Advances in CT Dose Reduction Technology

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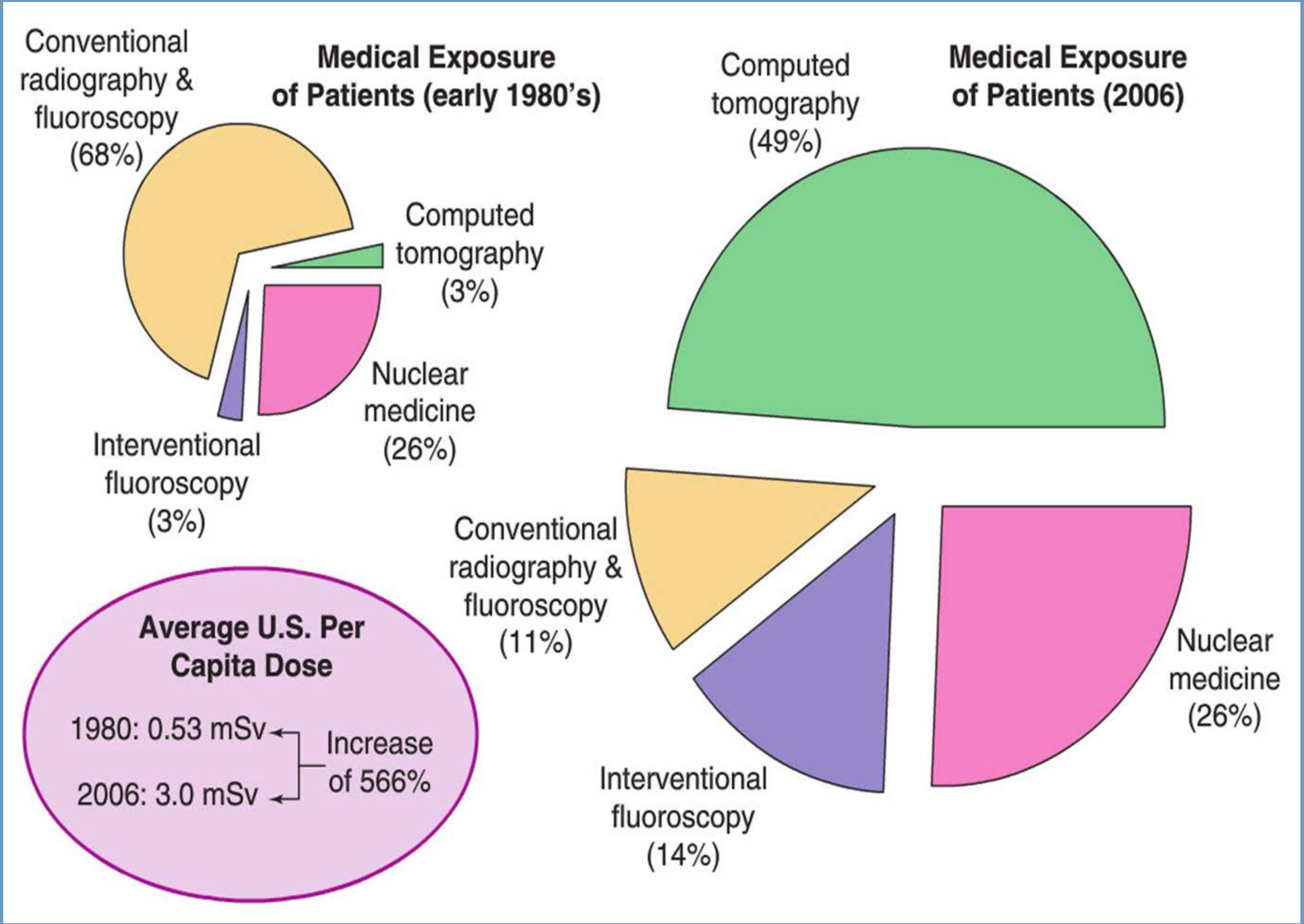
Outline

- Background
- Concerns about radiation dose from medical CT
- Concept of dose reduction
- Current techniques for dose reduction

Medical Radiation Exposure

Based on NCRP Report No. 160 (2009)
"Ionizing Radiation Exposure of the Population of the United States"



A 2007 Publication on CT Radiation Exposure

The NEW ENGLAND JOURNAL of MEDICINE

REVIEW ARTICLE

CURRENT CONCEPTS

Computed Tomography — An Increasing Source of Radiation Exposure

David J. Brenner, Ph.D., D.Sc., and Eric J. Hall, D.Phil., D.Sc.

N Engl J Med 2007; 357:2277-2284 | November 29, 2007 | DOI: 10.1056/NEJMra072149

AAPM effort

http://www.aapm.org/publicgeneral/StatementBeforeCongress.asp


AAPM Announcements - AAPM Statement Before Congress - Wednesday, February 10, 2010 - Windows Internet Explorer provided by M. D

http://www.aapm.org/publicgeneral/StatementBeforeCongress.asp

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The American Association of Physicists in Medicine

2011 Joint AAPM/COMP Meeting

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Photo: Sylvia Johnson Photography

As many of you know, there have been a number of recent articles in the press related to tragic errors in radiation therapy. This combined with the recent publicity on CT perfusion dose problems has prompted Congress to call a hearing entitled "Medical Radiation: an Overview of the Issues". AAPM, along with ASTRO, ACR, ASRT and MITA have been asked to testify to help guide direction for improving patient safety in the medical use of radiation. The Hearing has been rescheduled for Friday, February 26th in Washington. A copy of the written testimony submitted by AAPM is available below. We sincerely believe that working together with all stakeholders that we can improve safety and quality in the medical use of radiation.

Mike Herman, AAPM President

» If you missed it, you can watch video of the hearing and read witness testimonies.

Statement of Michael G. Herman, Ph.D., FAAPM, FACMP
On Behalf of the American Association of Physicists in Medicine (AAPM)
Before the Subcommittee on Health of the House Committee on Energy and Commerce

February 26, 2010

Chairman Pallone, Ranking member Deal and members of this distinguished committee, good morning and thank you for the opportunity to testify today on Medical Radiation: an Overview of the Issues.

It is my pleasure to be here representing the American Association of Physicists in Medicine, known generally as the AAPM. AAPM is a scientific and professional organization, founded in 1958, composed of nearly 7000 scientists whose clinical practice is dedicated to ensuring accuracy, safety and quality in the use of radiation in medical procedures such as medical imaging and radiation therapy. We are generally known as medical physicists and are http://www.pedrad.org/associations/5364/ig/

The Alliance for Radiation Safety in Pediatric Imaging

...re for kids! The ***image gently*** Campaign is an initiative of the Alliance for Radiation Safety in Pediatric Imaging. The ... practice by increasing awareness of the opportunities to promote radiation protection in the imaging of children.

... Impact

... launched ... of what has happened since:

12,783 medical professionals have taken the pledge

This website has been visited 354,691 times

The CT protocol has been downloaded over 26,000 times

Click here to take the image ...

Hot Off the Press...

AAPM Task Group Releases Dose Report

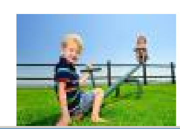
The AAPM Task group 204 document that now provides an estimate of patient dose within 10 - 20 percent for body CT by patient body habitus.

VIEW THE REPORT »

Protecting Kids | Butterfly Award | IAEA Video | Radiation Risk | Dose Report

Welcome & Latest News

News from Image Wisely



Public Service Announcement

http://www.pedrad.org/associations/5364/ig/?page=614 http://www.imagewisely.org/

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Pledge to image wisely by optimizing the use of radiation when imaging patients.

12268

PLEDGES TO DATE

In the News

RECENT DEVELOPMENTS

Image Wisely/Image Gently Posters Now Available

Show your commitment to Image Wisely and Image Gently -- display our full-color poster in your waiting rooms and scan rooms. Posters cost just $3 each and you may order as many as you like. Shipping is included free of charge.

>>Order your poster now

Note: *The order link will take you to the American College of Radiology online store. The poster measures 23 in. wide by 35 in. tall and will be shipped in a protective tube.*

Image Wisely is a program of the American College of Radiology, the Radiological Society of North America, the American Association of Physicists in Medicine and the American Society of Radiologic Technologists.

Concepts of Dose Reduction

- Many different concepts
- Do more with less (detector efficiency)
- Avoid unnecessary exposures (beam collimation)
- Optimum beam energy for low-contrast detectability and penetration (filtration and kVp)
- Appropriate tube current adapted to body habitus (TCM)
- Advanced reconstruction algorithms for noise reduction (iterative)

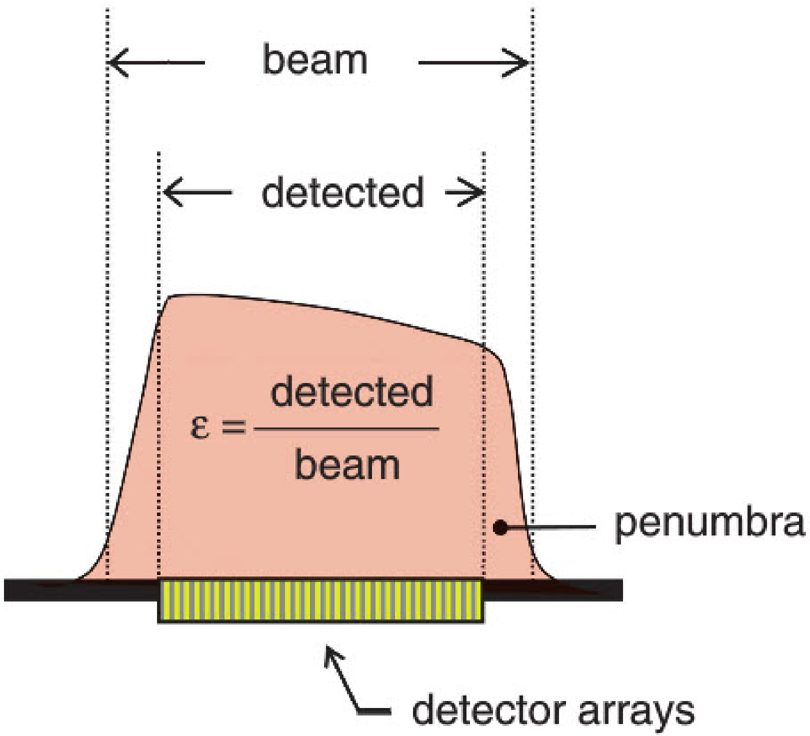
<u>A comprehensive review article:</u>

McCollough et al. CT dose reduction and dose management tools: Overview of available options. Radiographics. 2006;26:503-512.

