* mAs Reduction Factor | *Moderate* mAs Reduction Factor | *Aggressive* mAs Reduction Factor | *Limited* mAs SSDE (mGy) | *Moderate* mAs SSDE (mGy) | *Aggres-sive* mAs SSDE (mGy) | *Limited* NB = Adult SSDE Estimated mAs | *Moderate* NB = 0.75 * Adult SSDE Estimated mAs | *Aggressive* NB = 0.5 * Adult SSDE Estimated mAs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 14 | 11.8 | 4 | newborn | 0.52 | 0.39 | 0.25 | 23 | 17 | 11 | 104 | 77 | 50 |
| 11 | 16 | 13.3 | 10 | 1 yr | 0.55 | 0.42 | 0.29 | 23 | 18 | 12 | 110 | 84 | 59 |
| 14 | 20 | 16.7 | 18 | 5 yr | 0.62 | 0.50 | 0.39 | 23 | 19 | 15 | 123 | 100 | 78 |
| 16 | 25 | 20.0 | 33 | 10 yr | 0.70 | 0.62 | 0.53 | 23 | 20 | 18 | 140 | 123 | 106 |
| 19 | 29 | 23.5 | 54 | 15 yr | 0.80 | 0.74 | 0.68 | 23 | 21 | 20 | 160 | 148 | 137 |
| 22 | 32 | 26.5 | 65 | 20 yr | 0.89 | 0.86 | 0.83 | 23 | 22 | 22 | 179 | 172 | 165 |
| 25 | 35 | 29.6 | 75 | md adult | 1.00 | 1.00 | 1.00 | 23 | 23 | 23 | 200 | 200 | 200 |
| 31 | 41 | 35.7 | 110 | lg adult | 1.21 | 1.28 | 1.35 | 23 | 25 | 27 | 242 | 256 | 270 |

Table II: mAs Reduction Factors for the Pediatric Head

| Head Baseline: | Head Baseline: | Head Baseline: | kVp | mA | Time (sec) | Pitch During Measured CTDIvol | Pitch During Clinical Exam |
|---|---|---|---|---|---|---|---|
| | | | 120 | 300 | 1.00 | 1.0 | 1.0 |

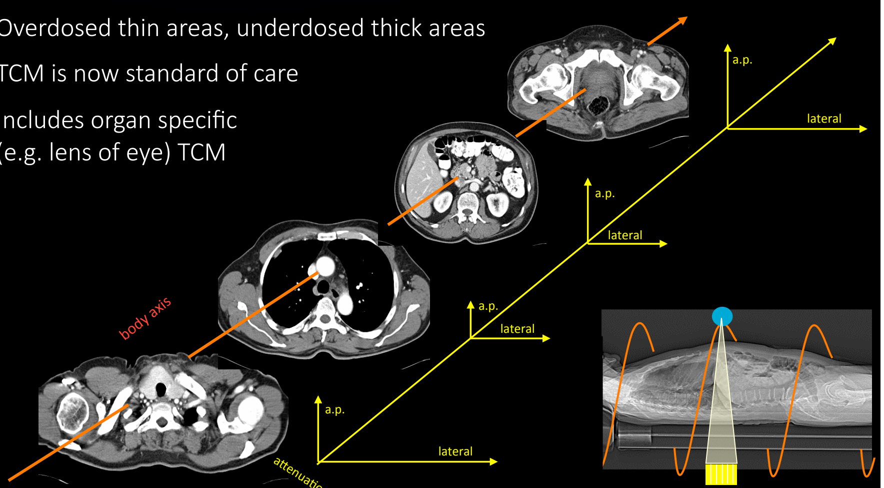
| AP Thickness (cm) | LAT Thickness (cm) | Effective Diameter (cm) | Mass (kg) | Age | *Limited* mAs Reduction Factor | *Moderate* mAs Reduction Factor | Limited Estimated mAs | Moderate Estimated mAs |
|---|---|---|---|---|---|---|---|---|
| 14 | 12 | 13 | 4 | newborn | 0.74 | 0.38 | 222 | 114 |
| 16 | 13 | 14.5 | 10 | 1 yr | 0.80 | 0.47 | 240 | 141 |
| 17 | 14 | 15.5 | 13 | 2 yr | 0.86 | 0.62 | 258 | 186 |
| 19 | 15 | 17 | 21 | 6 yr | 0.93 | 0.79 | 279 | 237 |
| 20 | 16 | 18 | 75 | md adult | 1 | 1 | 300 | 300 |

http://www.imagegently.org/Portals/6/IG%20CT%20PPT%20Tables%20Web%20Version%20(12-16-14).xls


MAYO CLINIC

# Tube current modulation (TCM)

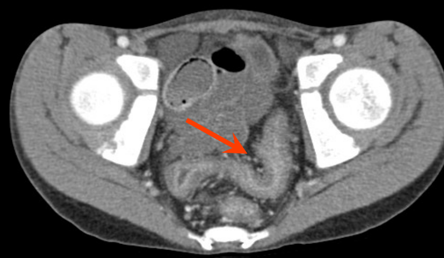
- Until early 2000s, one tube current used everywhere
- Overdosed thin areas, underdosed thick areas
- TCM is now standard of care
- Includes organ specific (e.g. lens of eye) TCM



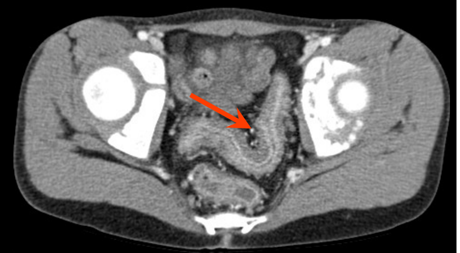
MAYO CLINIC

# Tube potential optimization

- Early scanners offered very few tube potentials
  - 120 kVp imaging was ubiquitous
  - now 70 to 150 kV options exist
- Automatically adjust to task and patient
  - More powerful tubes allow higher mA so can use lower kV



