Integrating Noise Reduction Technology into your Practice to Reduce Patient Dose without Sacrificing Image Quality

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DISCLOSURES

Research Support:

Siemens Healthcare

Off Label Usage

None

Overview

- Noise reduction
  - Context
  - Rationale
- Approaches
- Evidence for improvement of image quality and observer performance
- Clinical implementation
  - Practical approaches
  - For image quality improvement
  - For dose reduction

The "Good" Exam

- Justified

Benefit

Risk

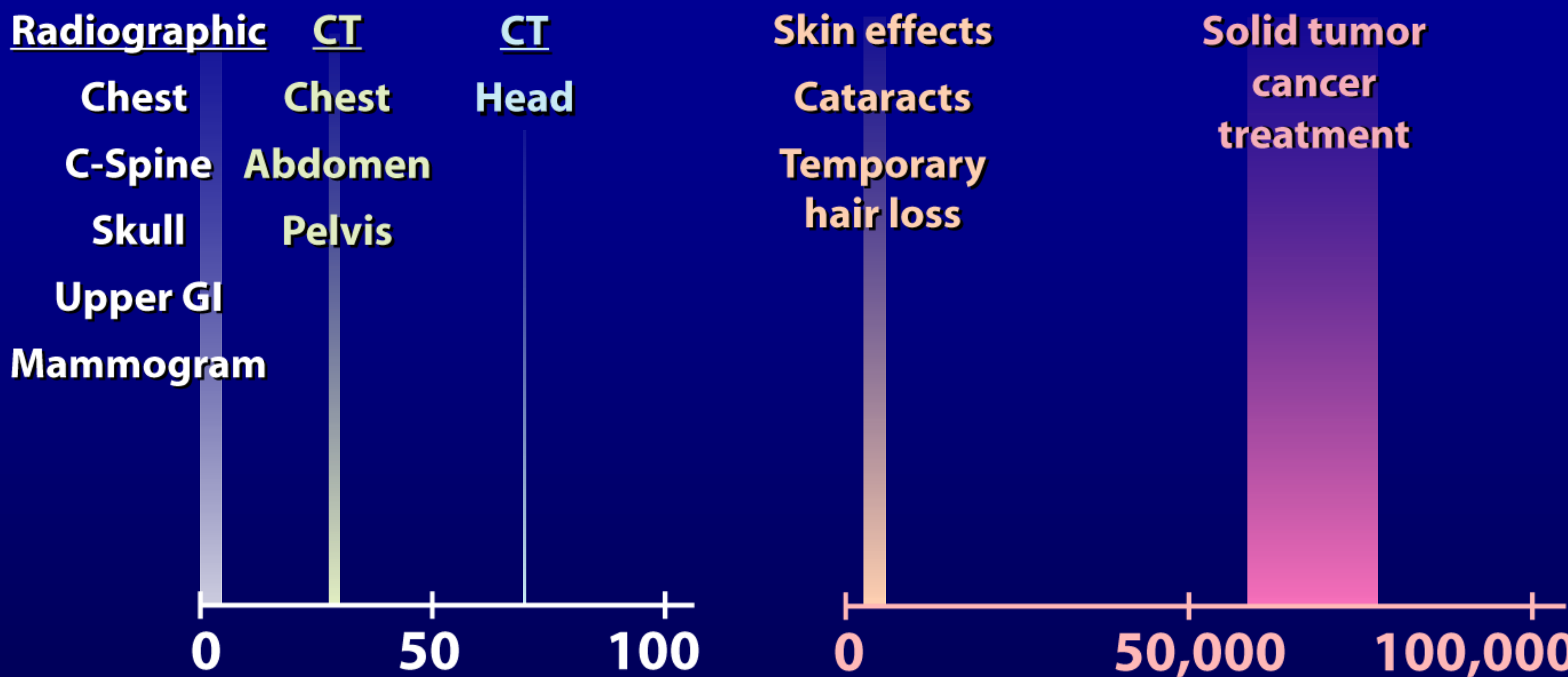
- Optimized

  - Use doses that are as low as reasonably achievable (ALARA) without compromising diagnostic task.

  - Adapts CT acquisition to patient and disease

McCollough et al. AJR 2009

Chance of an effect   Predictable effects

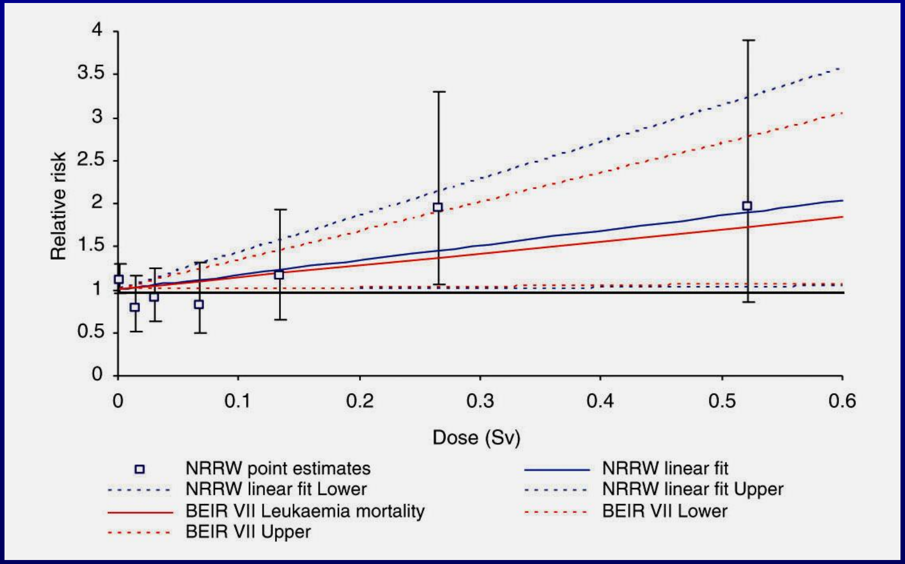


x 1000

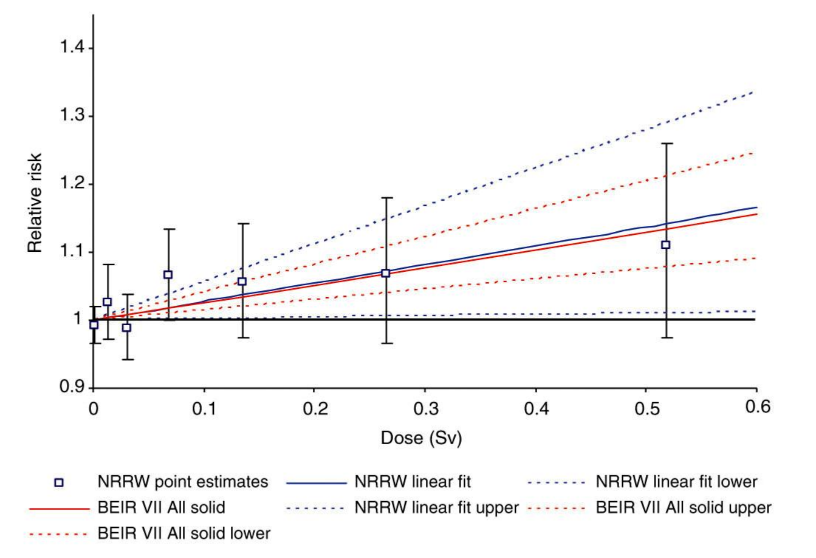
Typical Maximum Organ Doses (mGy)

Courtesy Dr. Cynthia McCollough

Radiation Risk



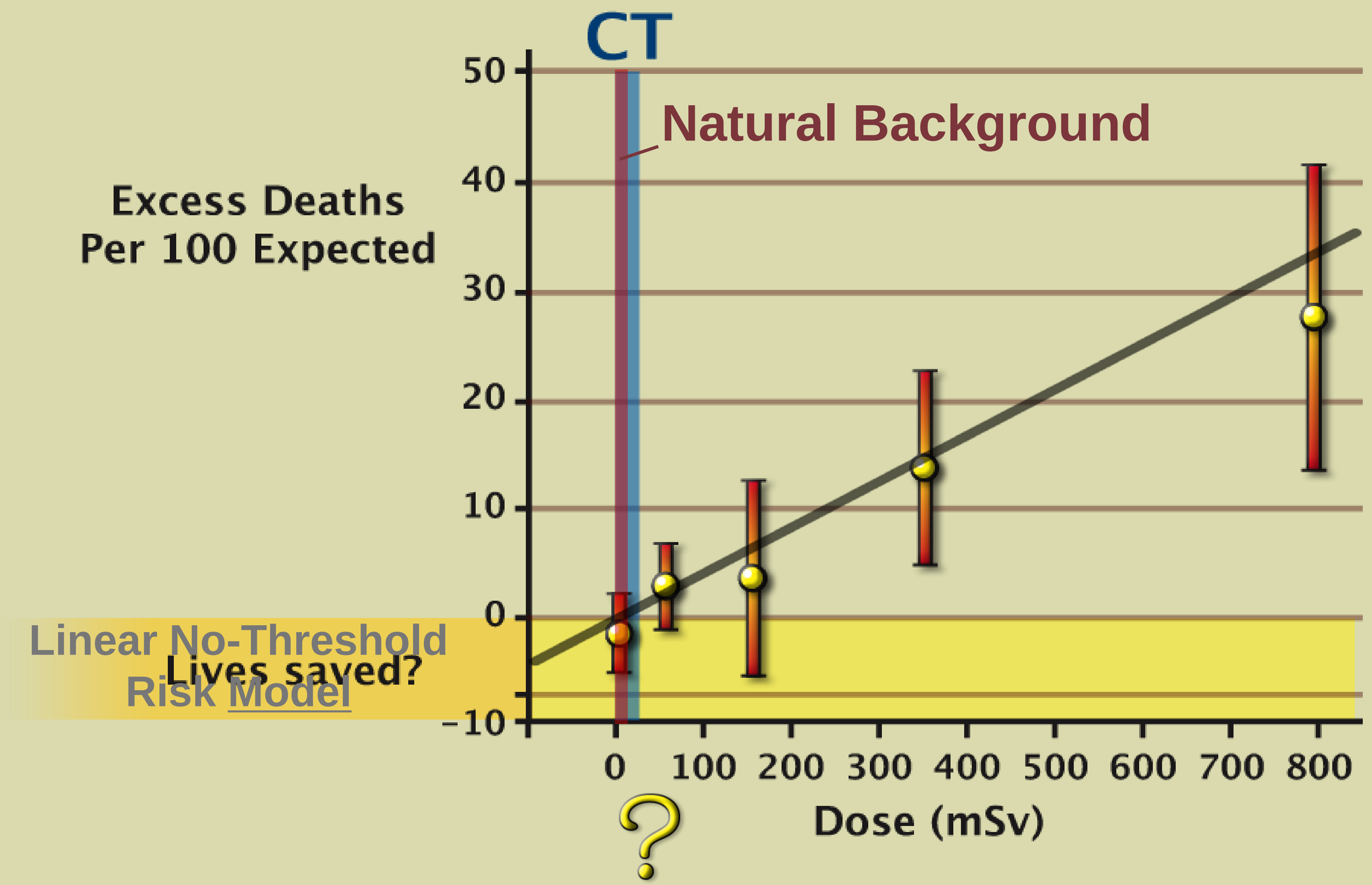
Leukemias excluding CLL



Solid Neoplasms

*** 174,541 British Radiation Safety Workers**
From Muirhead et al. Br J CA 2009

Radiation Risk



Reference: Cohen, AJR 2002; Pierce et al. Cancer 1996

BEIR VII

- "At doses of 100 mSv or less, statistical limitations make it difficult to evaluate cancer risk in humans."
- **"The preponderance of information indicates that there will be some risk, even at low doses, although the risk is small."**