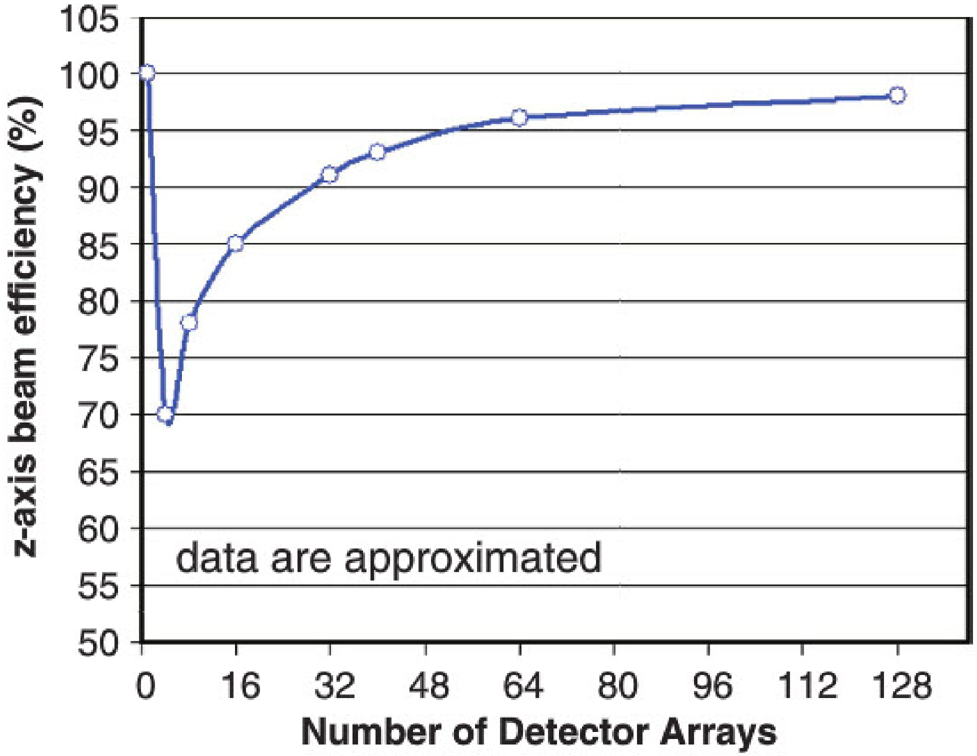
Dose Reduction Techniques

- Beam collimation
- Organ shields
- Tube current modulation (TCM)
- Auto kV optimization
- Iterative reconstruction

Geometric Efficiency of Radiation Beam



A. The shape of the x-ray beam and position of x-ray detector arrays are illustrated



B. The relative geometric dose efficiency as a function of detector arrays is shown

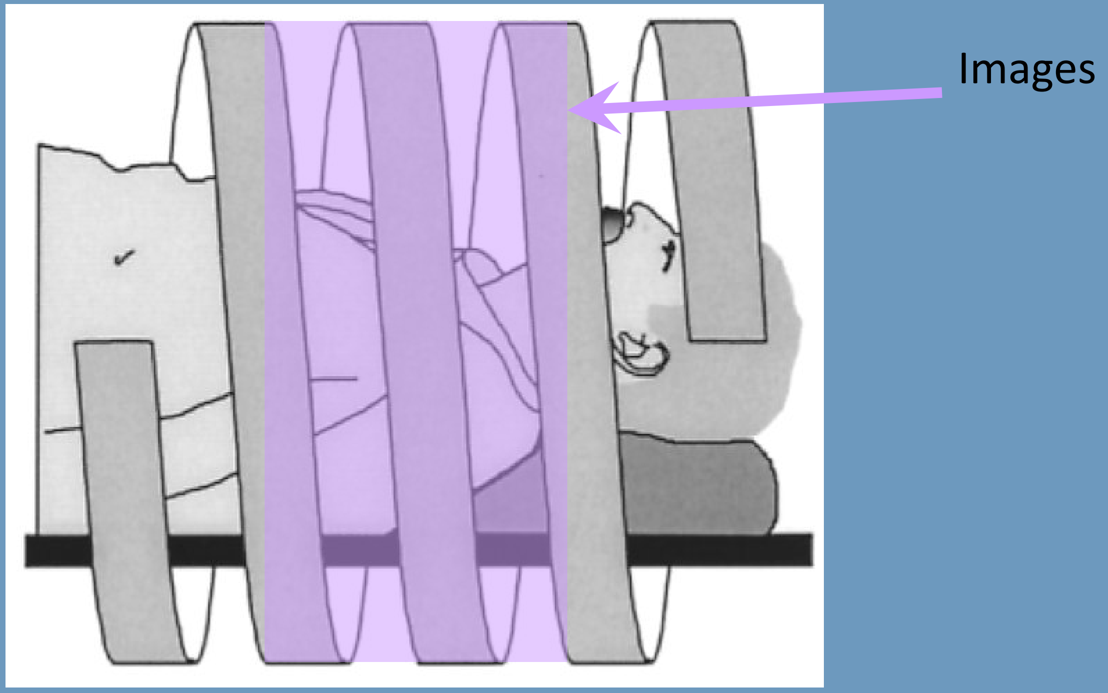
Wider beam width, higher geometric efficiency

- Fewer penumbra – less wasted radiation per rotation
- Fewer rotations to cover a scan range
  - Less wasted radiation overall
  - Faster scan time
  - Shorter exposure time (tube heat)
- Reduce dose by ~15%?

- **Should the widest beam be always the choice?**

What about Over-Ranging?

- Reconstruction for spiral scan needs data outside of the scan range so to include the selected anatomy in images
- 1-4 additional rotations on each end of spiral scan acquisition



What about Over-Ranging?

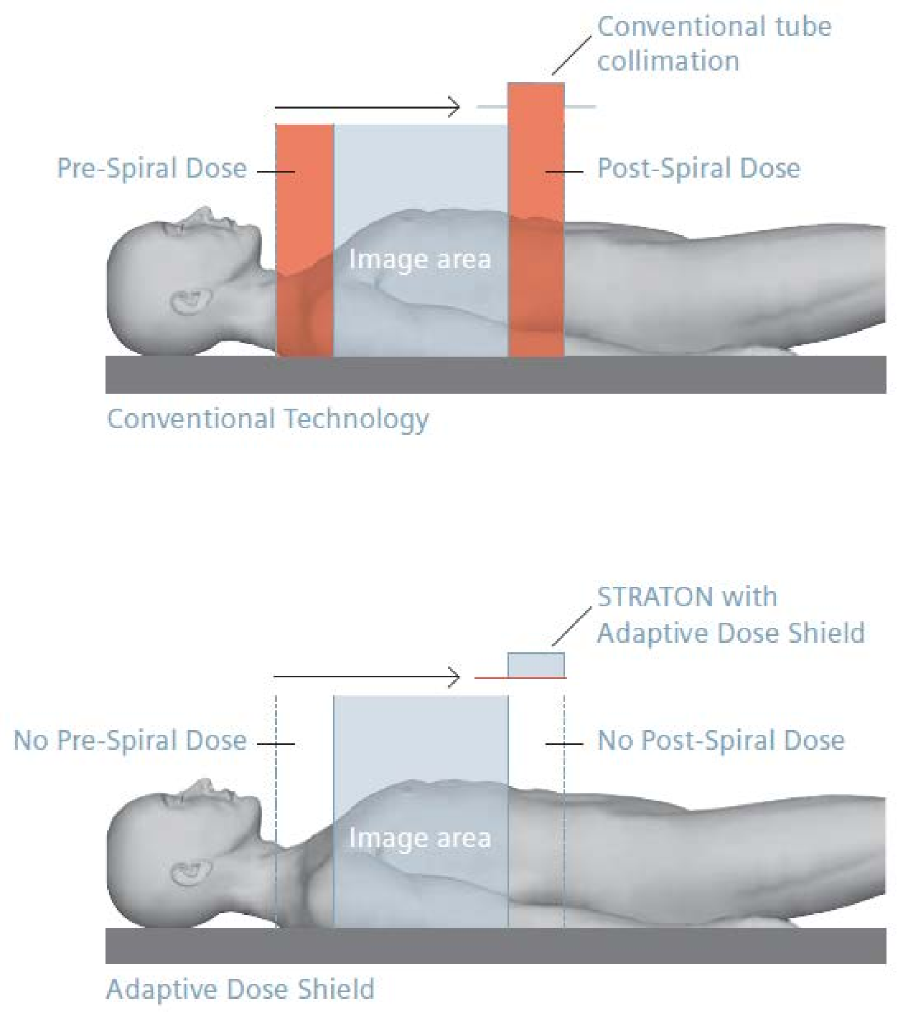
- Reconstruction for spiral scan needs data outside of the scan range so to include the selected anatomy in images
- 1-4 additional rotations on each end of spiral scan acquisition

- Delivers additional dose that is NOT accounted for in routine parameters
- Can add substantial dose when **wide beam** is used (like 40mm for instance)