120 kV, $CTDI_{vol}$= 5.2 mGy

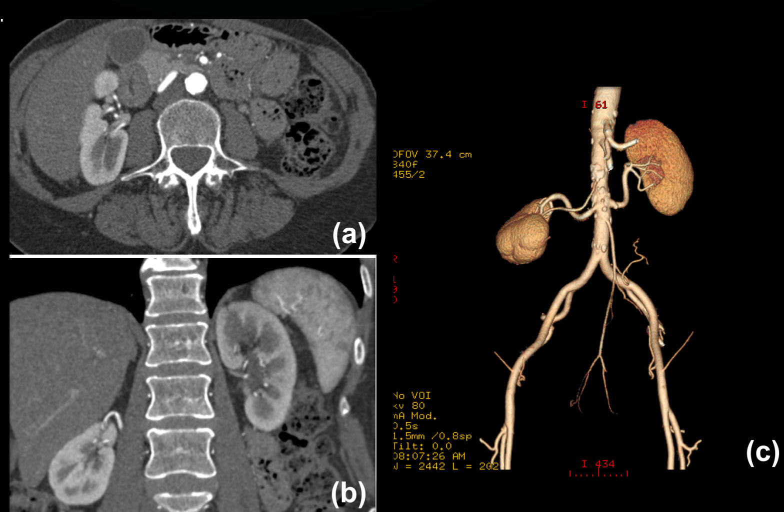


100 kV, $CTDI_{vol}$= 4.0 mGy

MAYO CLINIC

# Task specific protocols

22 mGy at 120 kV (not shown) vs. 11.5 mGy at 80 kV (shown)



MAYO CLINIC

# Detectors

- Originally used scintillators (e.g. NaI, CsI, BGO) and photomultiplier tubes
- High pressure gas (e.g. Xenon) detectors were used in early 3rd generation scanners, but were less dose efficient (about 60% vs. 98%)
- Now use more efficient scintillators and photodiodes
- Photon counting detector technology now under investigation

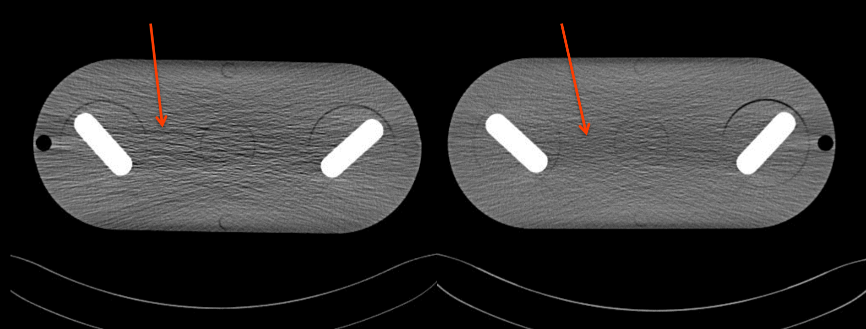
MAYO CLINIC

# Lower electronic noise detectors

80 kV (CTDIvol 10.5 mGy)

Conventional detector

Integrated detector



Phantom size: 36 x 16 cm

window center/width=150/650

MAYO CLINIC

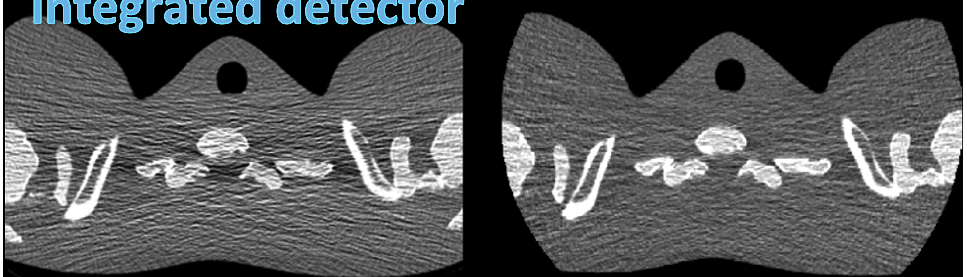
# Lower electronic noise detectors

- Less streaking artifacts and more homogeneous noise due to lack of electronic noise

$CTDI_{vol}$ = 2.27 mGy
120 kV, 30 mAs
[25, 120] keV
D30 kernel
1 mm slice

EID | PCD

**Integrated detector**



Zhicong Yu, et al., J. Med. Imag. **3(4), 043503 (2016)**

MAYO CLINIC

# Noise reduction algorithms

- Edge preserving image filtering
- Iterative reconstruction

MAYO CLINIC

# Noise Reduction: Image-space Denoising

- Linear or non-linear filters directly applied on the reconstructed images
- Independent of CT manufacturer
- Need to carefully control strength
- Performance requires careful evaluation for each diagnostic task