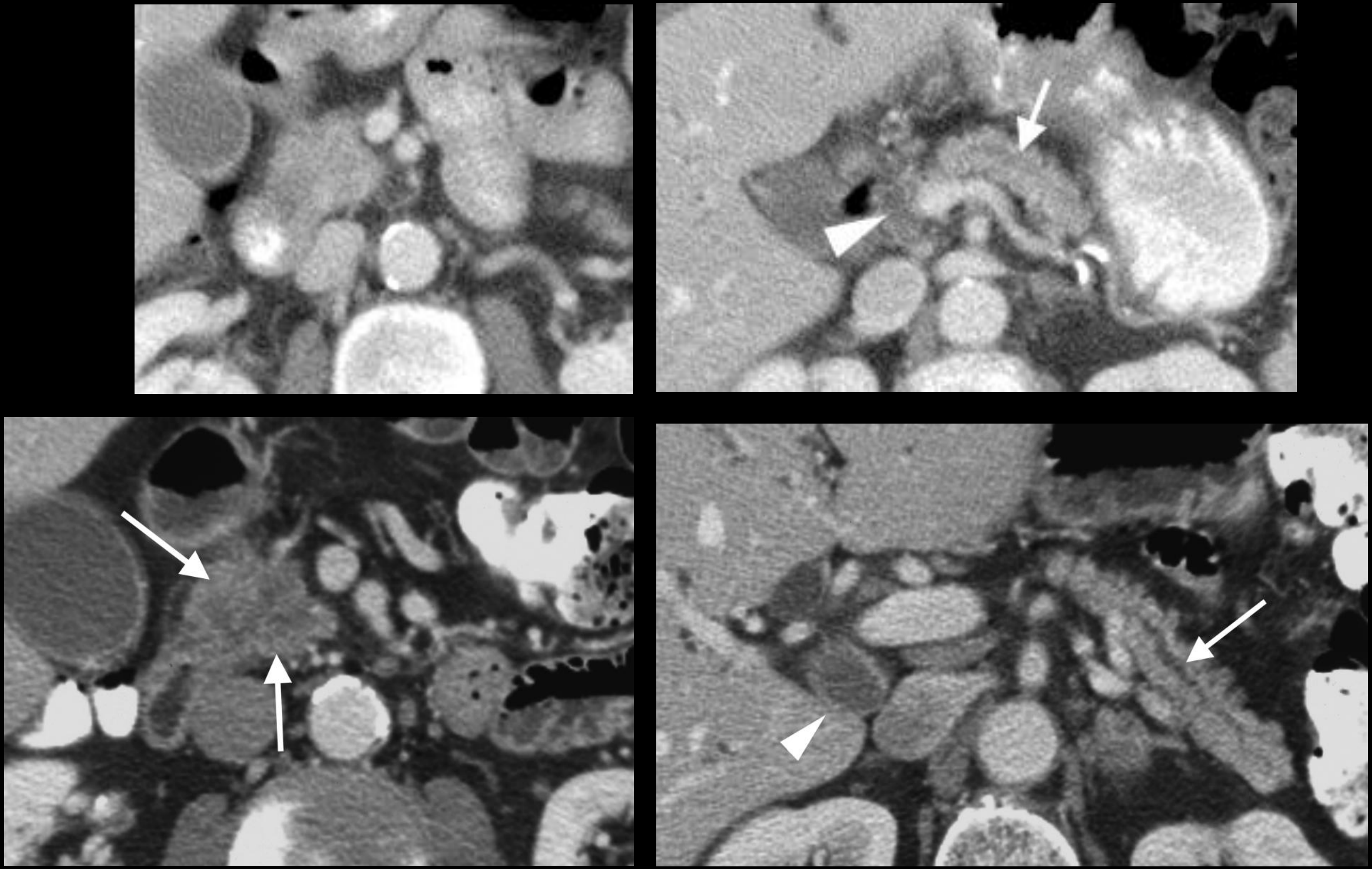
- U. S. National Academies of Science

Dealing with Small Potential Risks

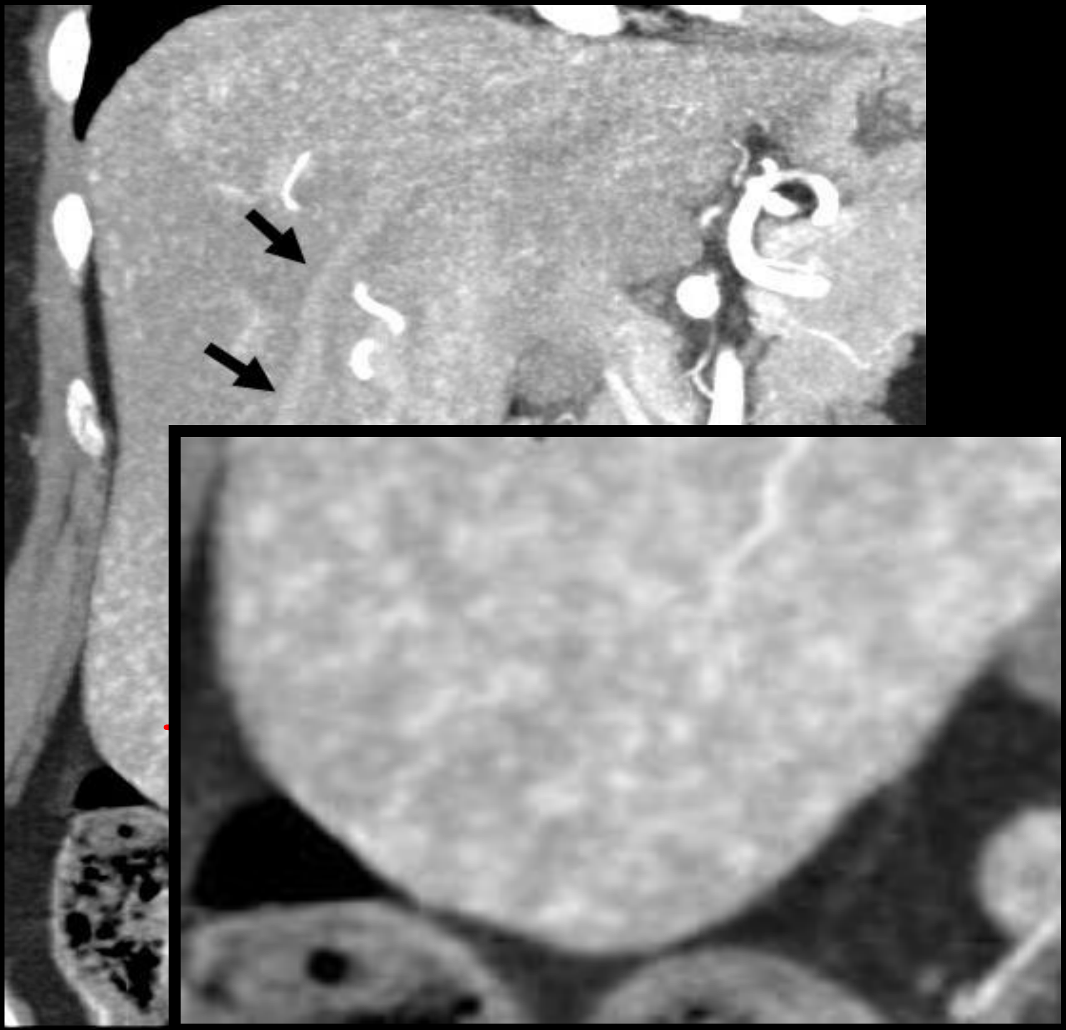
Benefit

Risk

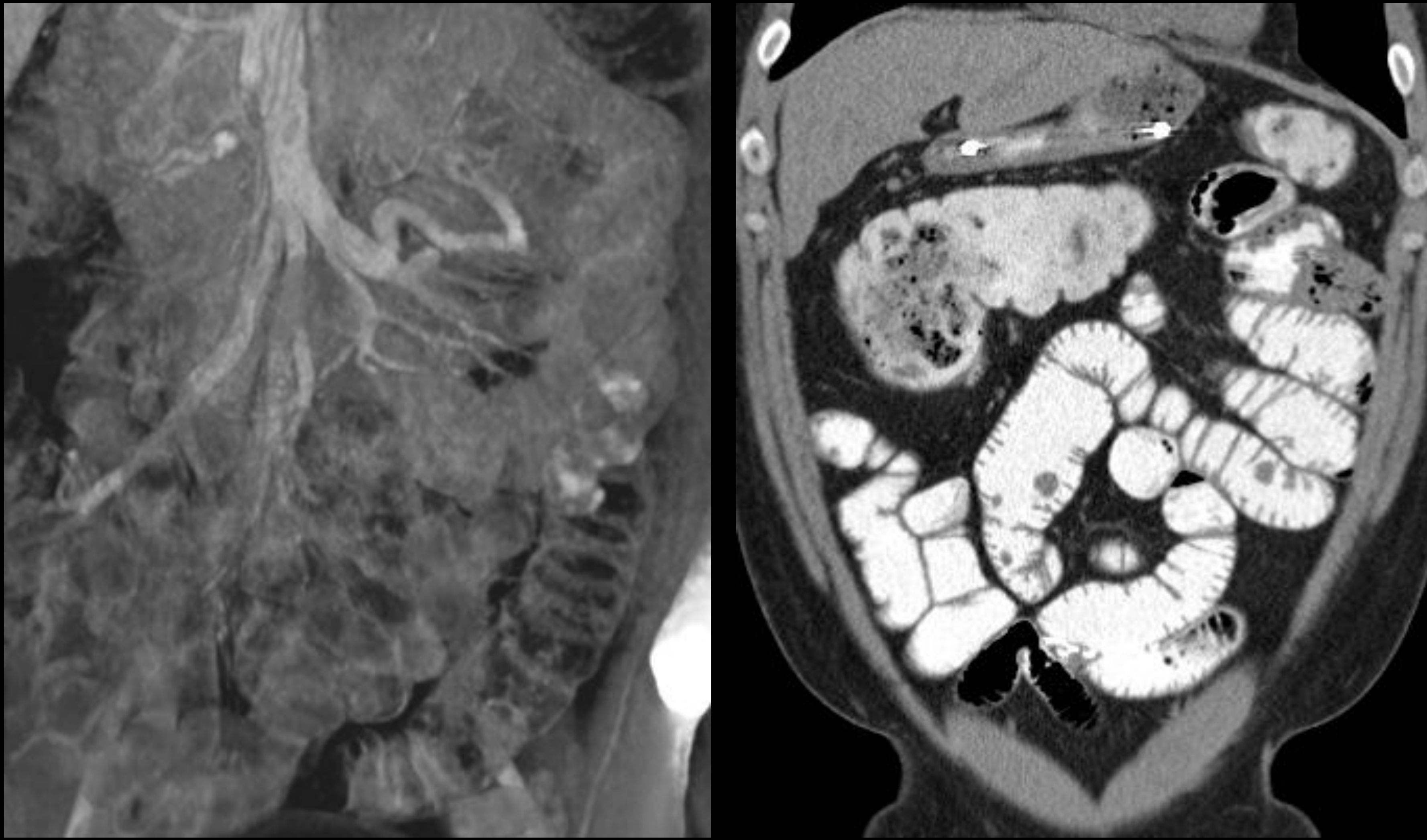
- Justification largely driven by benefit



Dose ***Is Not*** *Driving Justification*



Dose ***Is Not*** *Driving Justification*



Dose ***Is Not*** *Driving Justification*

Huprich et al. Radiology 2011

*Dose **Is Not** Driving Justification*

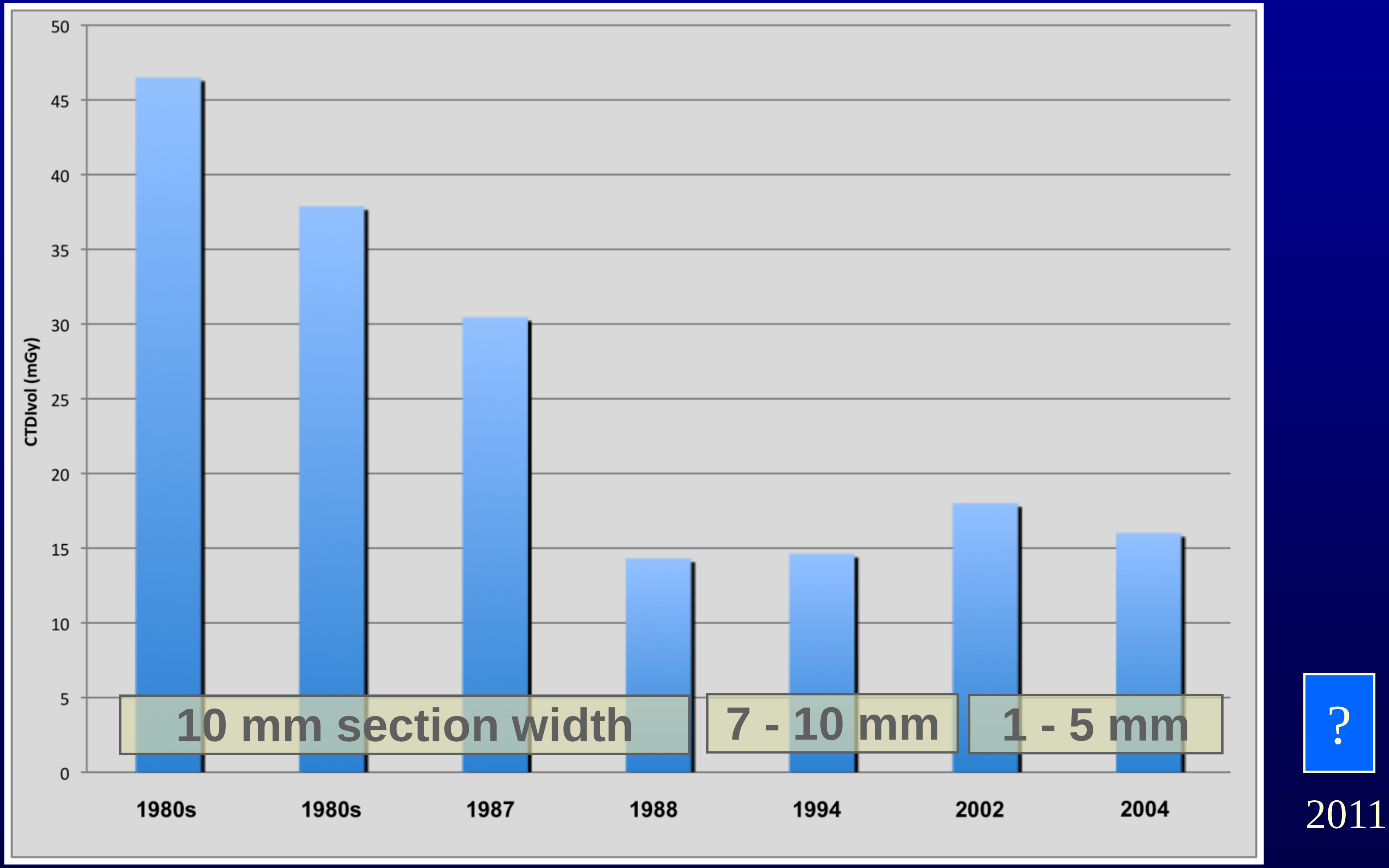
Dealing with Small Potential Risks

Benefit

Risk

- Justification largely driven by benefit
- Benefit of CT cannot be achieved without imaging

Typical Body CT Doses over 2 Decades



Courtesy Dr. Cynthia McCollough

Perception

USA TODAY

Study: Unnecessary CT scans exposing patients to excessive radiation

By Steve Sternberg, USA TODAY

Overuse of diagnostic CT scans may cause as many as 3 million excess cancers in the ... decades, ... T stands ... to

The New York Times

Report Links Increased Cancer Risk to CT Scans

By THE AS...
Published: ...