- **The widest beam may not always be the choice!**

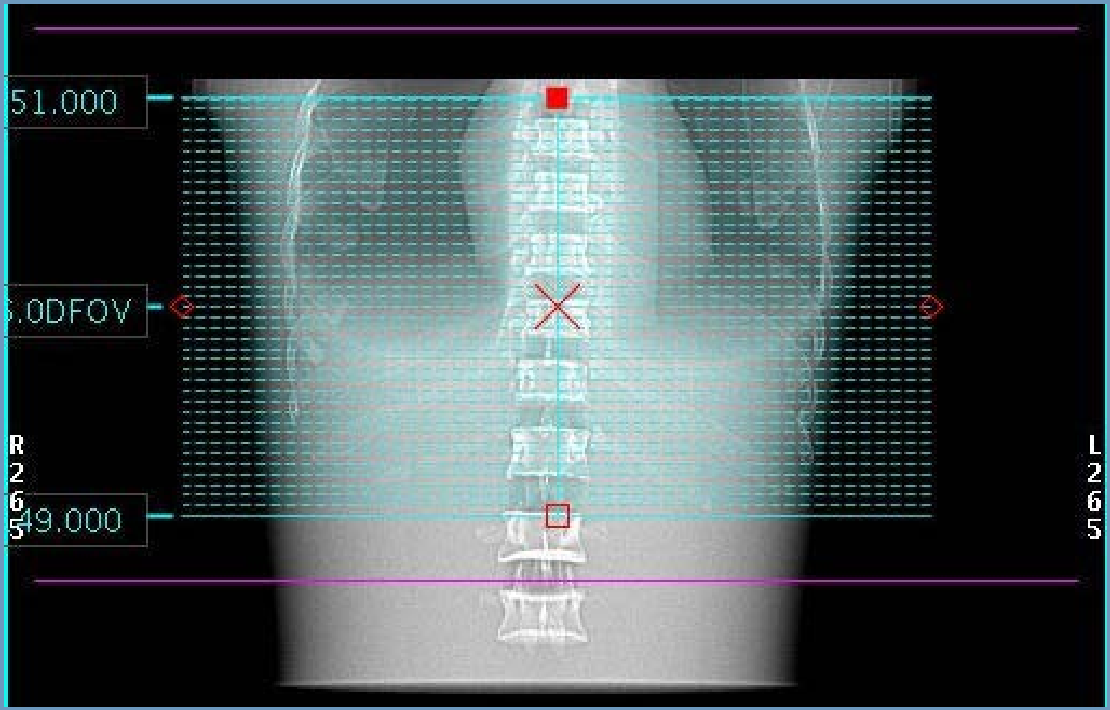
Siemens Adaptive Beam Collimation

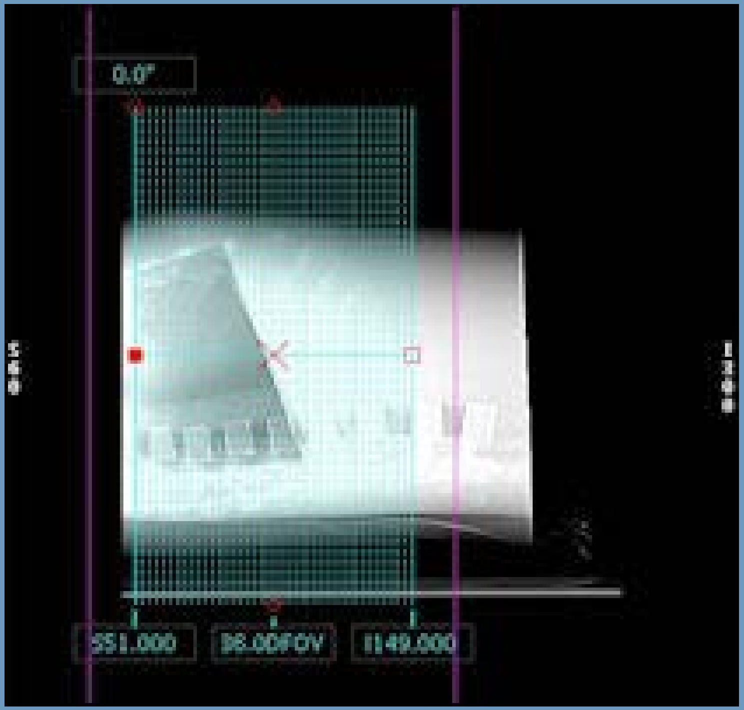
- Independent control of collimator jaws
- Cuts back on over-ranging exposure
  - o At start of helical acquisition
  - o At end of helical acquisition
- Claim dose reduction of up to 25%
- Will depend on beam width & pitch



SOMATOM Definition Flash brochure

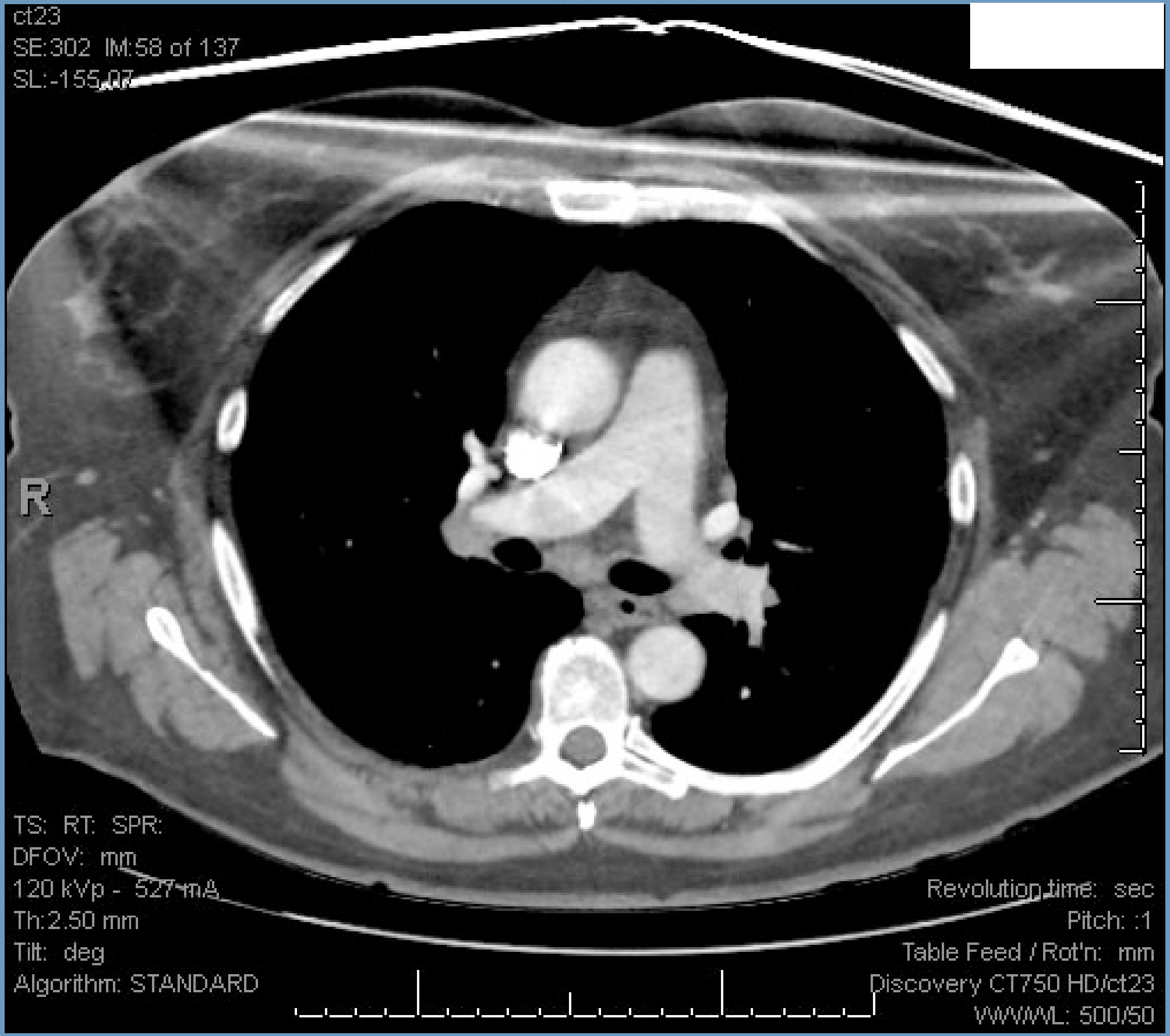
GE Dynamic Z-Axis Beam Tracking





GE HD750 User's manual

Bismuth Shields



Bismuth Shields: use or not

<u>Advantages</u>

- Only affects IQ in limited area
- Does result in lower dose to breast tissue
- Patients like them
- Radiologists feel they are doing something good

<u>Disadvantages</u>

- Affects IQ
  - ➢ Artifacts
  - ➢ Alter CT Numbers
  - ➢ Increase Noise
- Filters exit beam – wastes dose
- Training required (TCM)
- Disinfection required
- Size of shield important

A JACR article
Bismuth Shields for CT Dose Reduction: Do They Help or Hurt?

McCollough CH, Wang J, Berland LL: Bismuth Shields for CT Dose Reduction: Do They Help or Hurt? Journal of the American College of Radiology 2011, 8(12):878-879.

More publications from Mayo Clinic:

Wang J, Duan X, Christner JA, Leng S, Yu L, McCollough CH: Radiation Dose Reduction to the Breast in Thoracic CT: Comparison of Bismuth Shielding, Organ-based Tube Current Modulation and Use of a Globally Decreased Tube Current. Med Phys 2011, 38(11):6084-6092.

Wang J, Duan X, Christner JA, Leng S, Grant KL, McCollough CH: Bismuth Shielding, Organ-based Tube Current Modulation and Global Reduction of Tube Current for Dose Reduction to the Eye in Head CT. Radiology 2012, 262(1):191-8.

AAPM Position Statement (2/7/2012)

Use of Bismuth Shielding for the Purpose of Dose Reduction in CT Scanning

Bismuth shields are easy to use and have been shown to reduce dose to anterior organs in CT scanning. However, there are several disadvantages associated with the use of bismuth shields, especially when used with automatic exposure control or tube current modulation. Other techniques exist that can provide the same level of anterior dose reduction at equivalent or superior image quality that do not have these disadvantages. The AAPM recommends that these alternatives to bismuth shielding be carefully considered, and implemented when possible.

Tube Current Modulation

Tube Current Modulation (TCM) has been a popular and powerful tool for achieving radiation dose reduction.

Image noise (or ‘image quality’) is expected to be maintained at the same level across patient anatomy of different shapes/sizes.