MAYO CLINIC

# Edge preserving noise reduction

**Original** | **3D Edge Preserving Noise Reduction**

61.5 HU → 36.3 HU

**- 41%**

**Courtesy of R. Raupach**

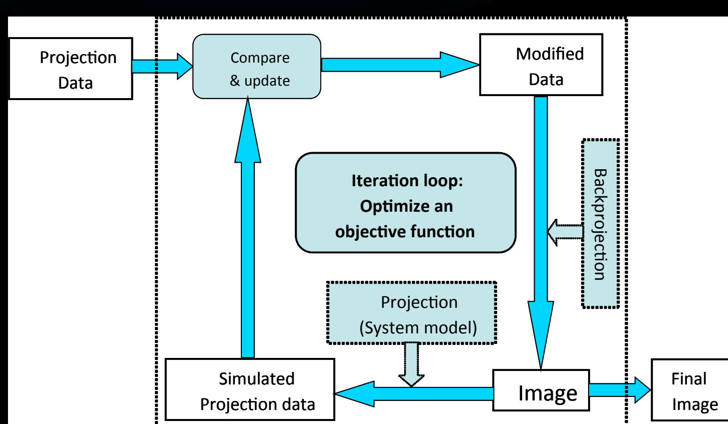
MAYO CLINIC

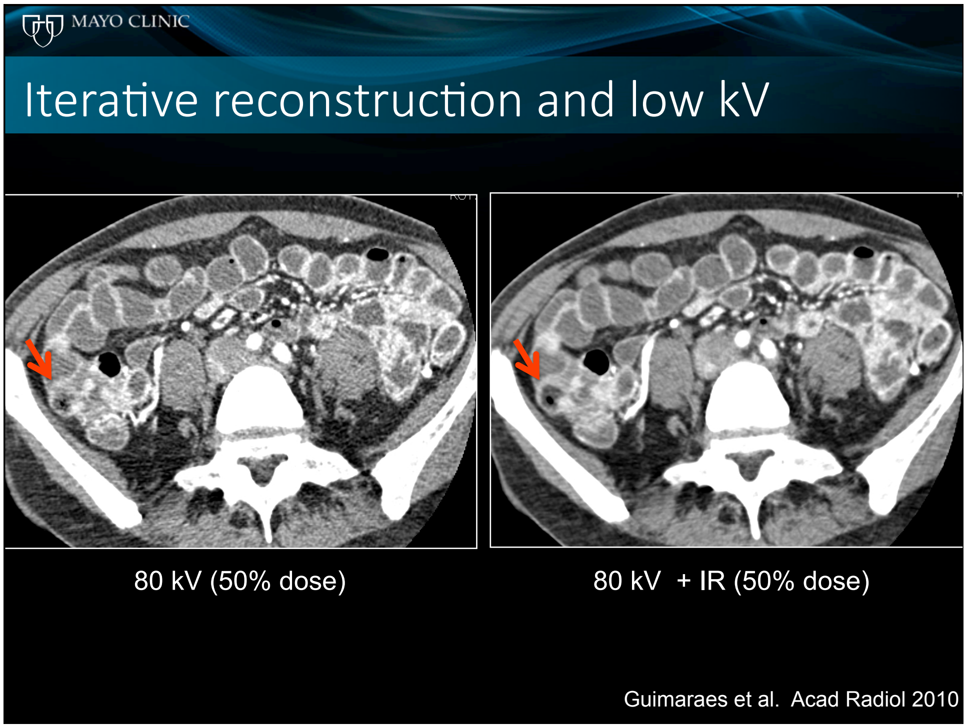
# Iterative Reconstruction

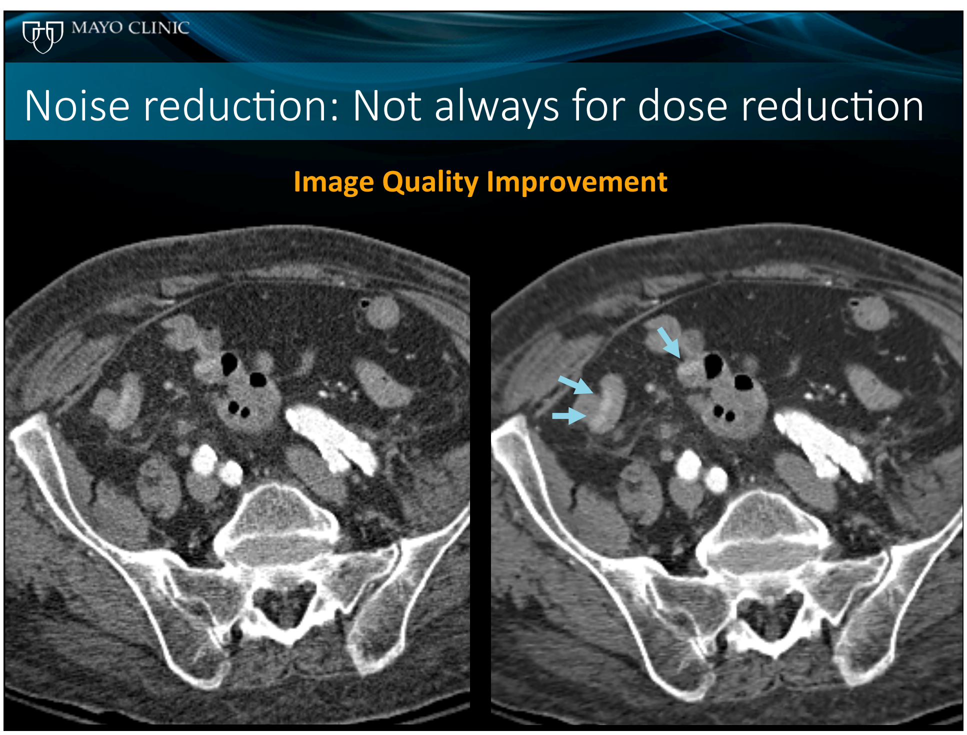
- Models noise statistics and possibly system geometry
- May improve spatial resolution and reduce image artifacts, typically reduces noise
- High computation load
- Can be used in a misleading fashion for marketing purposes

MAYO CLINIC

# Iterative reconstruction




MAYO CLINIC
Iterative reconstruction and low kV
80 kV (50% dose)
80 kV + IR (50% dose)
Guimaraes et al. Acad Radiol 2010


MAYO CLINIC
Noise reduction: Not always for dose reduction
Image Quality Improvement

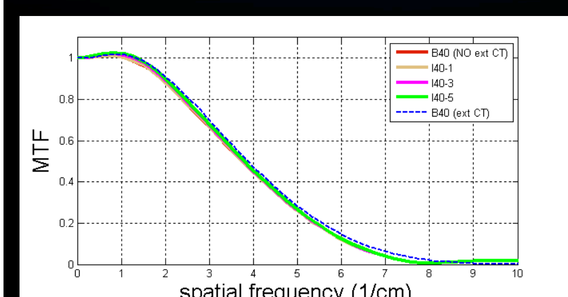
MAYO CLINIC

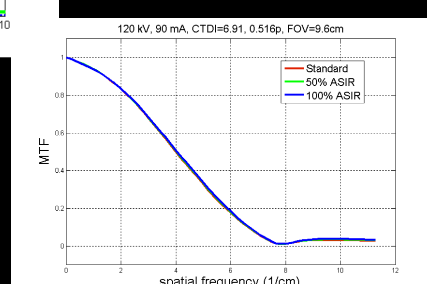
# Iterative reconstruction myths

- Iterative reconstruction reduces radiation dose
  - For most (but not all) systems, user has to manually decrease the dose
- Iterative reconstruction improves lesion detection
  - IR degrades edges of low contrast lesions