Millions ... dangero... and are ... warns. I... United S... acc...

The ... "we... said ... Uni...

Cedars-Sinai investigated for significant radiation overdoses of 206 patients

The finding prompts the FDA to issue an alert urging ... protocols for CT scans.

October 10, 2009 | Alan Zaremb...

More than 200 patients at Ceda...

Class Action Lawsuit Filed Against Cedars-Sinai Over CT Radiation Overdose

CT Scan Increase Could Mean More Cancer Down the Road

NEWSInferno.com

U.S. probing more cases of CT radiation overexposure

WASHINGTON (Reuters) - U.S. re... probing more cases of patients wh...

Doctors 'Shocked' by Radiation Overexposure at Cedars-Sinai

Medical Scans Continue Increasing Our Exposure to Radiation, Experts Say

By RADHA CHITALE
ABC News Medical Unit
Oct. 13, 2...

abc WORLD NEWS WITH DIANE SAWYER

23 comments

CT scan radiation can equal nuclear bomb e...

12:03 11 May 2007 NewScientist.com ne...

Overzealous doctors who order unnecessary body sca... use X-ray technology are placing their patients at risk of cancer radiologists warn.

Radiation from such scans is in some cases equivalent to that received by some survivors of the Hiroshima and Nagasaki atomic bombs, they say. In response, hospitals and pro... associations, such as the American College of Radiolog... taking new steps to promote more careful use of scanni... technologies.

CNN.com /health

Study: CT scans raise cancer risk

updated 7:45 p.m. EST, Wed November 28, 2007

Study: Increased Use of CT Scan Poses Cancer Risk

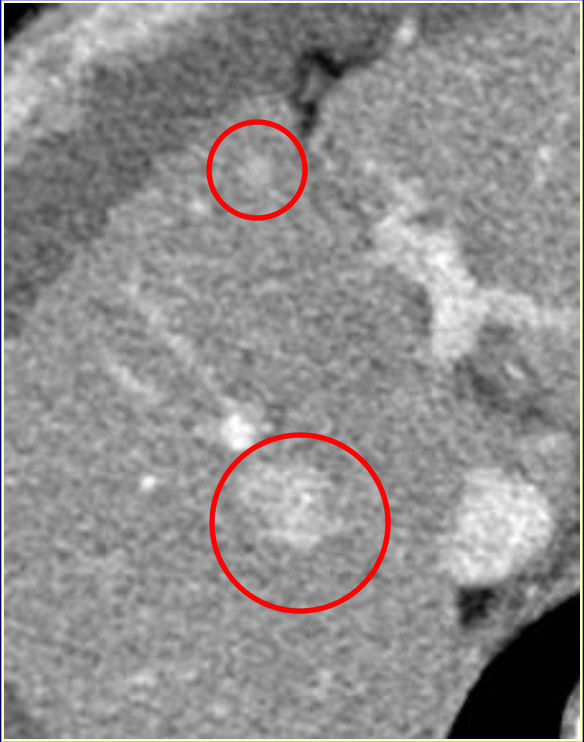
Thursday, November 29, 2007

Associated Press

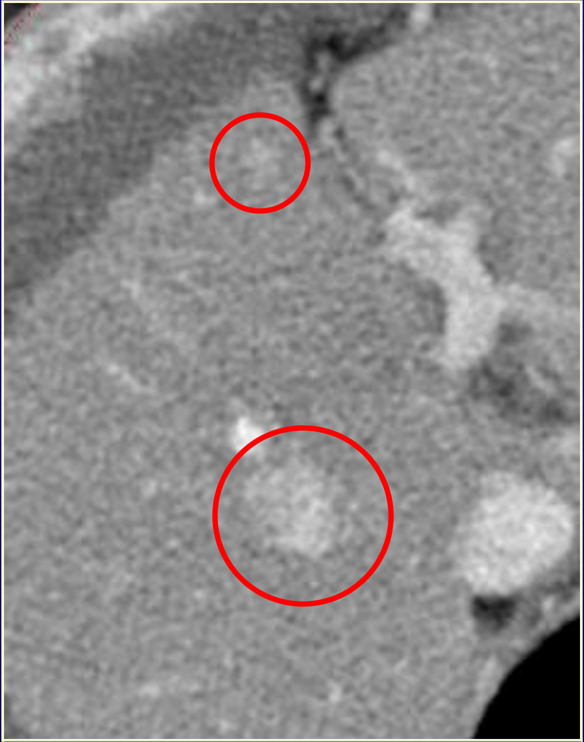
Rationale for Dose Reduction

- Lower doses can be used in numerous clinical situations to accomplish the diagnostic task
- With noise reduction, overall dose for many CT exams will be similar or less than annual background radiation
  - LARGE POTENTIAL to overcome patient/physician reticence to undergo *beneficial and justified* CT imaging
  - Especially important for screening, repeat exams, young patients

Noise Reduction



Half-Dose with Noise Reduction



Full Dose

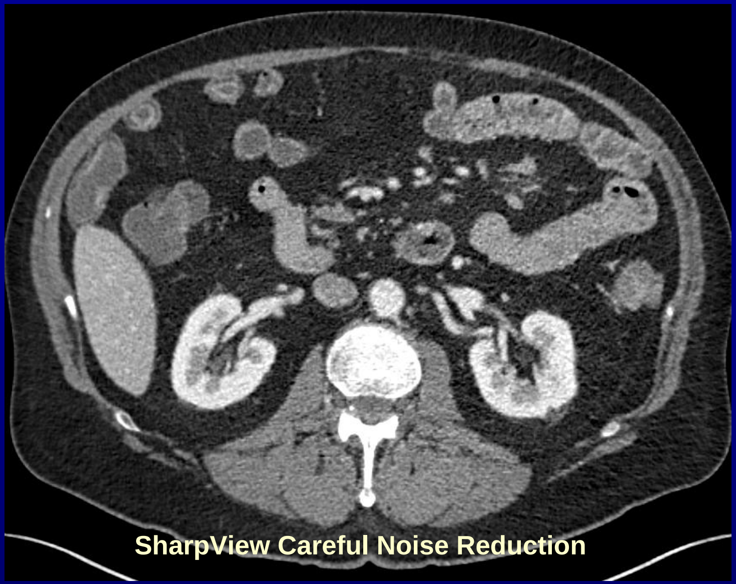
The purpose of noise reduction is to "increase fidelity to a higher dose image."- Amy Hara, MD

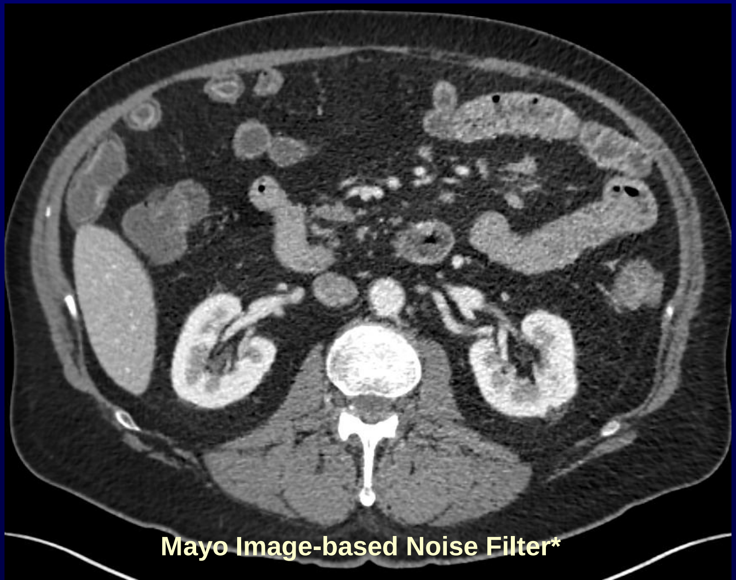
Noise Reduction

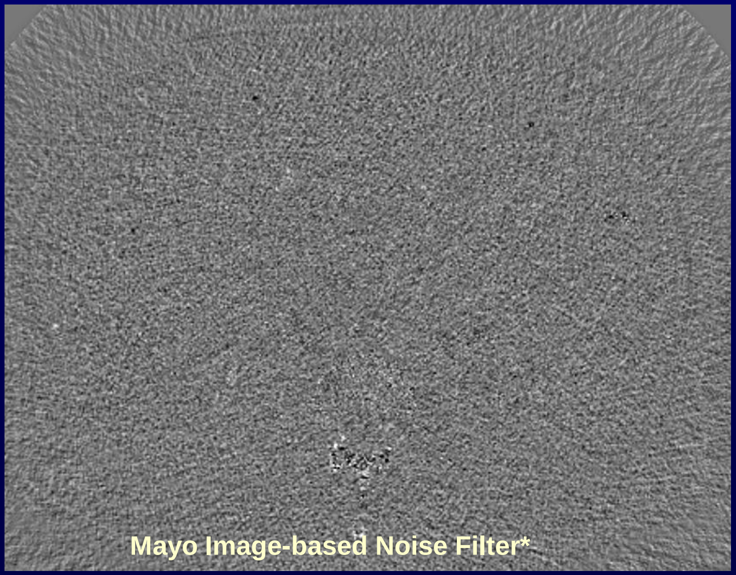
Full dose – 120 kV & 240 Qual Ref mAs

Half dose – 120 kV & 120 Qual Ref mAs
+ Noise Reduction

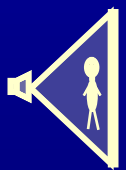
Differences in Image-based Noise Filters



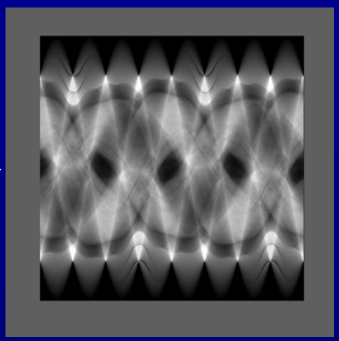




Differences in Method and Implementation



Acquisition



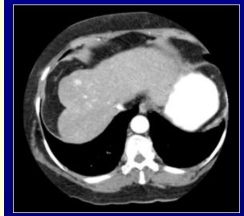
Projection Data

Projection-space Filters

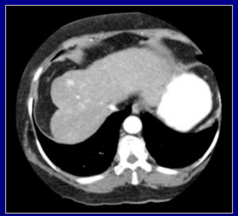
Image Reconstruction

- Filtered Back Projection
- Reconstruction kernel
- Iterative Reconstruction (e.g., MBIR)

Iterative Noise Reduction Methods (e.g., ASIR, SAFIRE)



CT image



Filtered CT image

Image-space Noise Reduction

(e.g., SharpView)

Noise Reduction Myths

- Noise reduction reduces radiation dose
  - “ASIR-enabled”, “SAFIRE-enabled”
- Noise reduction improves lesion detection
- It’s “iterative reconstruction”

Noise Reduction Myths

Noise Reduction Reduces Dose

- Only kV and mAs reduction reduces dose
- Noise floor and cross-scatter reduction would likely help
- Radiologists are really good at looking at low-dose images without noise reduction**
  - Crohn's, diverticulitis, appendicitis, renal stone detection
  - Observer performance is preserved