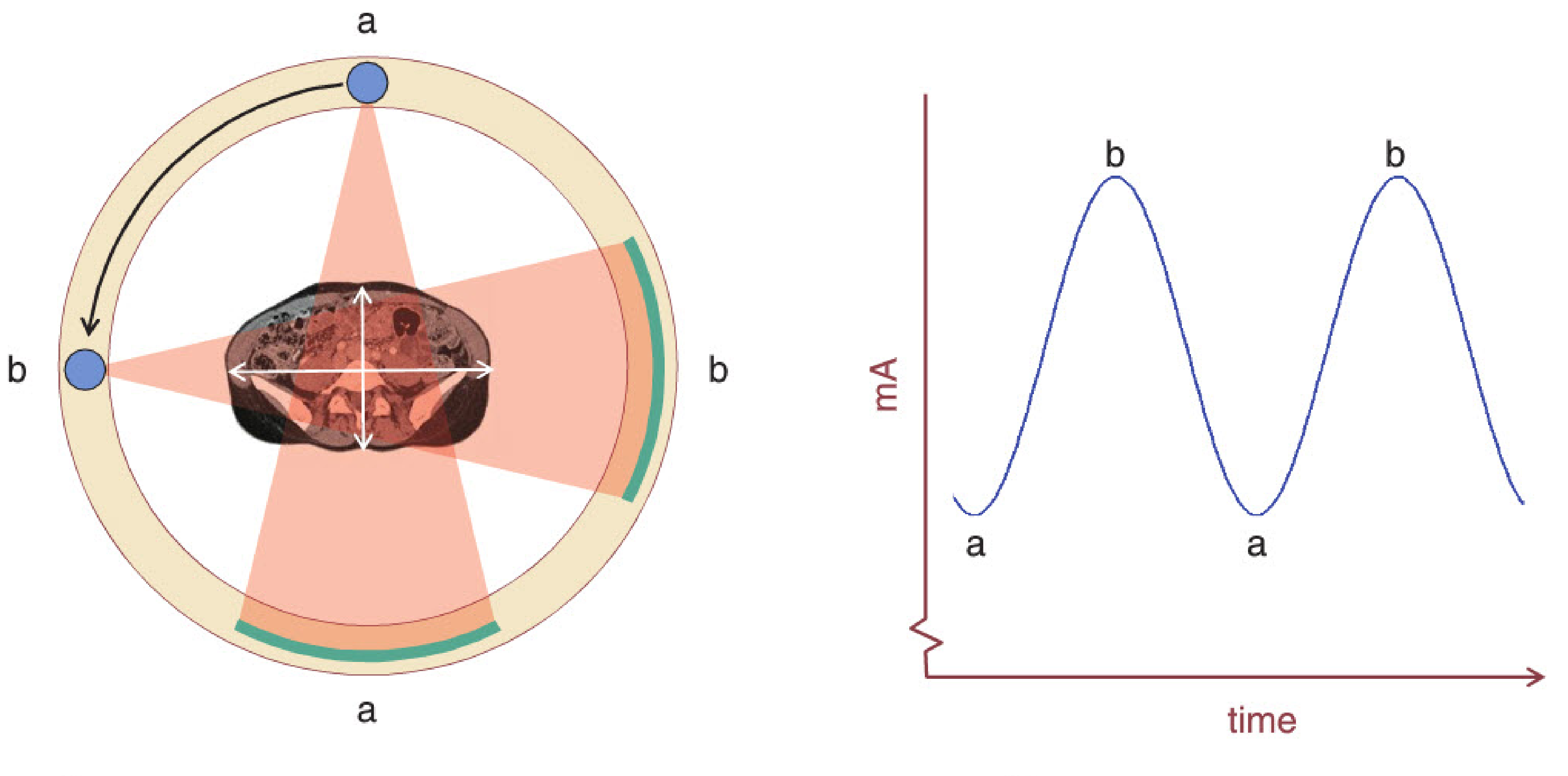
TCM: two schemes

- Angular (in-plane, x/y-axis) modulation
- Longitudinal (z-axis) modulation

Ibid.

TCM: angular modulation

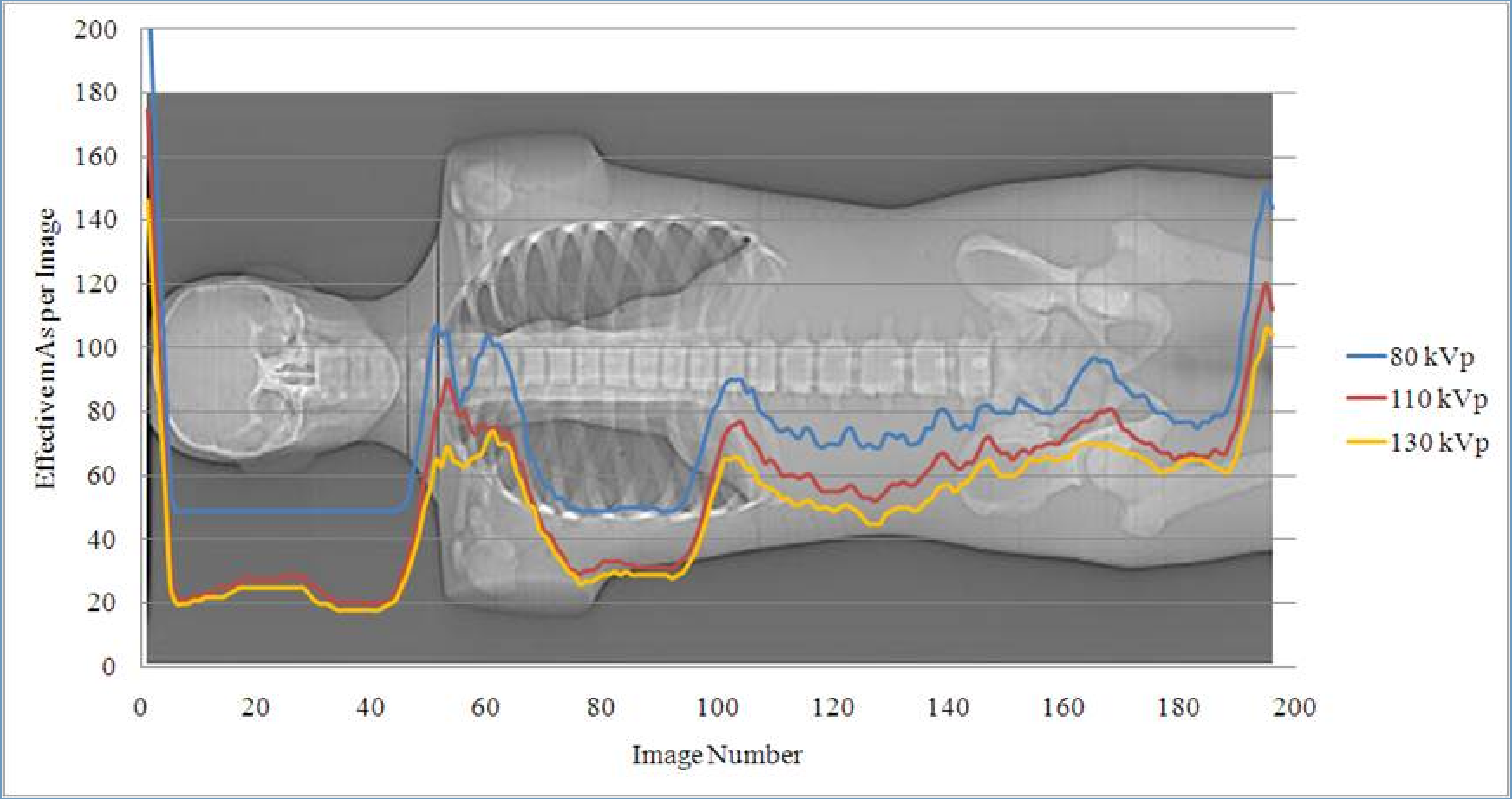
- Based on attenuation map for each rotation (patient size) to achieve “right sizes” mA in x/y plane



A. Tube rotation around oval patient **B.** mA modulation

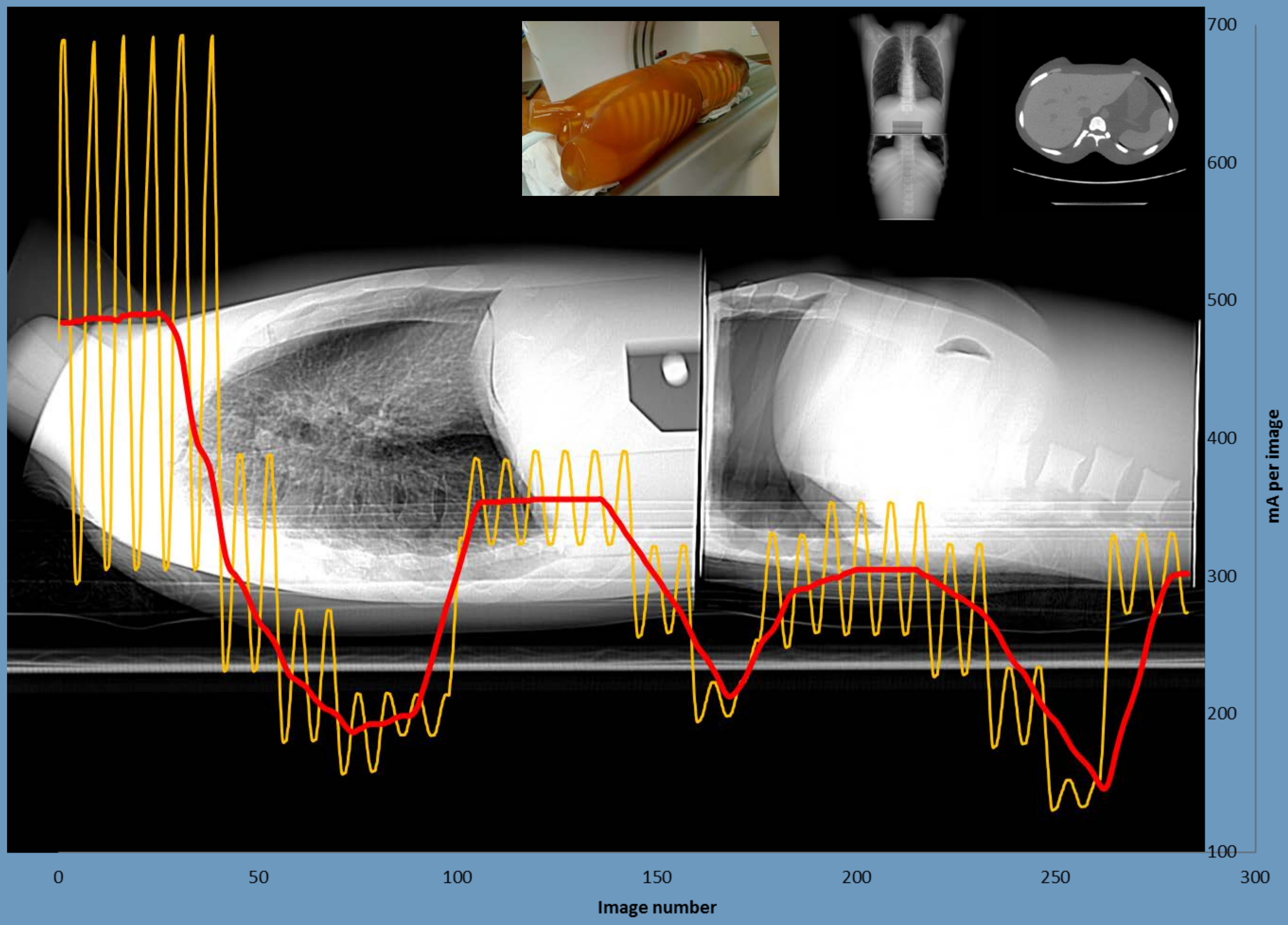
TCM: longitudinal modulation

- Based on shape of each patient to achieve “right shapes” mA along z-axis



Courtesy of Cheenu Kappadath, PhD

Example Tube Current Modulation (TCM) on GE HD750



Effects of TCM

- Can result in radiation dose decrease
  - Average to small patients
- Can also result in radiation dose increase
  - Large to extra-large patients

Must understand HOW a TCM scheme works!