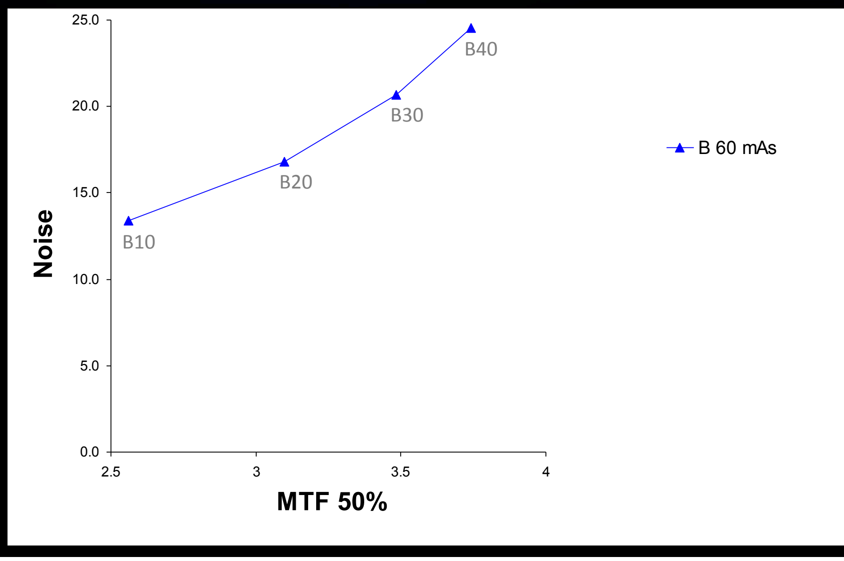
MAYO CLINIC

# High contrast spatial resolution

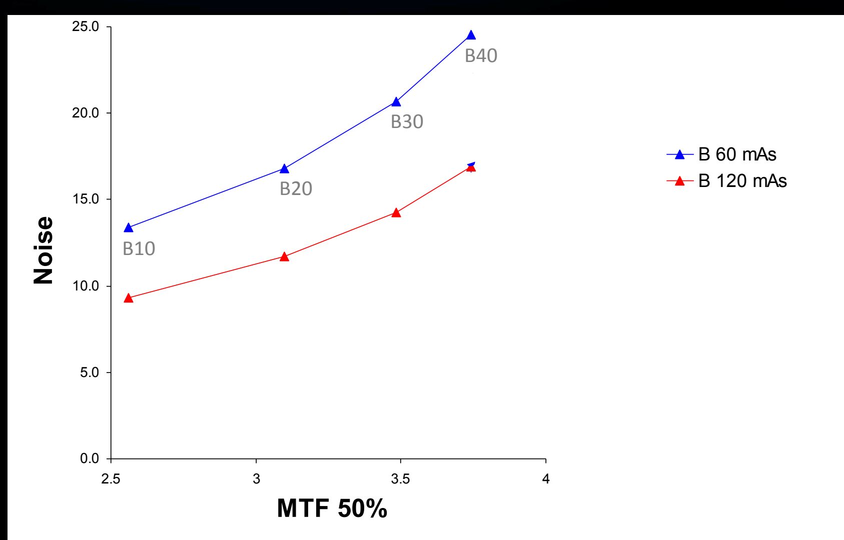


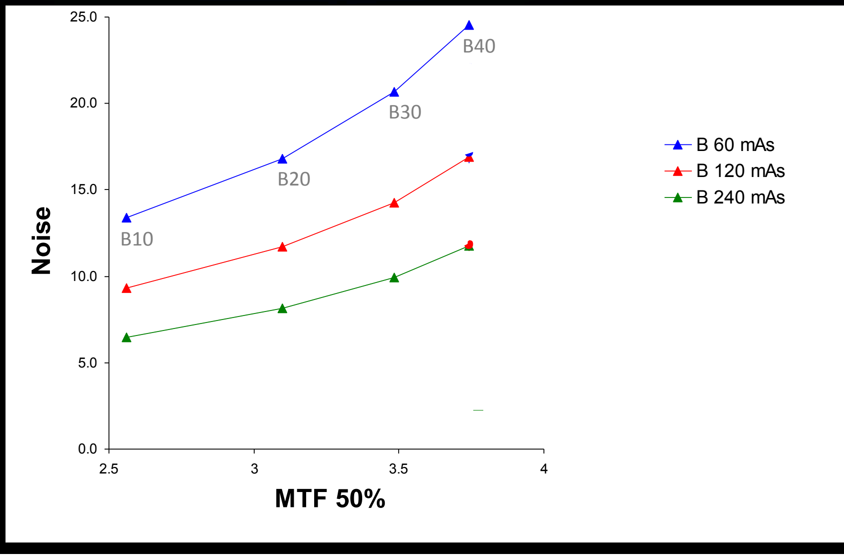
## Noise vs. high-contrast (spatial) resolution