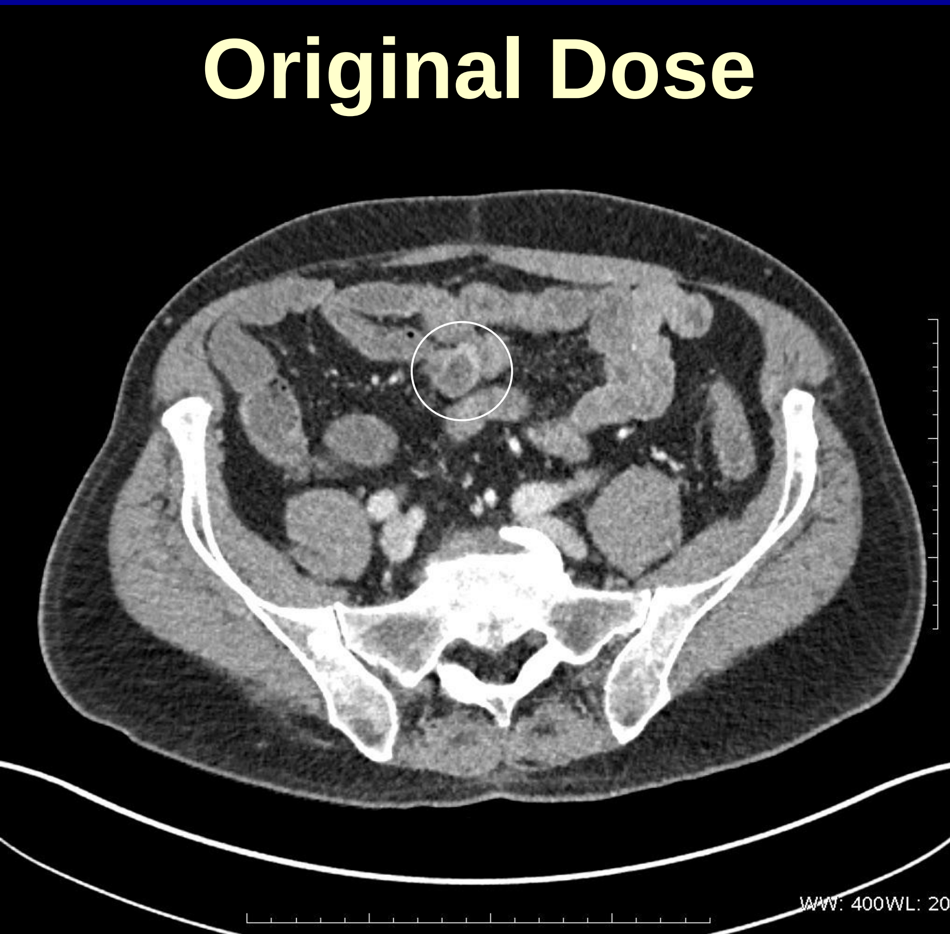
** Allen et al. AJR 2010; Kambadakone et al. AJR 2010; Seo et al. AJR 2009

Noise Reduction Myths

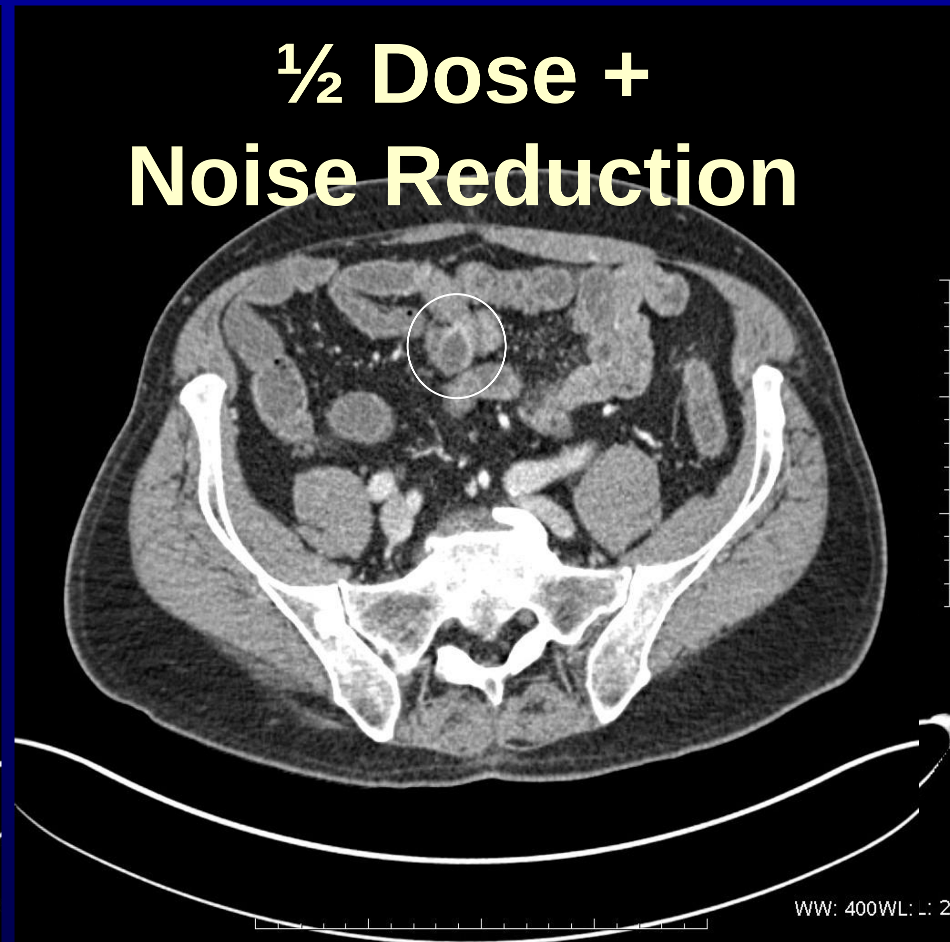
Noise Reduction Improves Detection

- Multiple studies have shown noise reduction *does* improve image quality
- *However*, low dose images without noise reduction show the same CT findings

Original Dose



**½ Dose +
Noise Reduction**



Is Noise Reduction Improving Diagnosis?

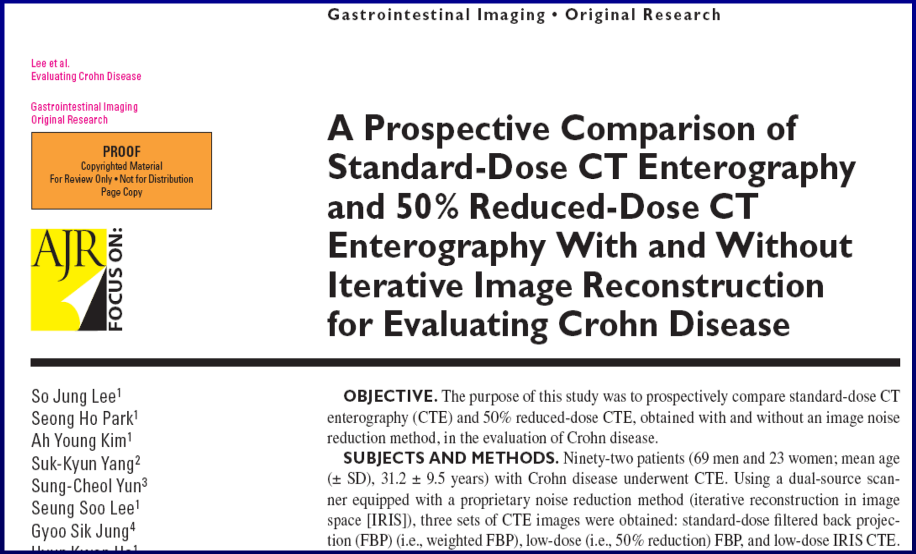
Myths: Denoising Improves Detection

Singh (2010). Abdominal CT: Comparison of Techniques

- 22 pts
- 4 additional scans @ 50 – 200 mAs, reconstructed with FBP & 30 – 70 % ASIR
- Significant improvement in noise, IQ, conspicuity at lowest dose level
- No loss of contrast or sharpness
- No lesions missed on FBP or ASIR images

Singh, et al. "Abdominal CT: comparison of adaptive statistical iterative and filtered back projection reconstruction techniques." *Radiology* 2010; 257: 373 - 383

Myths: Denoising Improves Detection



Gastrointestinal Imaging • Original Research

Lee et al.
Evaluating Crohn Disease

Gastrointestinal Imaging
Original Research

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AJR FOCUS ON:

A Prospective Comparison of Standard-Dose CT Enterography and 50% Reduced-Dose CT Enterography With and Without Iterative Image Reconstruction for Evaluating Crohn Disease

So Jung Lee[1]
Seong Ho Park[1]
Ah Young Kim[1]
Suk-Kyun Yang[2]
Sung-Cheol Yun[3]
Seung Soo Lee[1]
Gyoo Sik Jung[4]

OBJECTIVE. The purpose of this study was to prospectively compare standard-dose CT enterography (CTE) and 50% reduced-dose CTE, obtained with and without an image noise reduction method, in the evaluation of Crohn disease.

SUBJECTS AND METHODS. Ninety-two patients (69 men and 23 women; mean age (± SD), 31.2 ± 9.5 years) with Crohn disease underwent CTE. Using a dual-source scanner equipped with a proprietary noise reduction method (iterative reconstruction in image space [IRIS]), three sets of CTE images were obtained: standard-dose filtered back projection (FBP) (i.e., weighted FBP), low-dose (i.e., 50% reduction) FBP, and low-dose IRIS CTE.

Lee, Park, et al. AJR 2011 (July)

- 92 pts
- FD, ½ dose, ½ dose with noise reduction
- ½ dose = 3.5 mGy CTDIvol
- Evaluated imaging findings of inflammation at TI
- 1/2 dose with *and* without noise reduction found agreement with full dose in > 85% of cases

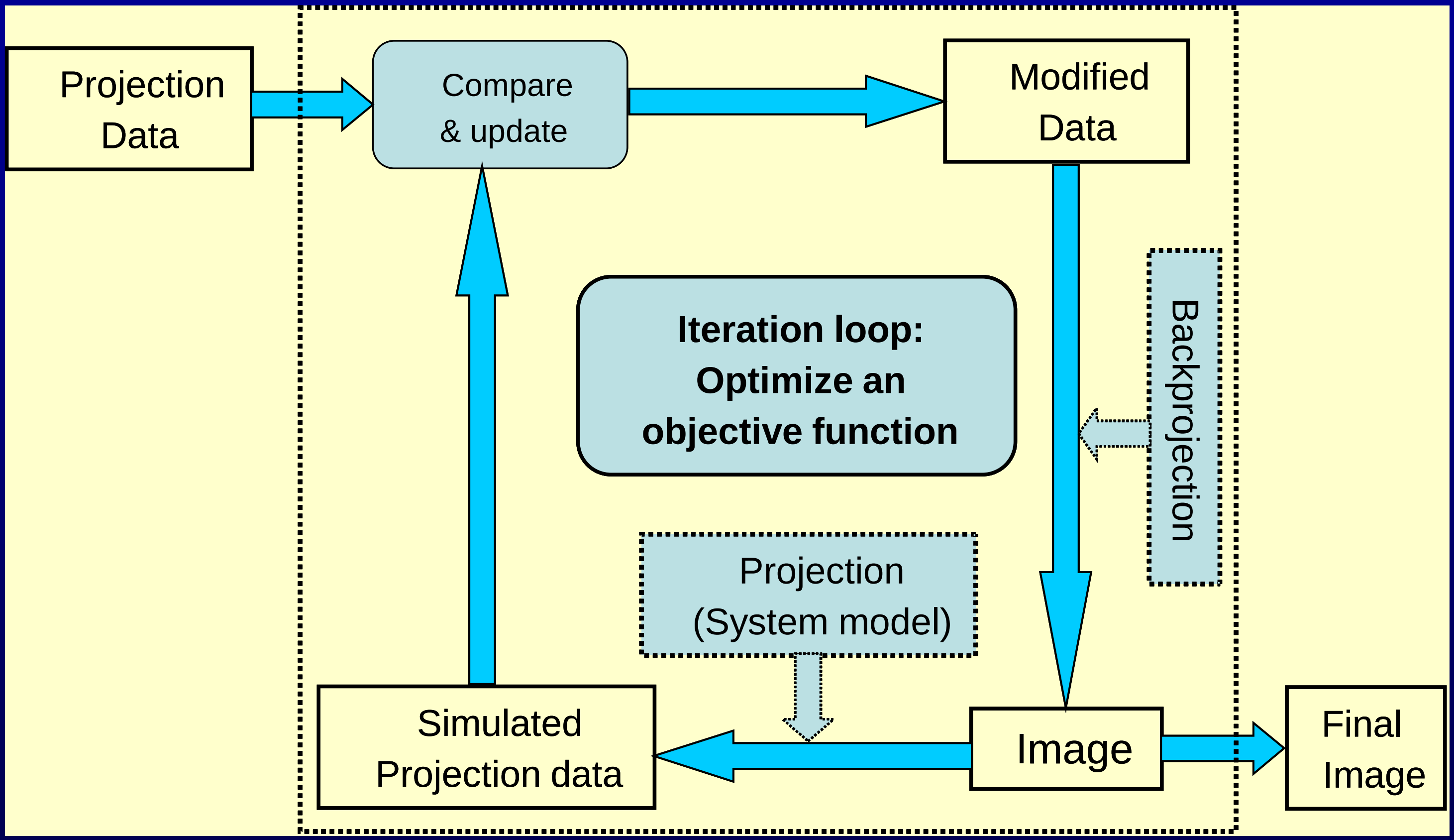
Myths: It's "Iterative Reconstruction"