TCM terms used by vendors

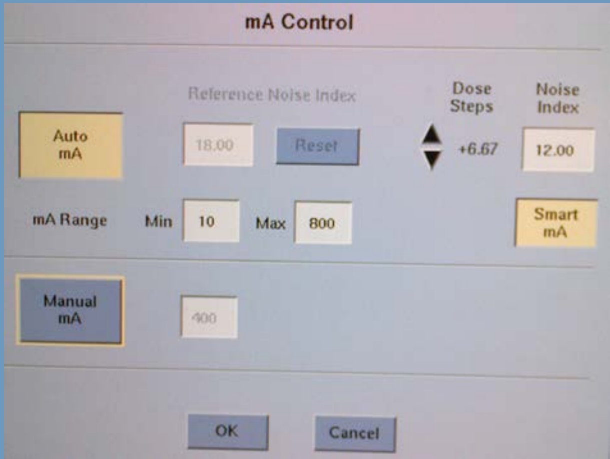
- GE: Smart Scan, Auto mA, Smart mA
- Siemens: CareDose, CareDose4D, XCARE (new)
- Philips: Angular, DOM, Z-DOM, DoseRight
- Toshiba: SureExposure, SureExposure3D

Image Quality Indicator

- GE: Noise index
- Siemens: Quality reference mAs
- Philips: Reference image
- Toshiba: Standard deviation

TCM on GE

- Auto mA: longitudinal TCM (*can be used alone*)
- Smart mA: angular TCM (*can only be used with Auto mA*)
- Based on scout images
- **Preset Noise Index (NI)**: to achieve predicted noise level (in terms of standard deviation) in 20 cm water phantom with Standard recon algorithm; and, **is expected to maintain the same noise level across different shapes/sizes**
- Choice of NI depends on factors such as:
  - recon algorithm (kernel)
  - image thickness

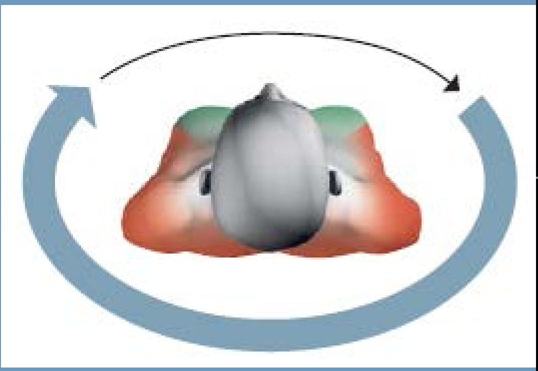


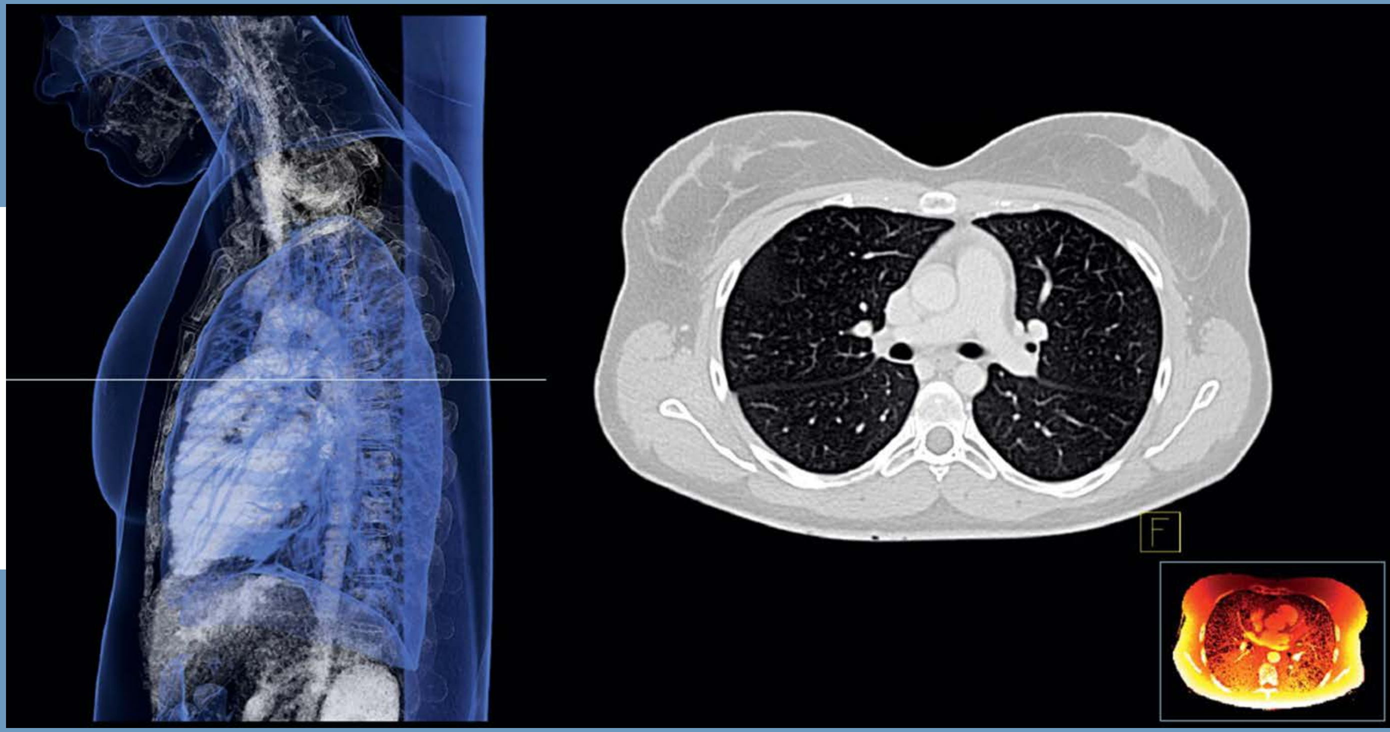
TCM on Siemens

- Quality Reference mAs (CARE Dose 4D)
- For each exam select mAs/pitch for a 70 kg patient
- In pediatric mode reference patient is 20 kg (5 yr old)
- Uses empirical impression of image quality algorithm
- Topograms (scouts) are used to predict tube current along x, y, and z axes
- Scaling for varying patient size can be “weak”, “average”, or “strong”
- Online real time (180 degree lag) feedback for fine-tuning (hence “4D”)

Siemens XCARE

- Dose reduction specific to sensitive organ (e.g. breast)
- Tube current OFF within a certain range of projections, minimizing direct exposure dose to sensitive organ
- Up to 40 % dose reduction to sensitive organ





SOMATOM Definition Flash brochure

Considerations in using TCM

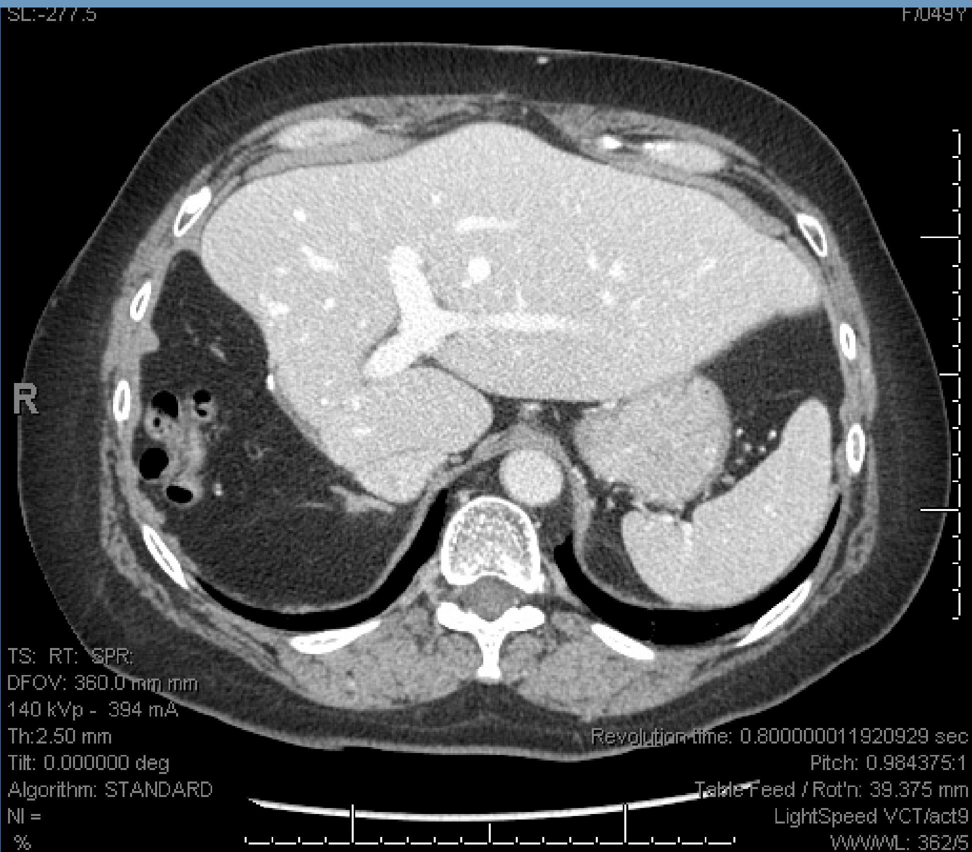
- Use in exams where max changes in attenuation path
  - Head/Neck/Shoulders
  - Chest/Abd/Pelvis
- Use for exams where patient size quite variable
  - Pediatric protocols

- Use in routine head exams? Not typically recommended
- NEVER in perfusion studies! (think Cedars-Sinai)

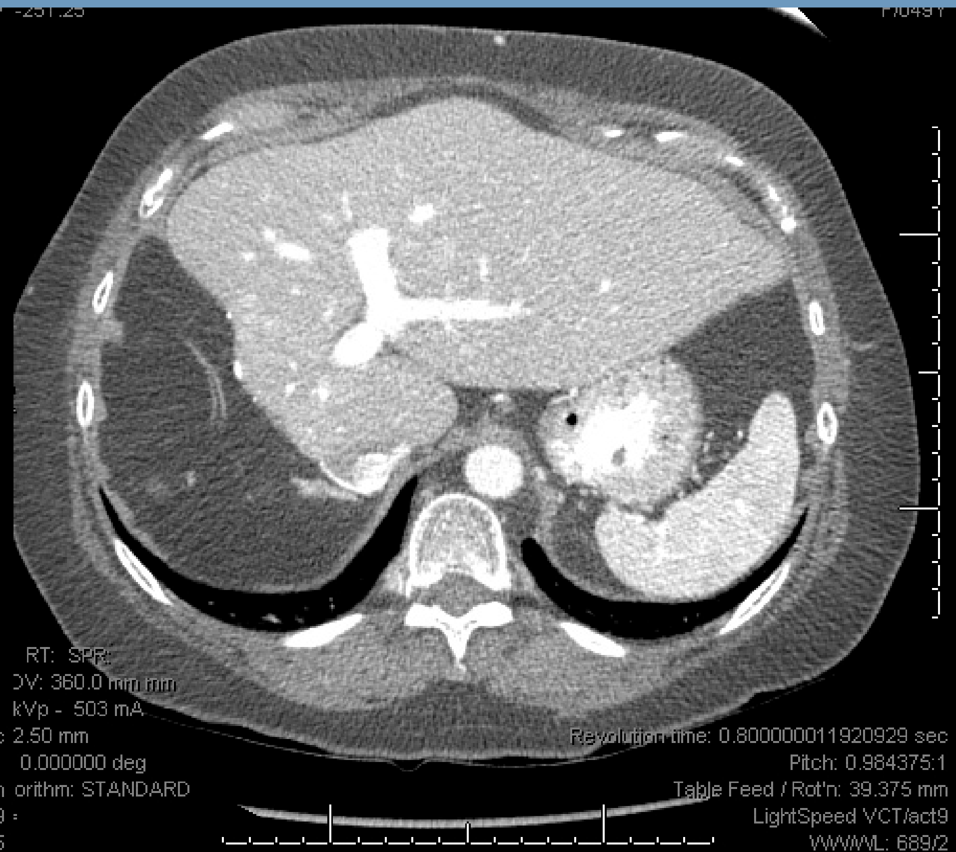
kV optimization

- Growing interest in optimizing kV settings below 120
- Lowering kV results in dramatic dose decrease with a constant mA; however, noise increases significantly.
- Push for this is some specialized exams (low-contrast, e.g. liver imaging)
- Lowering kV with TCM can increase image contrast in certain clinical exams and keeps the image noise constant. However, very little effect on the radiation dose.