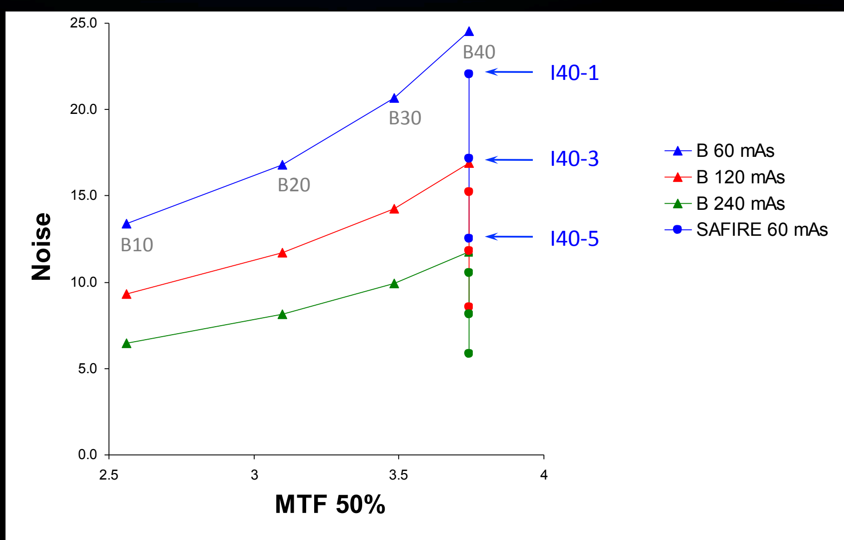

## Noise vs. high-contrast (spatial) resolution



## Noise vs. high-contrast (spatial) resolution

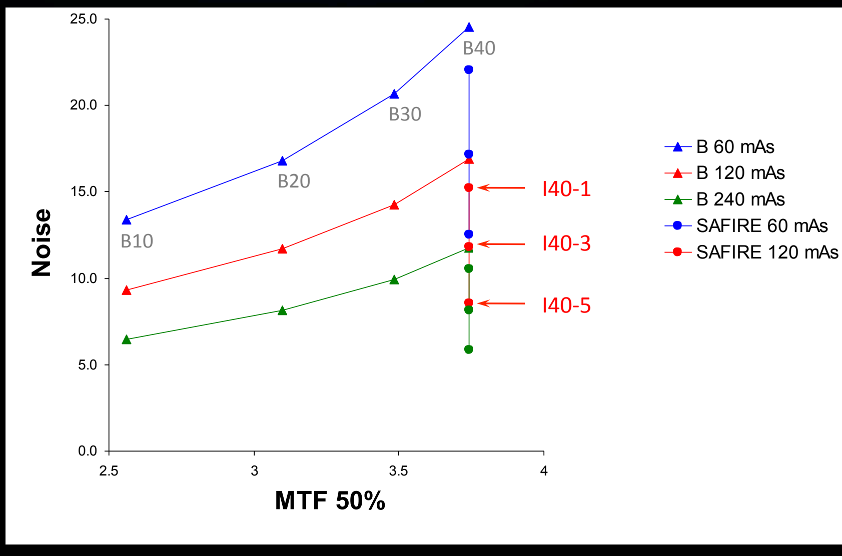



## Noise vs. high-contrast (spatial) resolution



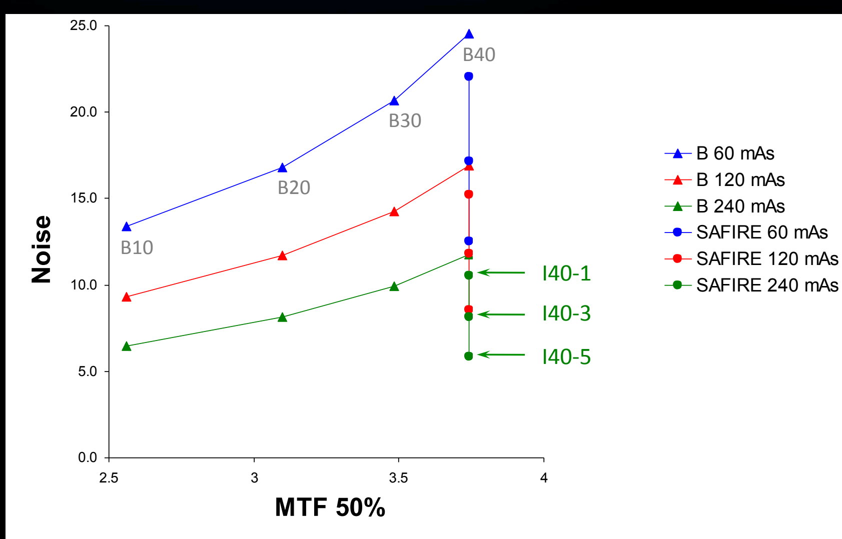
MAYO CLINIC

# Noise vs. high-contrast (spatial) resolution




MAYO CLINIC

# Noise vs. high-contrast (spatial) resolution



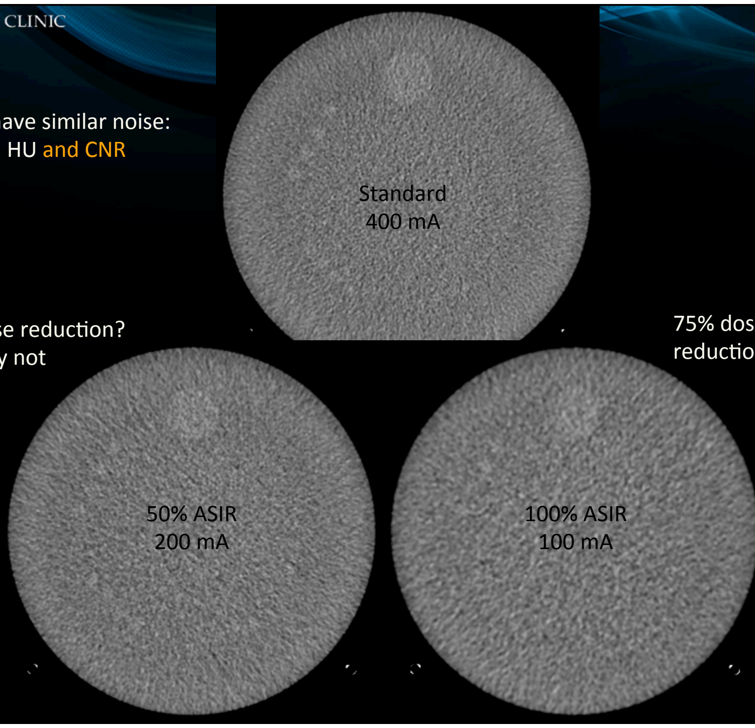
MAYO CLINIC

# Dose reduction potential

- Half dose with 50% ASIR or Safire +3 has similar noise as full dose + standard recon
- Quarter dose with 100% ASIR or Safire +5 has similar noise as full dose + standard
- Does this mean
  - 50% ASIR or Safire +3 can reduce dose by 50%?
  - 100% ASIR or Safire +5 can reduce dose by 75%?

MAYO CLINIC

All three have similar noise:
12-13 HU and CNR

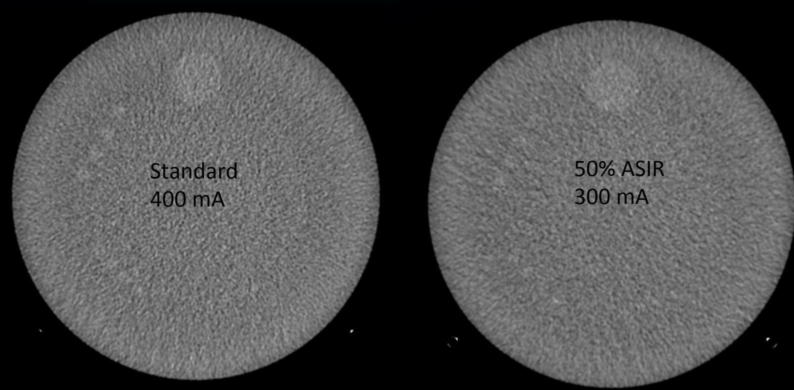



50% dose reduction?
Probably not

75% dose
reduction? NO

MAYO CLINIC

Even 25% dose reduction is questionable!

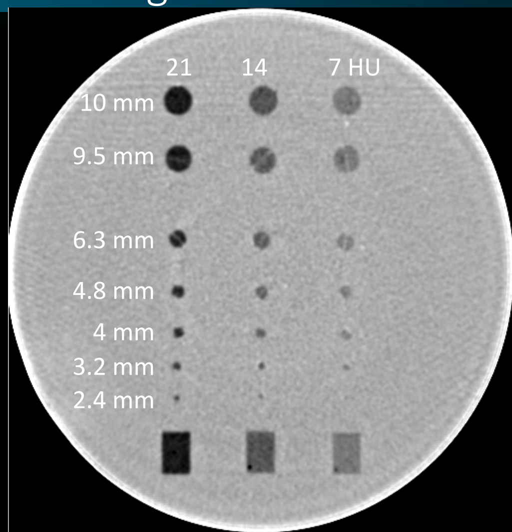



MAYO CLINIC

# Dose reduction must not compromise diagnostic performance

MAYO CLINIC

## Low contrast detection phantom: Ensemble average

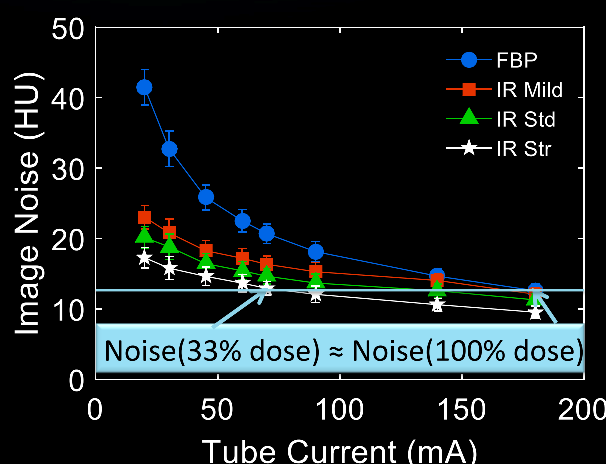



51

Favazza *et al.*, Use of a channelized Hotelling observer to assess CT image quality and optimize dose reduction for iteratively reconstructed images, *JMI (subm.)*, 3/2017