- Explanation of MBIR or "true" IR
- Other "iterative" noise reduction methods that sample projection space
- Other "iterative" noise reduction in image space
- Observer comparisons not done
- Differences may be idiosyncratic (to practices) and practical

Iterative Reconstruction

- IR has an advantage in accurately modeling the system geometry, incorporating physical effects like beam spectrum, noise, beam hardening effect, scatter and incomplete data sampling.
- Different degrees of credibility among projection data
- More accurate noise models
  - photon statistics
  - other physical properties of the data acquisition
- May improve spatial resolution and reduce image artifacts such as beam hardening, windmill, and metal artifacts
- High computation load

Iterative reconstruction

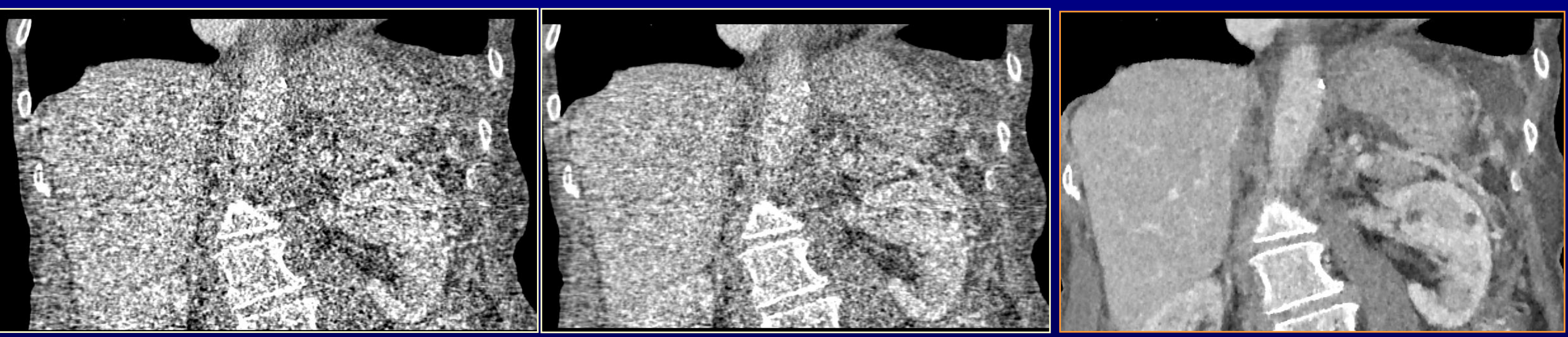


Ultra low dose with MBIR

MBIR = Model based iterative reconstruction

Example: CT at 10 mAs (routine = 200 mAs)

FBP | **50% ASIR** | **MBIR**



64 x 0.625, helical pitch 1, 120kVp

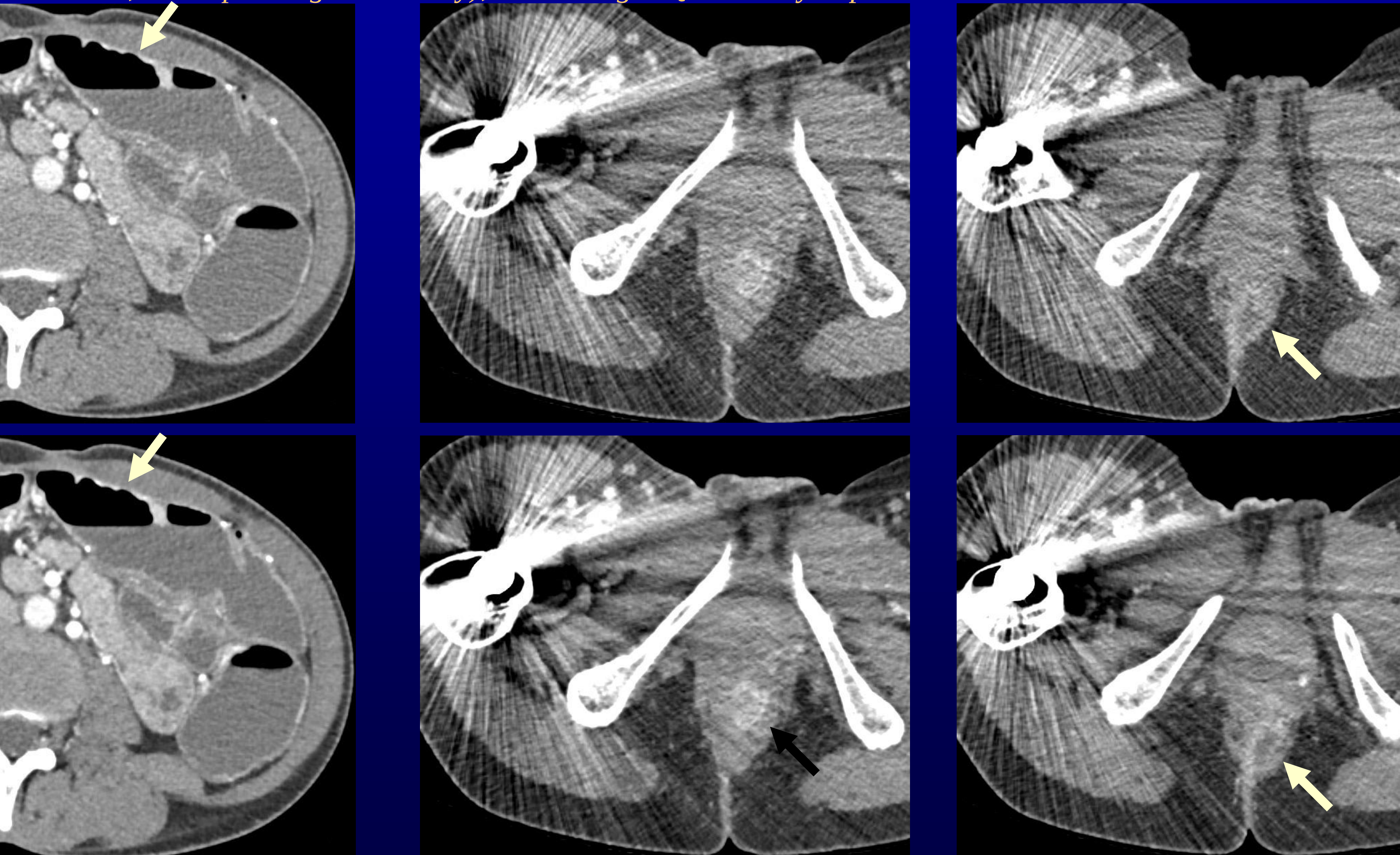
Same pt, same scan

(MBIR, GE Healthcare)

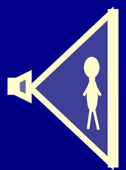
Courtesy Dr. Amy Hara

Artifact Improvement with Iterative Sampling of Projection Data

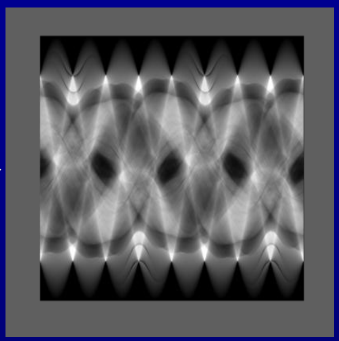
Subtle Dz Neo-terminal ileum and Perianal Fistula Can be seen on half –dose ± SAFIRE (2 mm slice thickness, corresponding to 3.3 mGy), even though IQ markedly improved



Differences in Method and Implementation



Acquisition



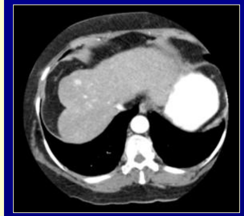
Projection Data

Projection-space Filters

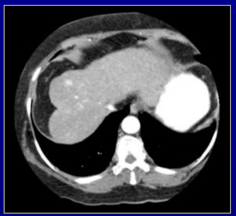
Image Reconstruction

- Filtered Back Projection
- Reconstruction kernel
- Iterative Reconstruction (e.g., MBIR)

Iterative Noise Reduction Methods (e.g., ASIR, SAFIRE)



CT image



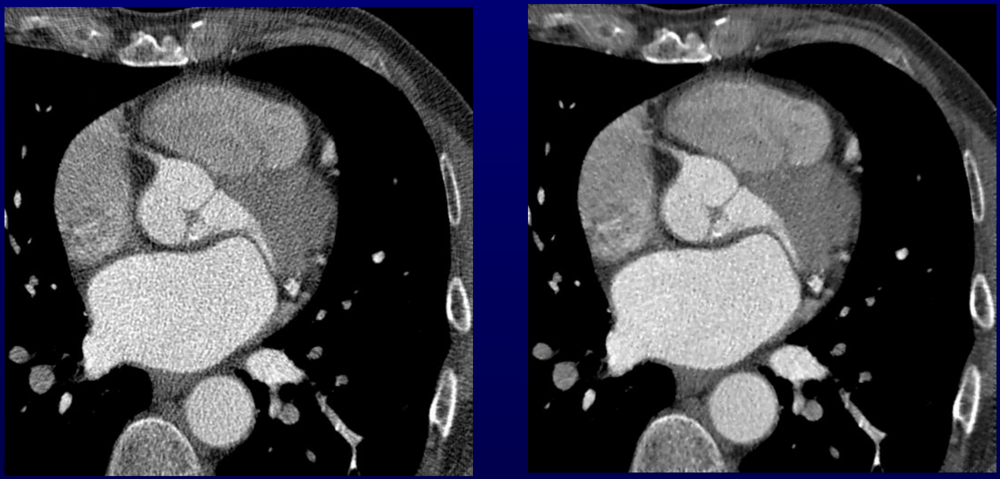
Filtered CT image

Image-space Noise Reduction

(e.g., SharpView)

Several Noise Reduction Strategies

- Reconstruction kernel
- Image-space denoising
- Iterative reconstruction
- Iterative noise reduction methods sampling projection space



Courtesy of R. Raupach

61% noise reduction (3D ORA kernel)

Comparison of Noise Reduction Methods

IRIS I40

SharpView A81

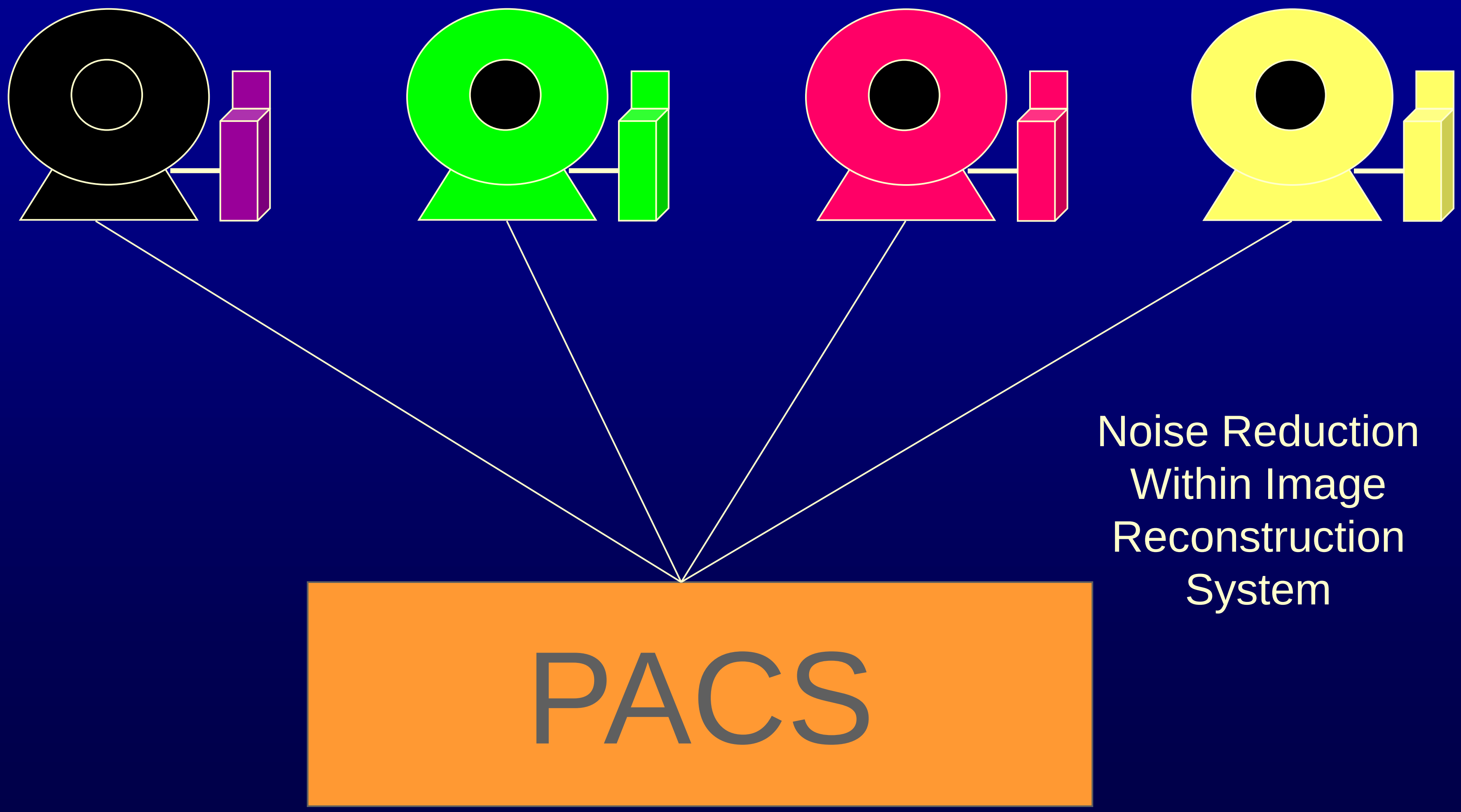
Original B40

Projection Space 1

SAFIRE

Projection Space 2

Integration of Noise Reduction on a Departmental Basis: Practical Considerations



Integration of Noise Reduction on a Departmental Basis: Practical Considerations

Steps for Implementation

- Start with exams where image quality improvement will help
  - e.g., small bowel masses, HCC, pancreatic mass