Patient Example



140 kV NI = 10



80 kV NI = 10, max mA 500

Exam Description: CAP W CON-- LIVER

Dose decreased by 76%

Dose Report

Series	Type	Scan Range (mm)	CTDIvol (mGy)	DLP (mGy-cm)	Phantom cm
1	Scout	-	-	-	-
2	Helical	I193.500-I463.500	26.19	827.72	Body 32
200	Axial	I332.250-I332.250	10.58	5.30	Body 32
4	Helical	I195.000-I405.000	41.86	1071.95	Body 32
4	Helical	I195.000-I405.000	41.85	1071.70	Body 32
4	Helical	I406.500-I711.500	54.39	1909.35	Body 32
7	Helical	I30.000-I360.000	19.13	720.20	Body 32
7	Helical	I195.000-I445.000	33.40	988.86	Body 32
7	Helical	I530.000-I645.000	37.58	605.41	Body 32
			Total Exam DLP:	7200.49	

108 mSv using 140kV

26 mSv using 80kV

LIV)

Dose Report

Series	Type	Scan Range (mm)	CTDIvol (mGy)	DLP (mGy-cm)	Phantom cm
1	Scout	-	-	-	-
2	Helical	I175.500-I390.500	8.32	217.28	Body 32
200	Axial	I285.000-I285.000	2.34	1.18	Body 32
4	Helical	I178.750-I343.750	10.40	219.58	Body 32
4	Helical	I178.750-I343.750	10.40	219.58	Body 32
4	Helical	I345.000-I640.000	8.32	283.86	Body 32
7	Helical	I1.250-I331.250	11.86	446.53	Body 32
7	Helical	I181.500-I406.500	8.32	225.60	Body 32
7	Helical	I538.000-I613.000	8.32	100.77	Body 32
			Total Exam DLP:	1714.38	

When is low kV the best option?

- When dose is a concern:
  - Drop from 120kV to 80kV
    - Dose drops in half without any other changes
  - Neuro CT Perfusion protocols (80 kV)
  - Newborns

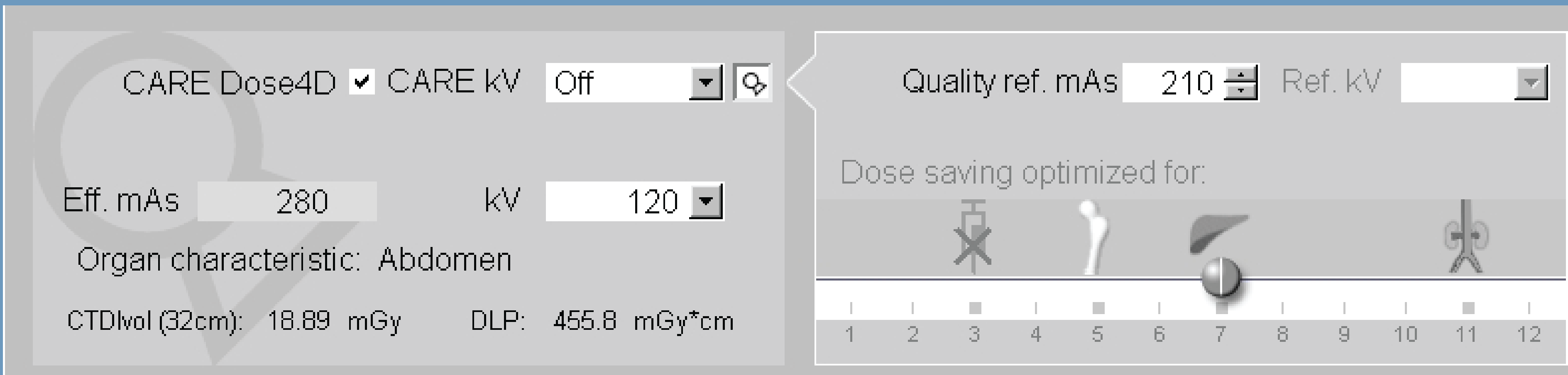
- Pediatric patients! (80kV, 100kV)

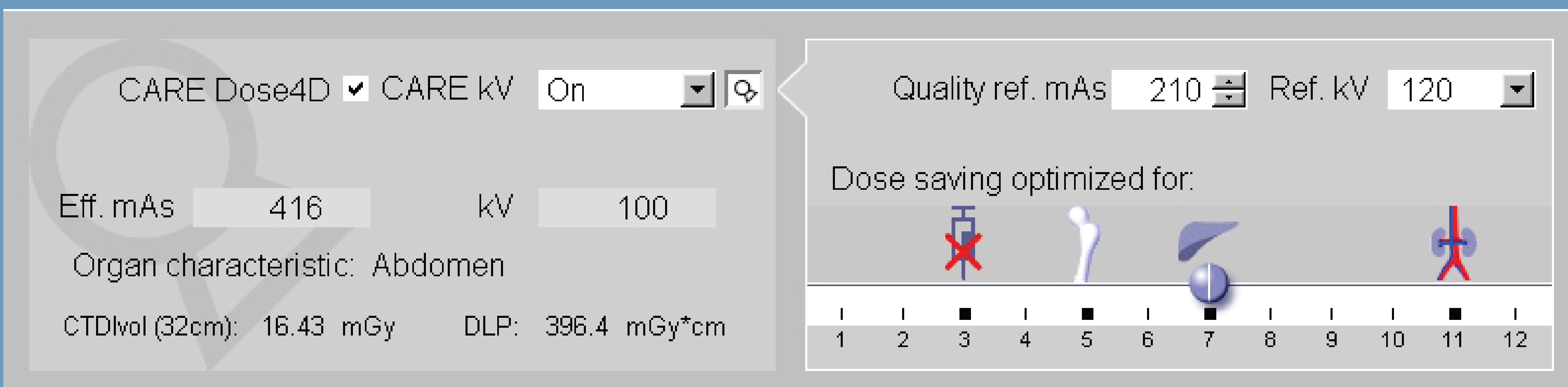
Auto kV

- Care-kV option on newer Siemens scanners
  - Suggests kV to use based on localizer analysis
  - Very often selects kV lower than would be assumed

- kV Assist option on GE scanners with newer console
  - Use the localizer images
  - Optimized for clinical tasks

CARE-kV


CARE Dose4D
CARE kV
Off
Quality ref. mAs
210
Ref. kV
Dose saving optimized for:
Eff. mAs
280
kV
120
Organ characteristic: Abdomen
CTDIvol (32cm): 18.89 mGy
DLP: 455.8 mGy*cm
1 2 3 4 5 6 7 8 9 10 11 12


CARE Dose4D
CARE kV
On
Quality ref. mAs
210
Ref. kV
120
Dose saving optimized for:
Eff. mAs
416
kV
100
Organ characteristic: Abdomen
CTDIvol (32cm): 16.43 mGy
DLP: 396.4 mGy*cm
1 2 3 4 5 6 7 8 9 10 11 12

CARE-kV

kV	mAs	Pitch	CTDI
80	462	1.00	—
100	297	1.00	-20%
120	210	1.00	11.00
140	147	1.00	+5%