MAYO CLINIC

## Using noise level to reflect image quality leads to conclusion that 33% of original dose maintains "image quality" for IR

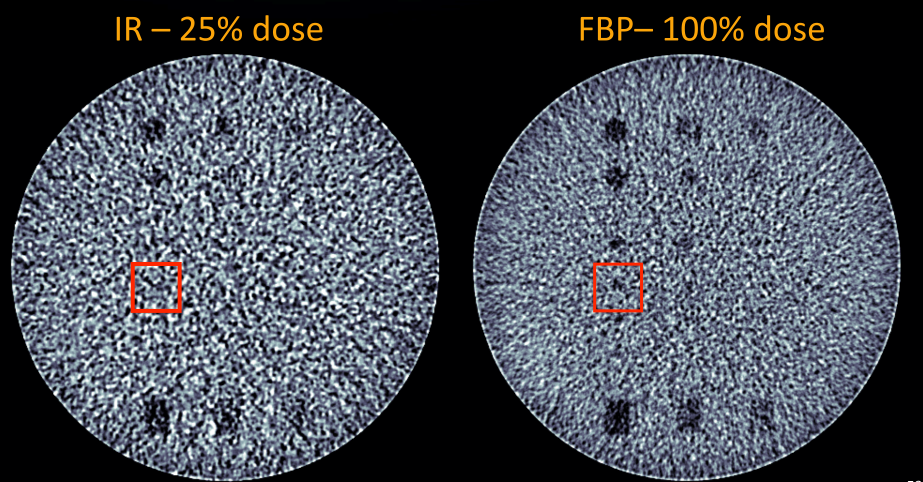



52

Favazza *et al.*, Use of a channelized Hotelling observer to assess CT image quality and optimize dose reduction for iteratively reconstructed images, *JMI (subm.)*, 3/2017

MAYO CLINIC

## However, for similar image noise, detection and characterization performance has been compromised

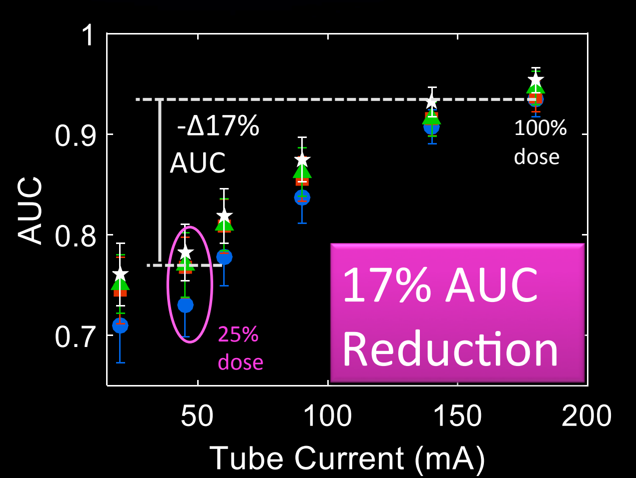



53

Favazza *et al.*, Use of a channelized Hotelling observer to assess CT image quality and optimize dose reduction for iteratively reconstructed images, *JMI (subm.), 3/2017*

MAYO CLINIC

## Our validated Channelized Hotelling observer (task-based metric) predicts degraded performance at 25% dose

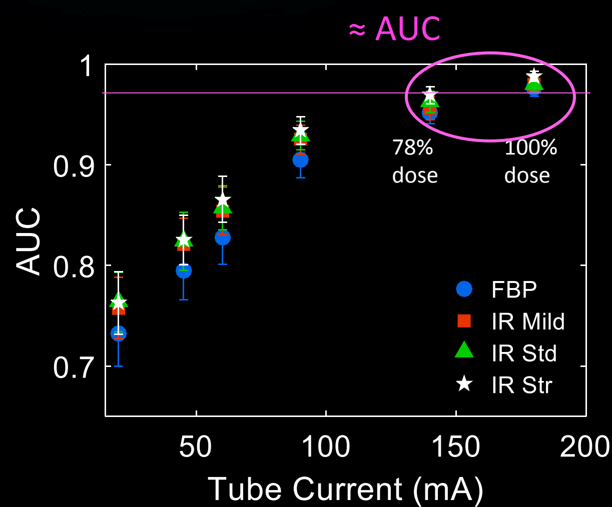



54

Favazza *et al.*, Use of a channelized Hotelling observer to assess CT image quality and optimize dose reduction for iteratively reconstructed images, *JMI (subm.), 3/2017*

MAYO CLINIC

## Our validated Channelized Hotelling observer (task-based metric) predicts comparable performance at 78% dose

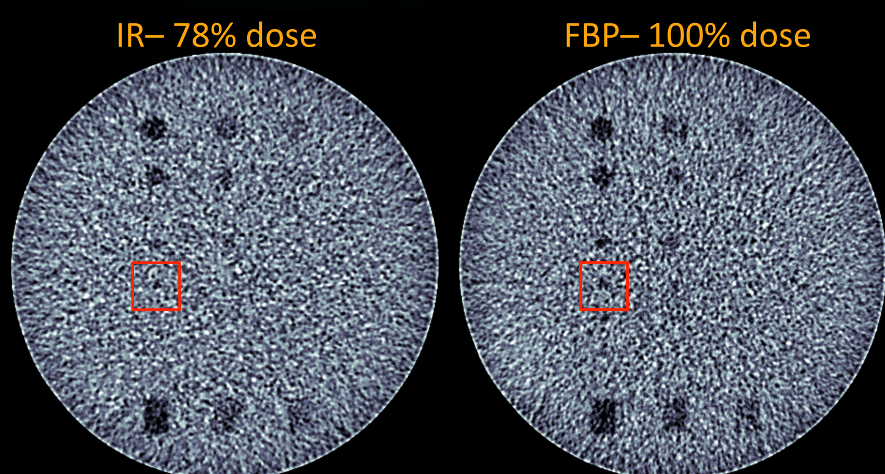



55

Favazza *et al.*, Use of a channelized Hotelling observer to assess CT image quality and optimize dose reduction for iteratively reconstructed images, *JMI (subm.)*, 3/2017