Image-based Denoising

Image Quality Improvement

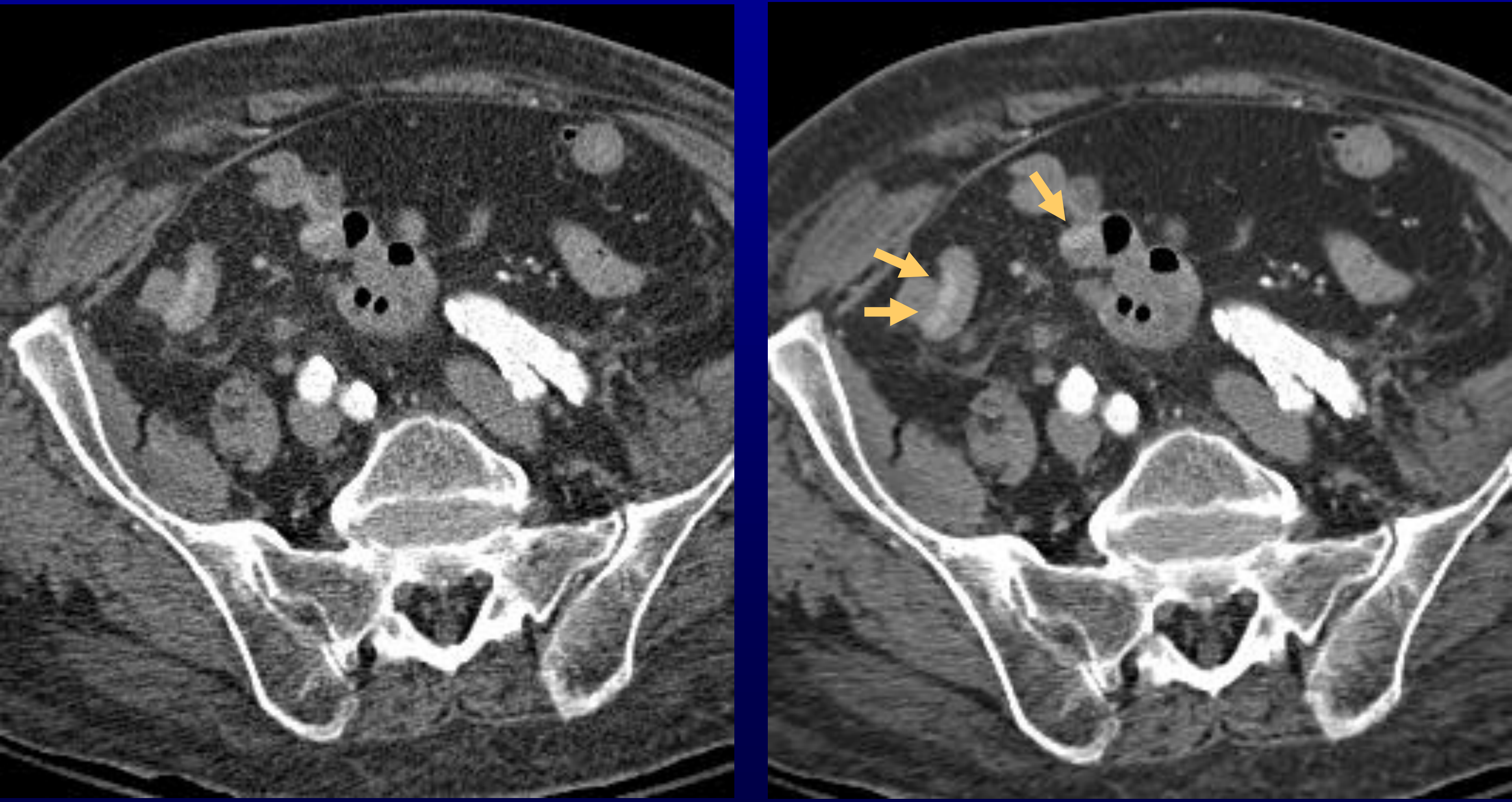
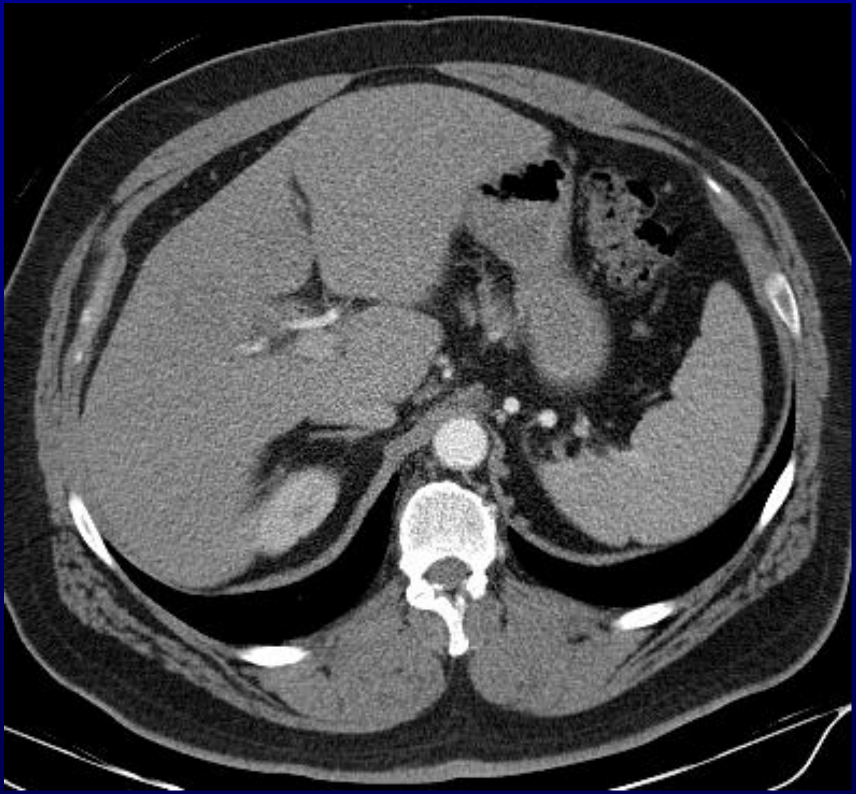
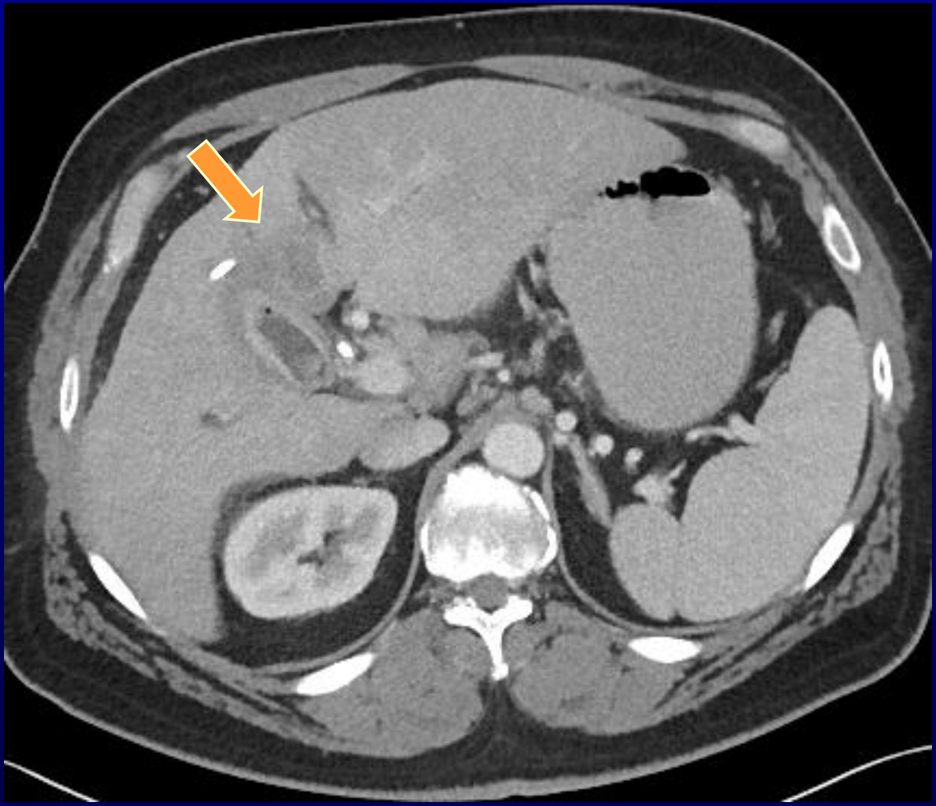


Image-based Denoising
Image Quality Improvement



August 5, 2011



September 30, 2011

Steps for Implementation

- Start with exams where image quality improvement will help
  - e.g., small bowel masses, HCC
- Satisfy yourself that you will not loose small low contrast objects
  - Try your noise reduction out on thinner slices with subtle lesions

What about low contrast detectability?

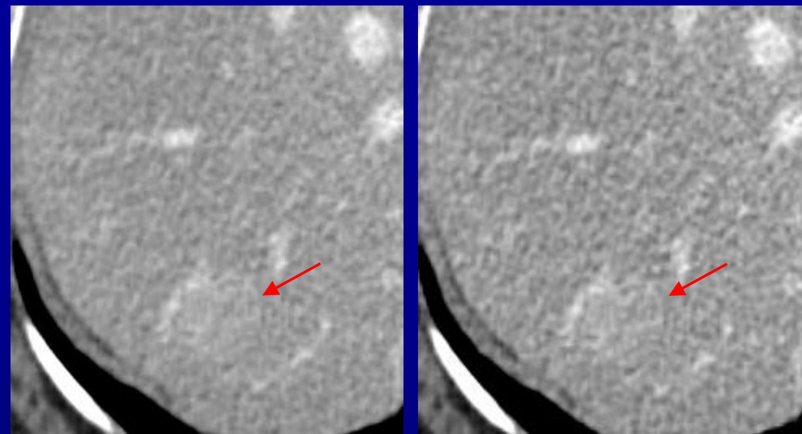
2 mm B40

1 mm B40

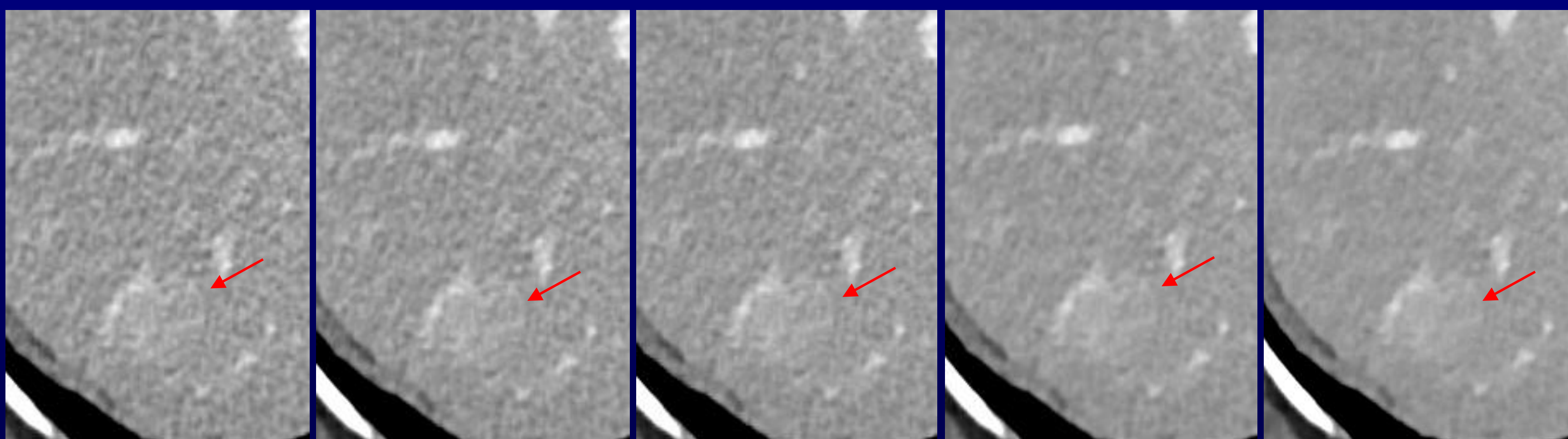
15 HU Δ

What about low contrast detectability?