CARE-kV

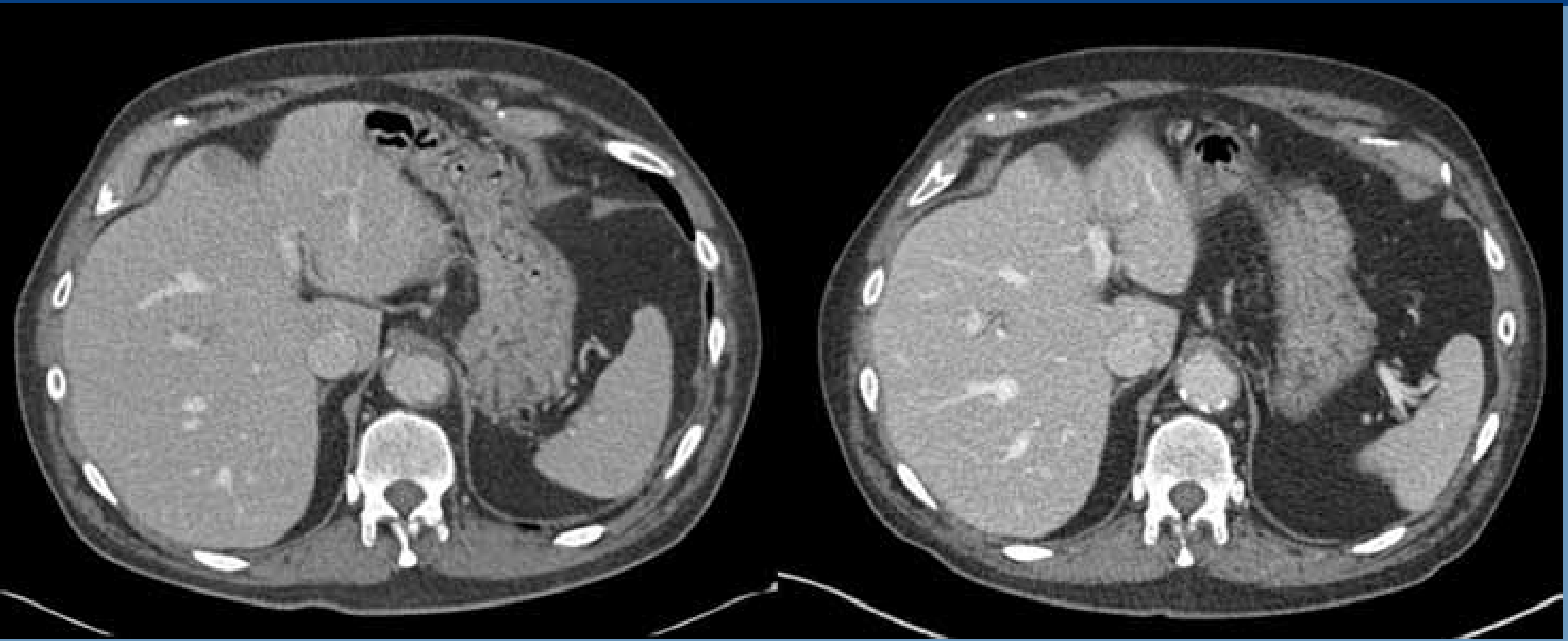
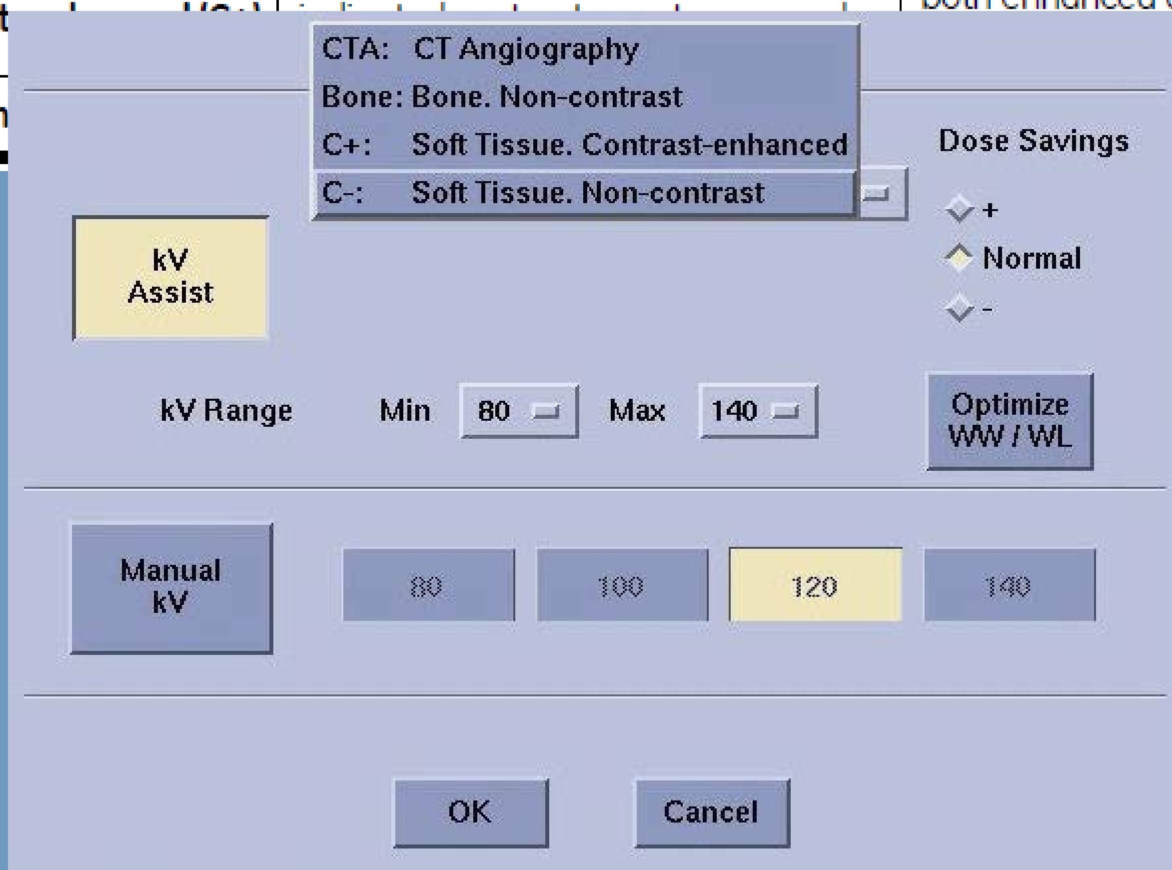


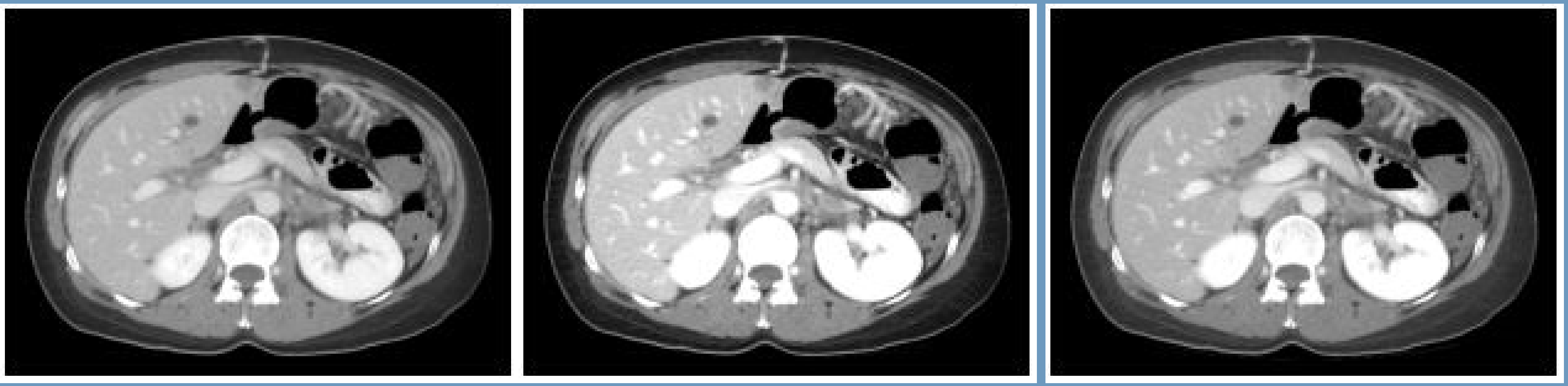
Figure 4. Siemens CARE-kV brochure.
Images showing **dose savings of 14%** using CARE kV. Original image on left (120 kV, eff. mAs 199), ref. mAs 240, CTDI 15.31mGy. CARE kV on right (100 kV, eff. mAs 324) ref. mAs 337, CTDI 13.33 mGy.

kV Assist

Clinical Modes	Scan situation	Region of primary importance
CT Angiography (CTA)	iodinated contrast agents are used	enhanced tissue regions
Bone, non-contrast (BONE)	contrast agents are not used	bony regions
Soft Tissue, contrast		both enhanced and non-enhanced tis-
Soft Tissue, non-con		ssue regions



kV Assist



Original liver image (left), lower kV image with higher iodine contrast and noise (middle) and same image as middle with WW and WL adjusted (right)
GE HD750 User's manual

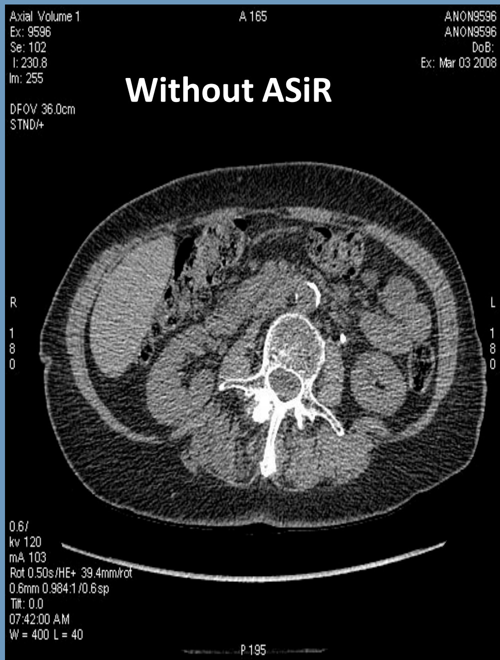
Iterative Reconstruction

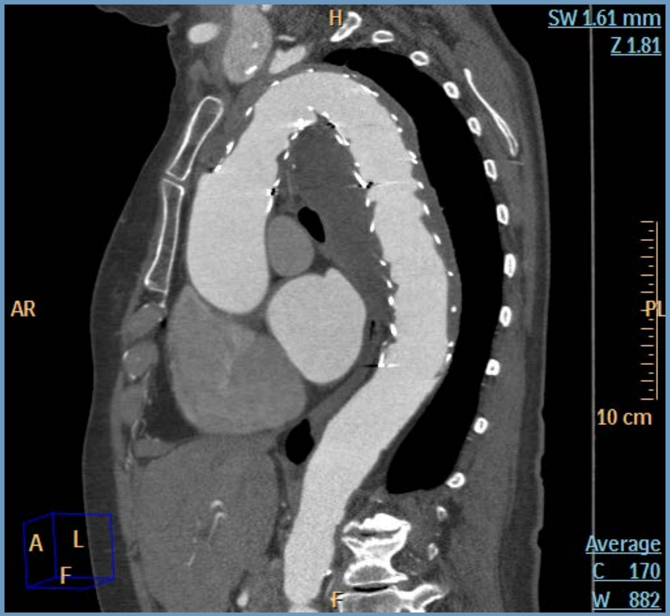
- GE – ASiR (adaptive statistical iterative recon), MBIR (model based iterative recon)

- Philips – iDose

- Siemens – IRIS (iterative recon in image space), SAFIRE (sinogram affirmed iterative recon)

- Toshiba – AIDR (adaptive iterative dose reduction)