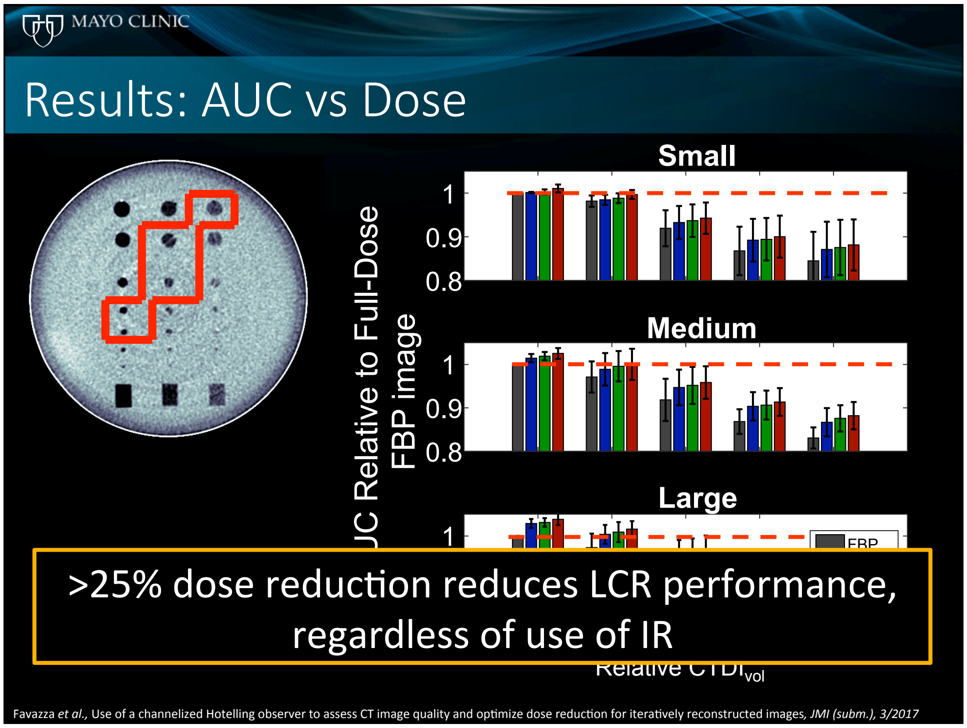
MAYO CLINIC

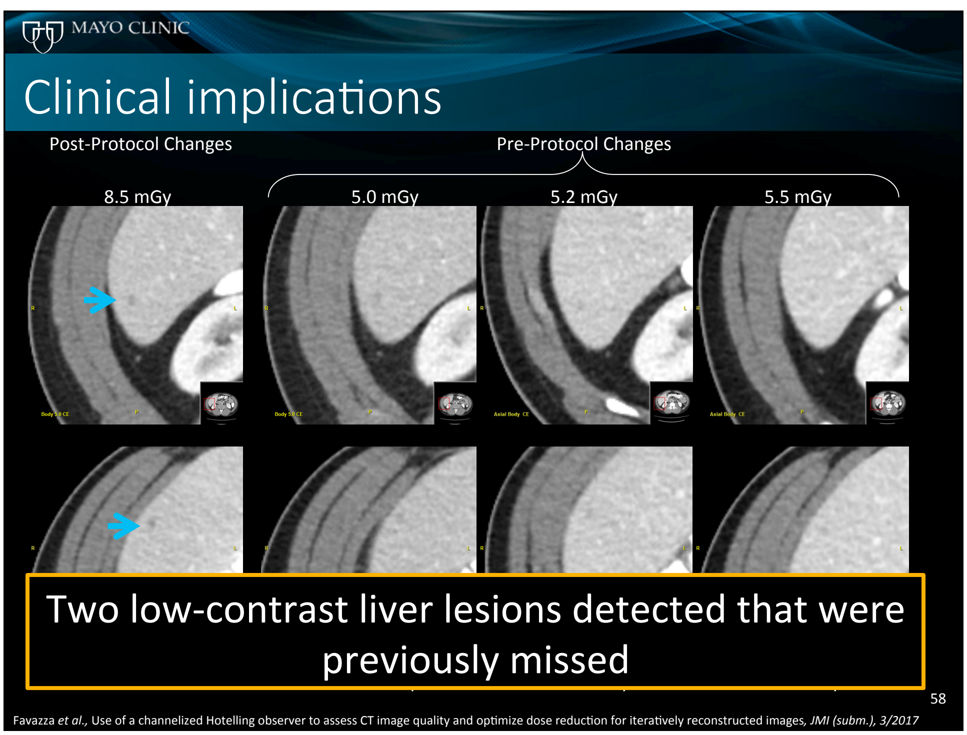
## Visual comparison at 78% dose




56

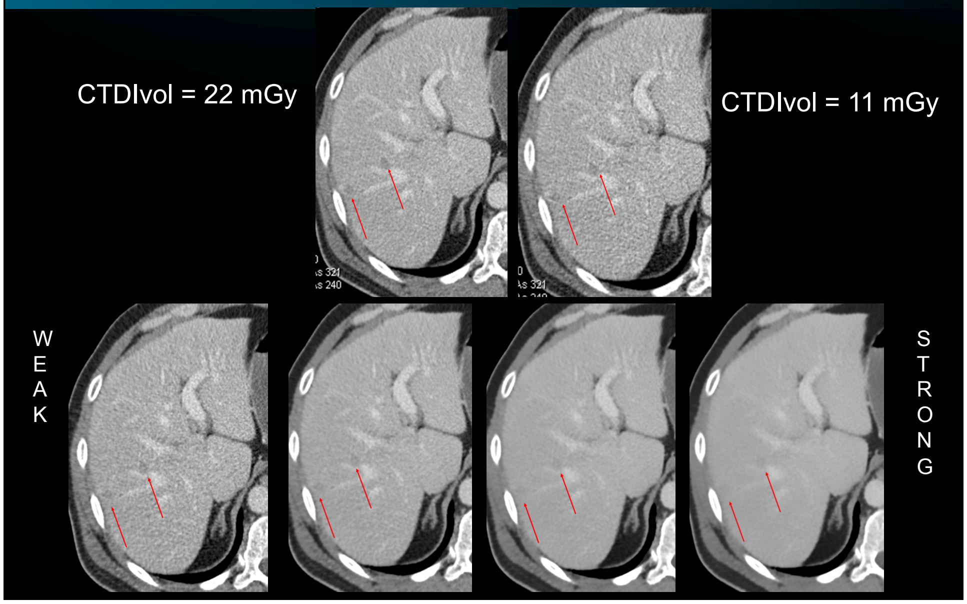
Favazza *et al.*, Use of a channelized Hotelling observer to assess CT image quality and optimize dose reduction for iteratively reconstructed images, *JMI (subm.)*, 3/2017