2 mm
B40



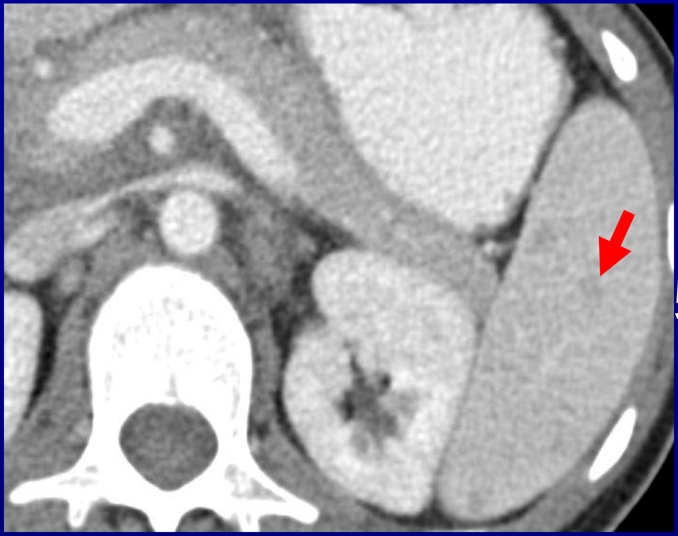
1 mm
B40



I40_1 I40_2 I40_3 I40_4 I40_5

1 mm Slices with SAFIRE

What about low contrast detectability?



20 HU Δ lesion

5 mm => 3 mm

I40_1

I40_2

I40_3

I40_4

I40_5

3 mm Slices with SAFIRE

Steps for Implementation

- Start with exams where image quality improvement will help
  - e.g., small bowel masses, HCC
- Satisfy yourself that you will not loose small low contrast objects
  - Try your noise reduction out on thinner slices with subtle lesions
- Focus on targeted exams
  - Reduce dose using AEC settings and implement noise reduction
  - Increase dose reduction as you feel more comfortable

Steps for Implementation

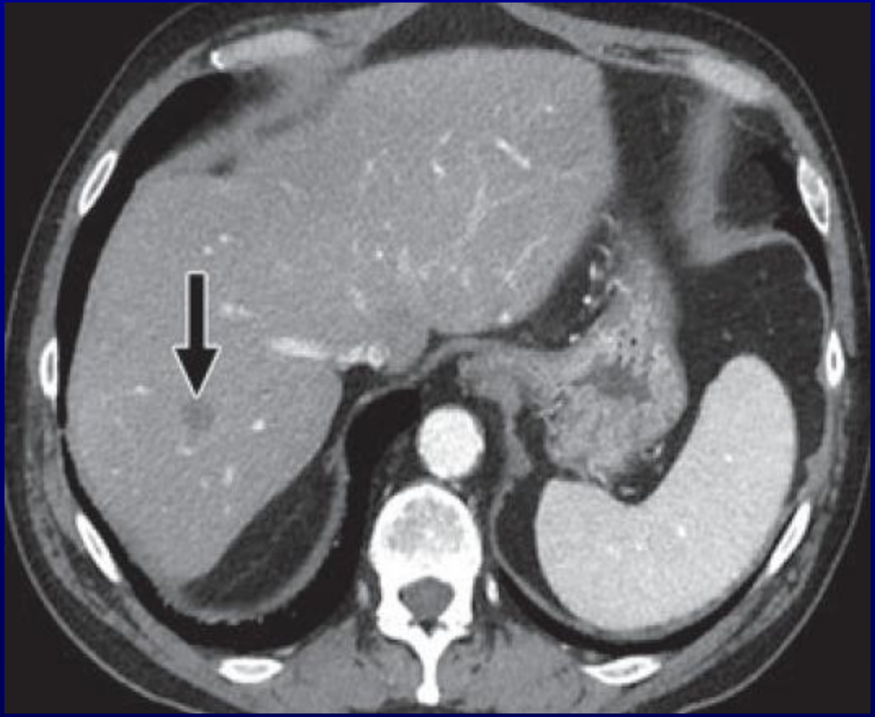
- Targeted exams
  - Younger patients (e.g., CT enterography)
  - Screening, f/u exams (e.g., CT colonography, CTU)
  - Routine abdomen pelvis
- Establish how to image at lower dose level that does not diminish observer performance
  - In your own practice
  - In the literature
  - Use your AEC to accomplish (usually 30 – 40%) dose reduction
- Compare image quality to pts with prior exams

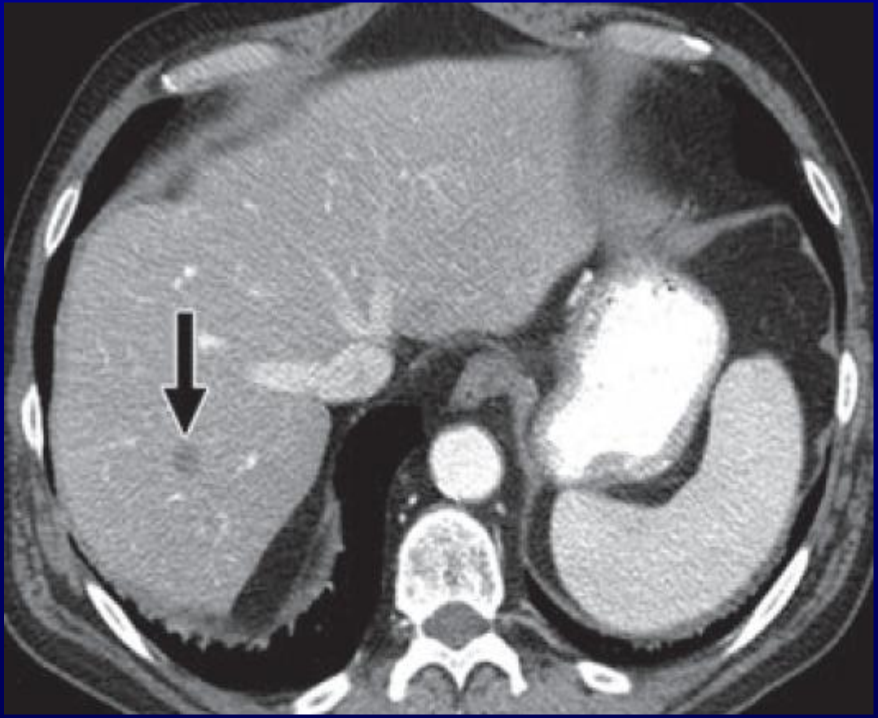
Implementing Noise Reduction

- Sagara, Hara, Pavlicek, et al. AJR 2010; 195: 713 – 719
  - Lowered dose by using AEC (noise index: 22 → 31) followed by recon using 40% ASIR
  - 53 pts with prior CT exams
  - Overall 33% reduction in dose (25 → 17 mGy CTDIvol)
  - Compared image quality to prior exams at routine dose
  - Lower-dose ASIR: ↓noise, ↓sharpness, = diagnostic acceptability

Iterative Noise Reduction

Impact on Implementation & Image Quality





17 mGy CTDIvol
40% ASIR

3.75 mm slices

27 mGy CTDIvol
FBP

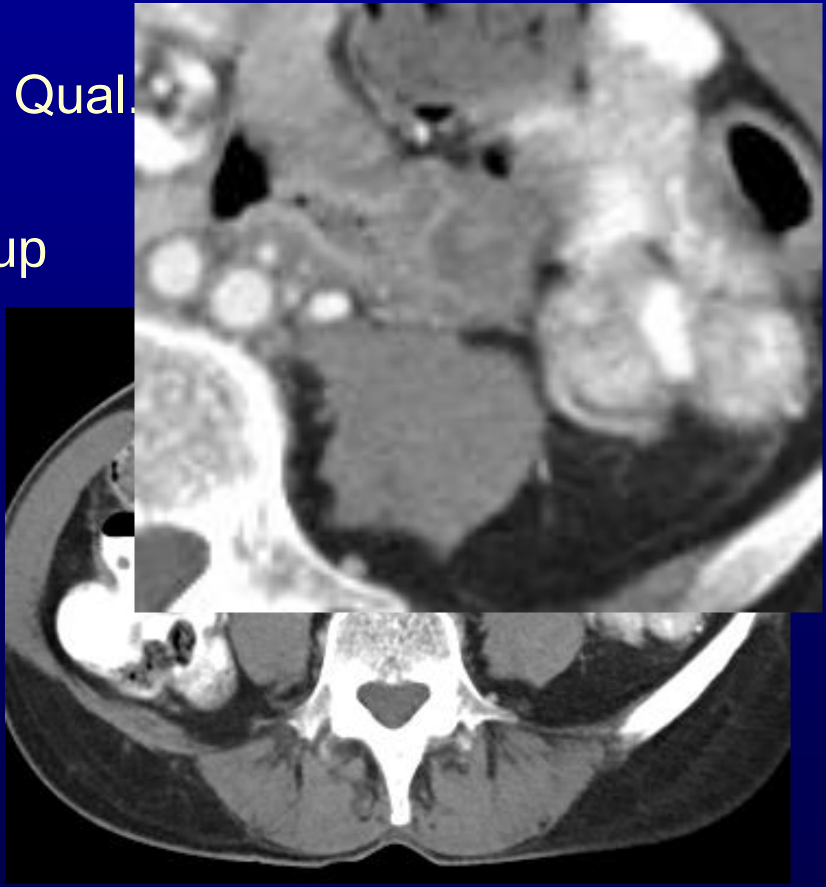
From Sagara, Hara, Pavlicek, et al. AJR 2010; 195: 713 – 719

Implementing Noise Reduction

Routine Abdomen Pelvis with Contrast

- Lower AEC settings by 1/3
- Care kV (120 kV, 240 → 180 Qual.
- Apply noise reduction
- Non-cancer & cancer follow-up

CTDIvol = 10.2 mGy



CTDIvol = 5.7 mGy

2 weeks apart

Implementing Noise Reduction

Routine Abdomen Pelvis with Contrast

- Lower AEC settings by 1/3
- Care kV (120 kV, 240 → 180 Qual. ref. mAs)
- Apply noise reduction
- Non-cancer & cancer follow-up

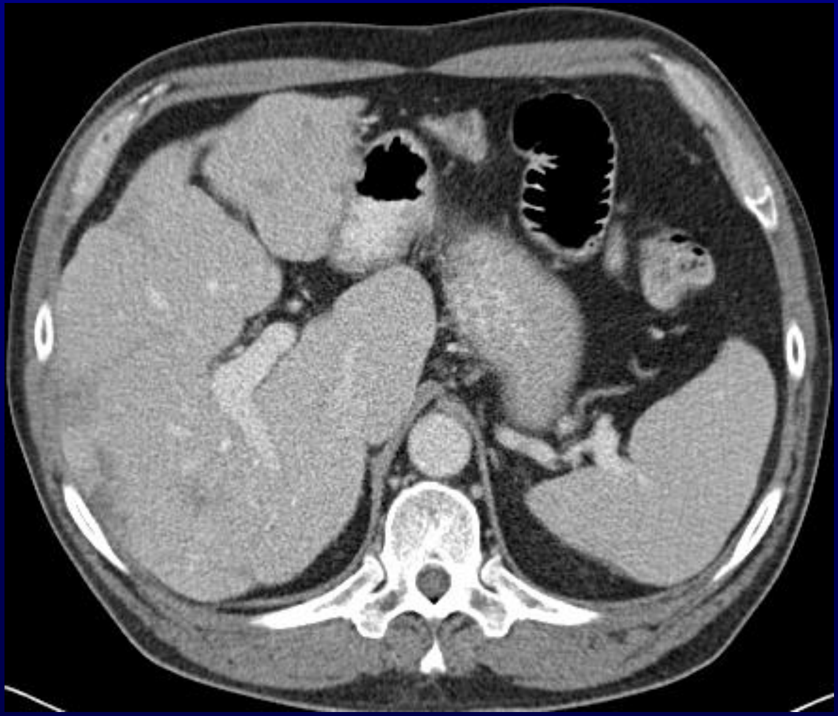
CTDIvol = 12.4 mGy

CTDIvol = 5.9 mGy

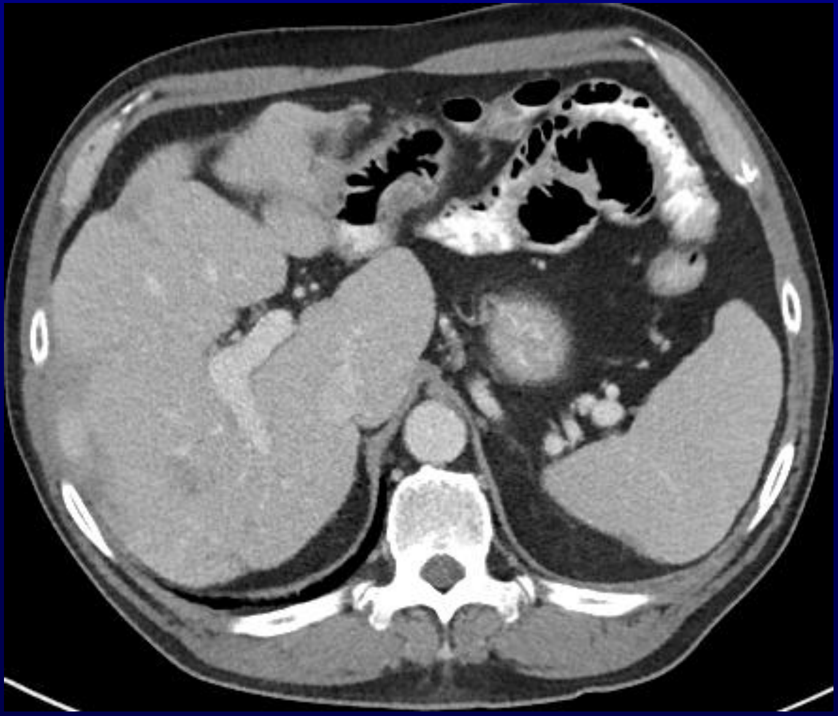
Implementing Noise Reduction

Biphase Liver with Contrast

- Lower AEC settings by 1/3
- Care kV (120 kV, 350 → 180 Qual. ref. mAs)
- Apply noise reduction
- Follow-up

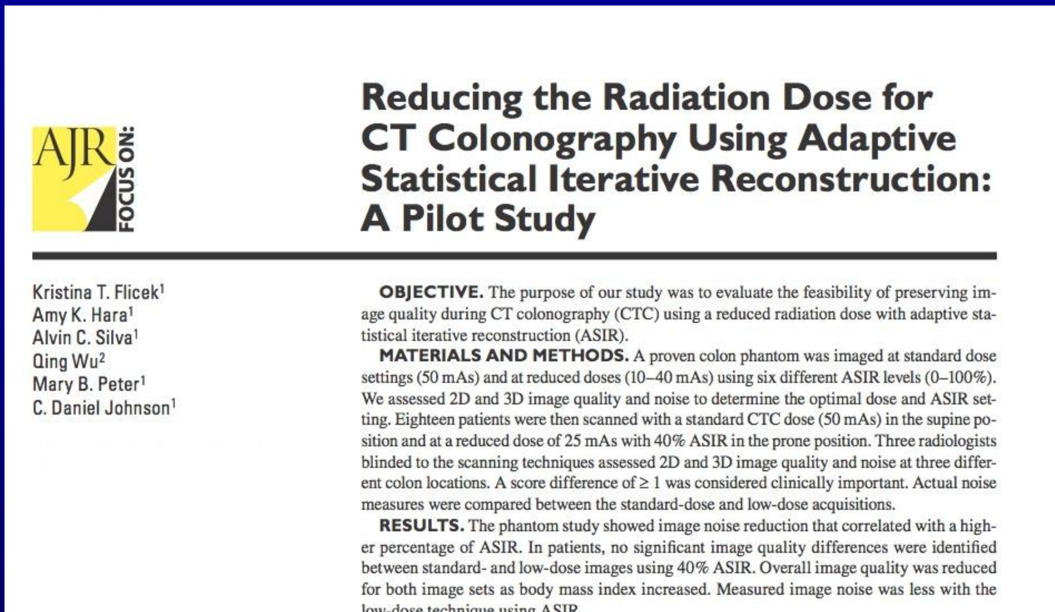


CTDIvol = 24.0 mGy



CTDIvol = 16.8 mGy

Implementing Noise Reduction



AJR FOCUS ON:

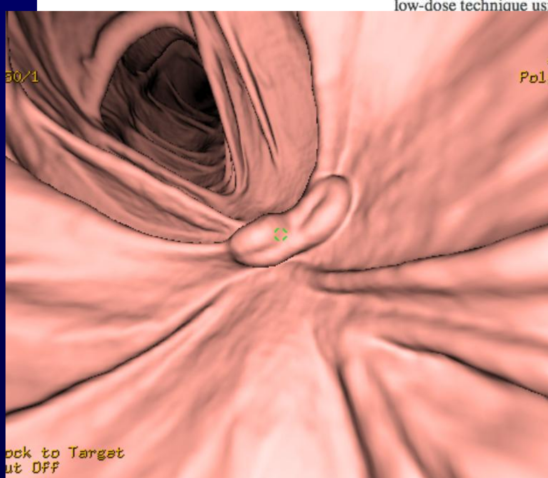
Reducing the Radiation Dose for CT Colonography Using Adaptive Statistical Iterative Reconstruction: A Pilot Study

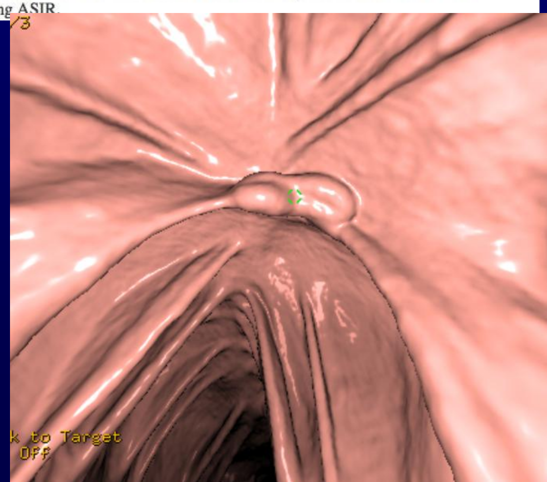
Kristina T. Flicek[1]
Amy K. Hara[1]
Alvin C. Silva[1]
Qing Wu[2]
Mary B. Peter[1]
C. Daniel Johnson[1]

OBJECTIVE. The purpose of our study was to evaluate the feasibility of preserving image quality during CT colonography (CTC) using a reduced radiation dose with adaptive statistical iterative reconstruction (ASIR).

MATERIALS AND METHODS. A proven colon phantom was imaged at standard dose settings (50 mAs) and at reduced doses (10–40 mAs) using six different ASIR levels (0–100%). We assessed 2D and 3D image quality and noise to determine the optimal dose and ASIR setting. Eighteen patients were then scanned with a standard CTC dose (50 mAs) in the supine position and at a reduced dose of 25 mAs with 40% ASIR in the prone position. Three radiologists blinded to the scanning techniques assessed 2D and 3D image quality and noise at three different colon locations. A score difference of ≥ 1 was considered clinically important. Actual noise measures were compared between the standard-dose and low-dose acquisitions.

RESULTS. The phantom study showed image noise reduction that correlated with a higher percentage of ASIR. In patients, no significant image quality differences were identified between standard- and low-dose images using 40% ASIR. Overall image quality was reduced for both image sets as body mass index increased. Measured image noise was less with the low-dose technique using ASIR.

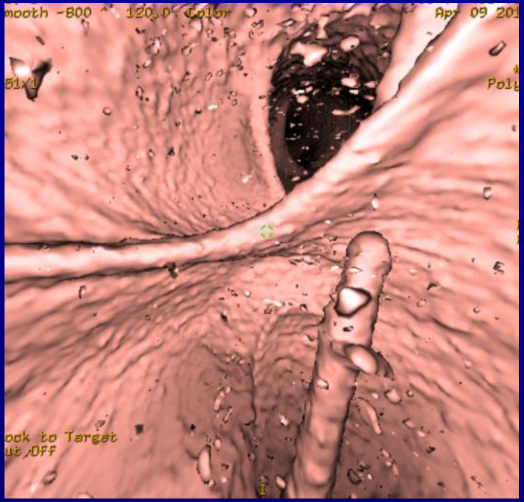


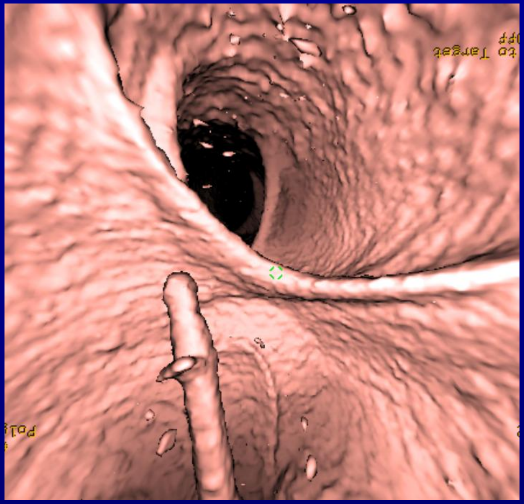


Flicek et al. AJR 2010

- Phantom & human study (18 pts)
- 50 mAs supine vs. 25 mAs prone + ASIR
- Lower dose ASIR acquisition – no difference in 2D or 3D IQ

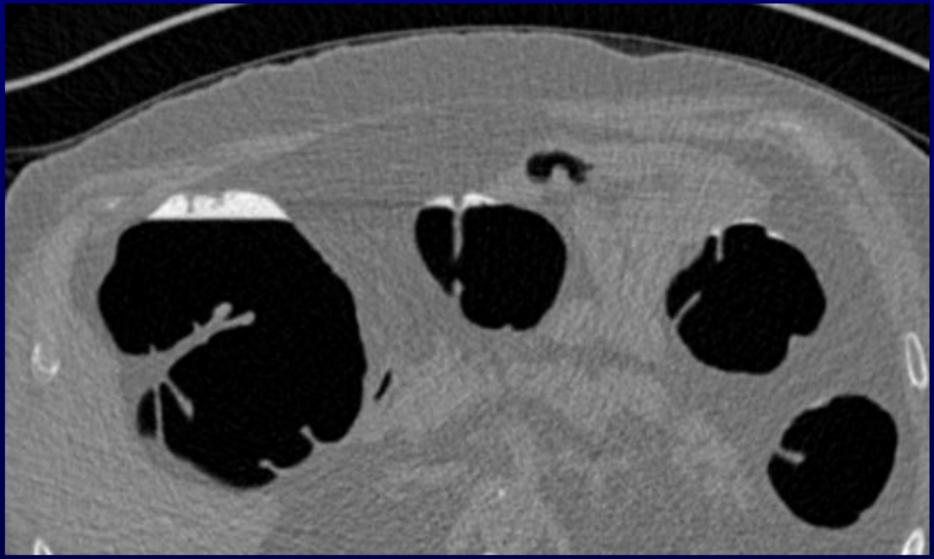
Implementing Noise Reduction

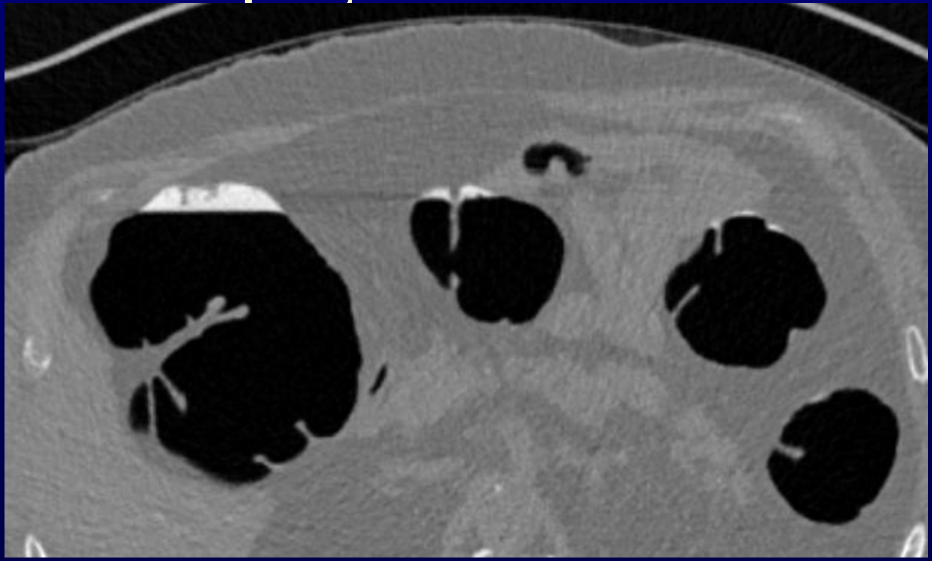




Practice Change

- Routine dose supine
- ½ dose additional positions with noise





Important Reasons to Consider Noise Reduction

Image quality, confidence, fatigue & acceptability

19 yo female
CTDI vol 3.5 mGy

2mm slice
B40

2mm slice
SAFIRE

Conclusions

- Noise reduction can significantly improve image quality
  - Improves conspicuity of subtle lesions
  - Facilitates substantial and routine dose reduction without sacrificing image quality
  - Dose reduction comes from lowering mAs settings appropriately
- Observer performance data lacking
- Should be utilized differently depending on diagnostic task
- Multiple approaches have different practical implications