MAYO CLINIC
Results: AUC vs Dose
Small
Medium
Large
1
0.9
0.8
AUC Relative to Full-Dose FBP image
FBP
>25% dose reduction reduces LCR performance, regardless of use of IR
Relative CTDIvol
Favazza et al., Use of a channelized Hotelling observer to assess CT image quality and optimize dose reduction for iteratively reconstructed images, JMI (subm.), 3/2017


MAYO CLINIC
Clinical implications
Post-Protocol Changes
Pre-Protocol Changes
8.5 mGy
5.0 mGy
5.2 mGy
5.5 mGy
Two low-contrast liver lesions detected that were previously missed
58
Favazza et al., Use of a channelized Hotelling observer to assess CT image quality and optimize dose reduction for iteratively reconstructed images, JMI (subm.), 3/2017

MAYO CLINIC

## How much denoising or IR is too much?




MAYO CLINIC

## Practical tips for implementing low dose CT

- Start by turning on IR or denoising while keeping the dose the same
  - To get radiologists used to different noise texture
  - To sort out any workflow issues
  - View both full dose FBP and full dose IR/denoised images
  - You may have to find a work around on some systems if they couple dose level and use of IR

MAYO CLINIC

# Practical tips for implementing low dose CT

- Incrementally turn down the dose
  - Use phantom studies to compare low dose with full dose
  - Start with higher contrast tasks (angiography, stones, diverticulitis, appendicitis, chest)
  - Run at reduced dose several weeks between decrements
  - Compare to prior exams whenever possible
  - Involve multiple radiologists
  - Introduce dose reduction in low contrast tasks last
  - Don't exceed about approx. 25% dose reduction for low contrast tasks

MAYO CLINIC

# Implementing Noise Reduction

- Routine Abdomen Pelvis with Contrast
  - Compare back to prior exams

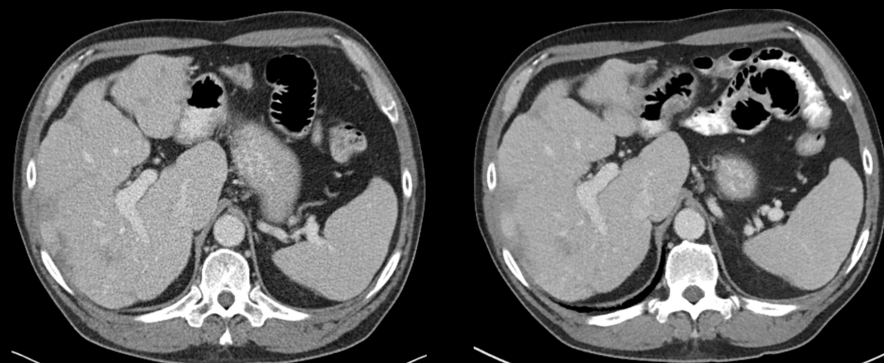
CTDIvol = 12.4 mGy

CTDIvol = 5.9 mGy

MAYO CLINIC

# Implementing Noise Reduction

- Biphase Liver with Contrast
  - Compare back to prior exams

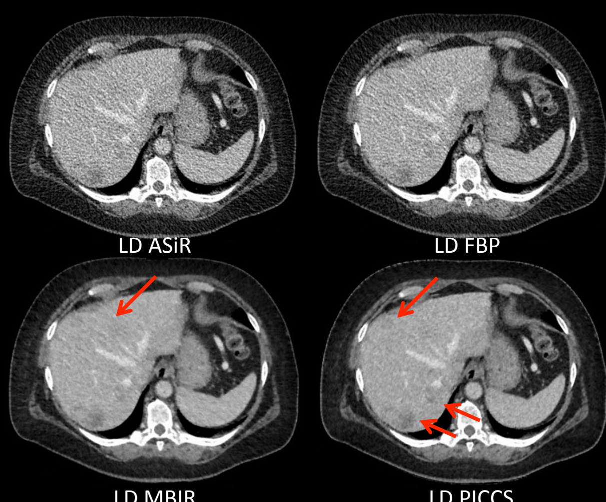


CTDIvol = 24.0 mGy

CTDIvol = 16.8 mGy

MAYO CLINIC

# Overaggressive dose reduction!




**You don't know you've missed what you couldn't see**

IV-contrast CT
Standard Dose (SD) = [illegible] mSv
Low Dose (LD) = 2.3 mSV
88% dose reduction

Courtesy Perry Pickhardt, AJR 2012

MAYO CLINIC

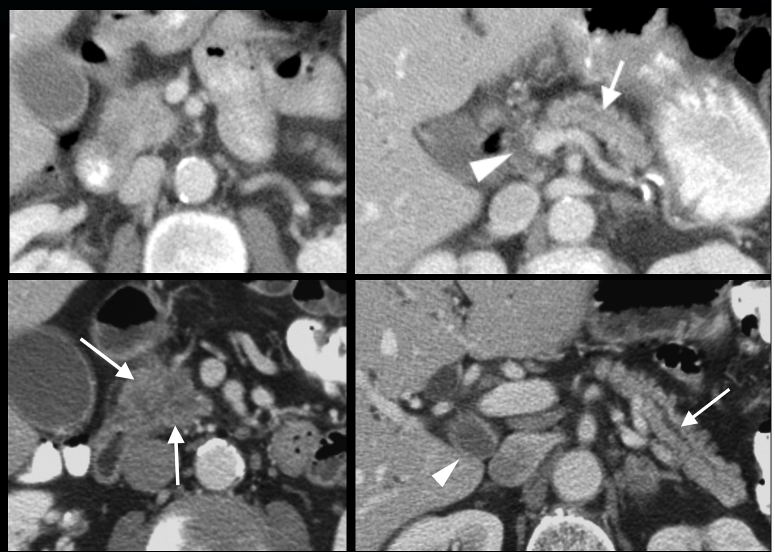
Courtesy of Dr. Joel Fletcher

## Don’t Let Low Dose CT Destroy Medical Benefit

Low dose
6 mm thick
Single phase
-----
Pancreatic tumor missed

*2 days later*

Routine dose
2 mm thick
Bi-phasic
-----
Clear low atten. mass
Ductal dilation



MAYO CLINIC


http://mayoresearch.mayo.edu/ctcic