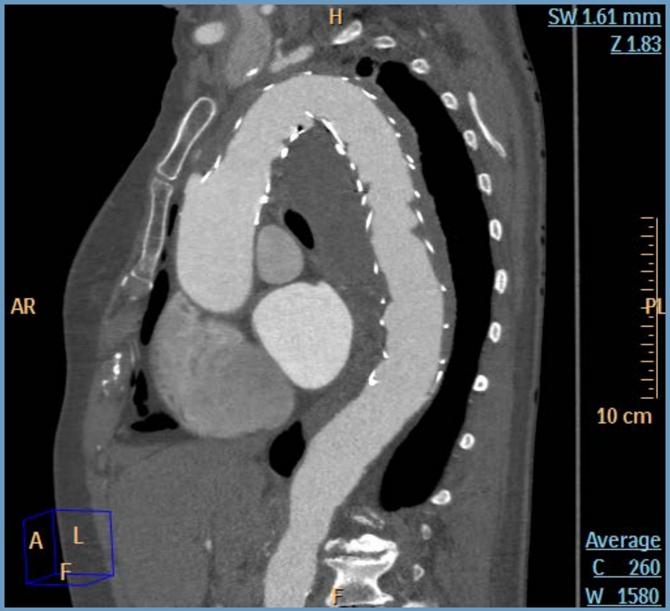




FBP at full dose

Full dose without IRIS

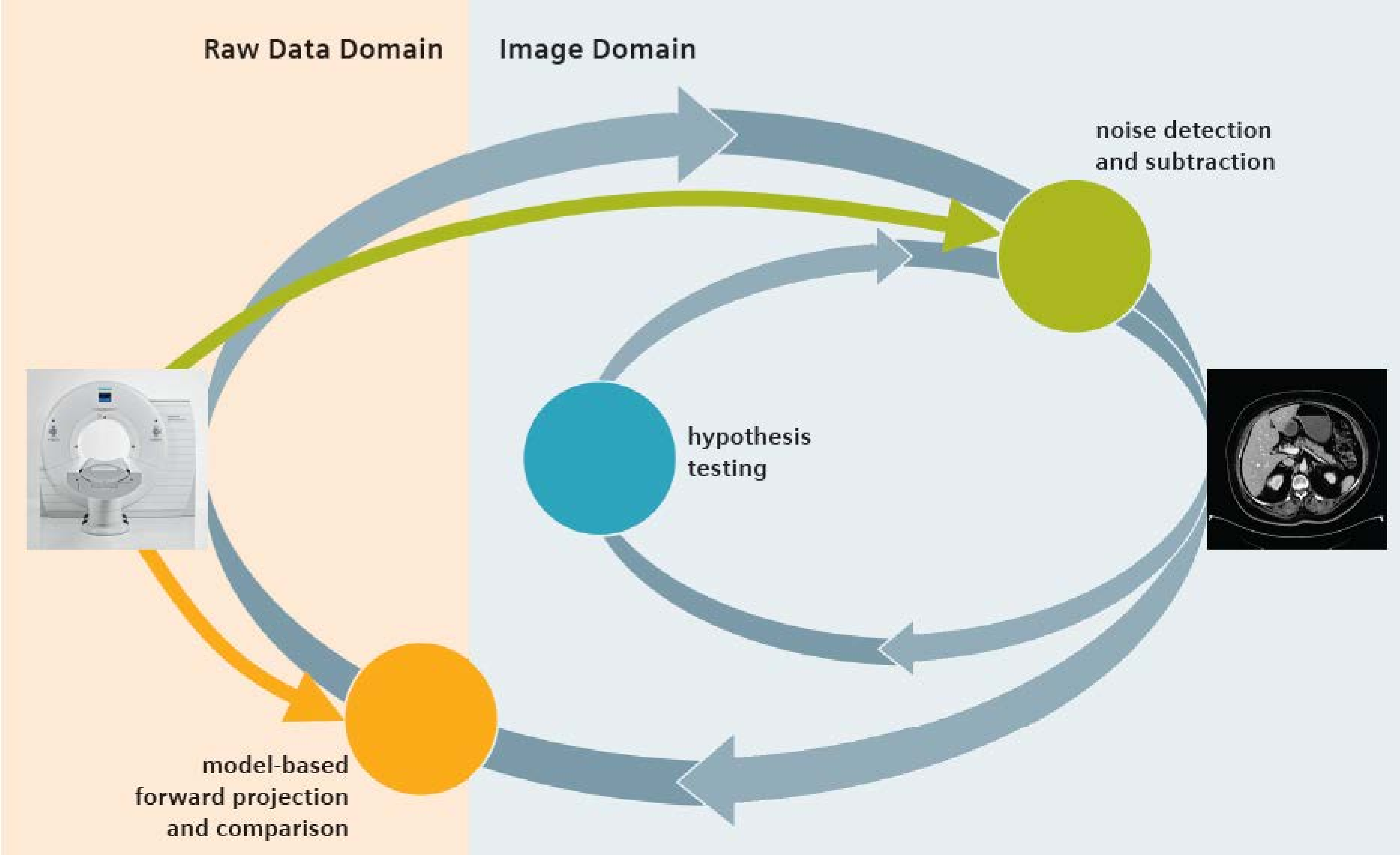
60% less dose with IRIS



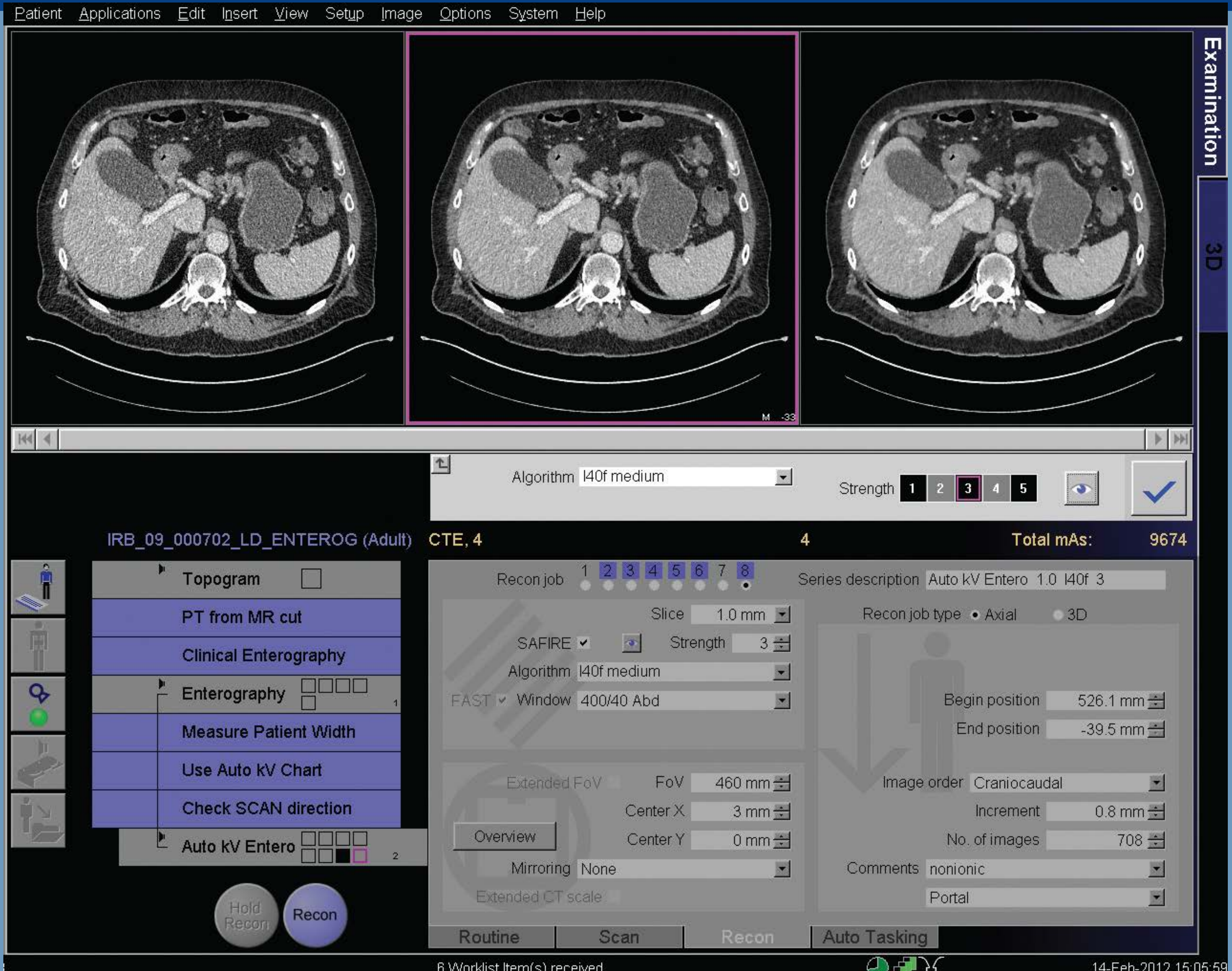
70% less dose with iDose[4]

Iterative Reconstruction: ASIR & VEO

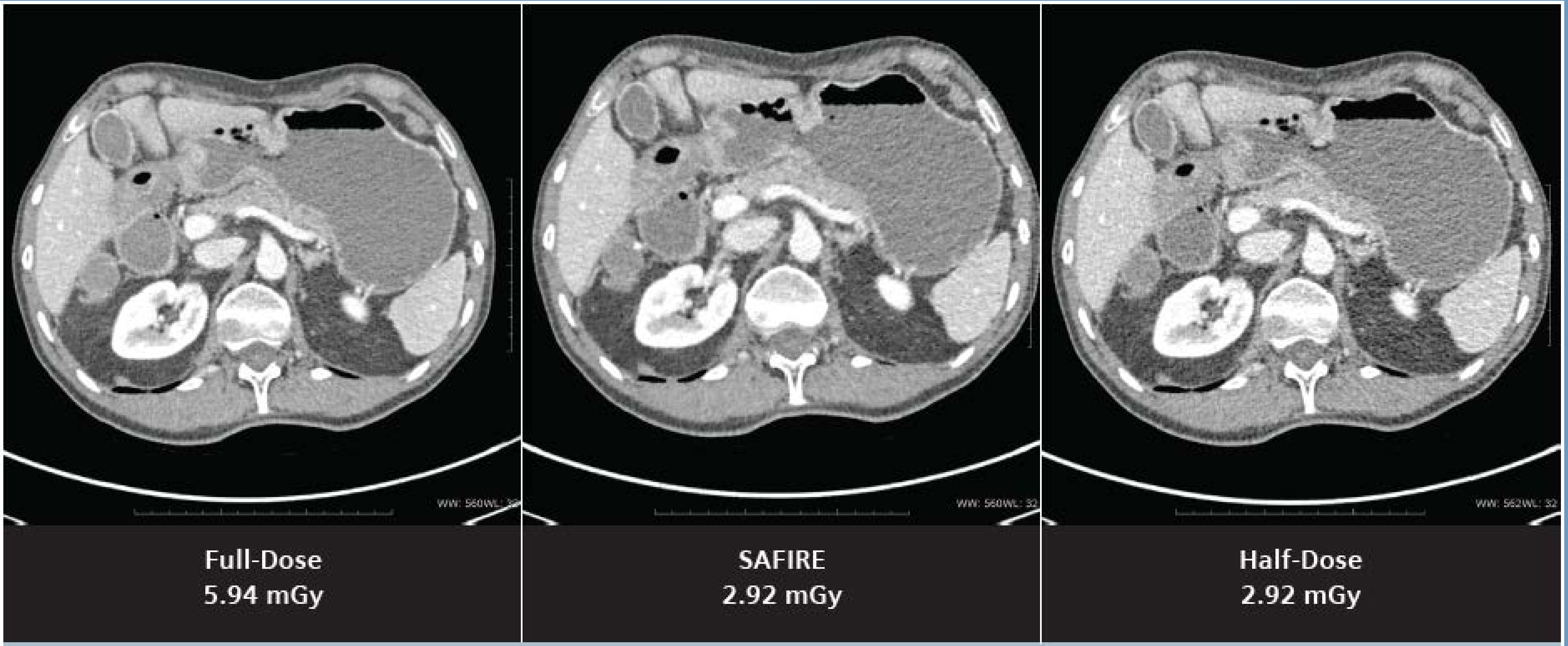
Iterative Reconstruction: SAFIRE



SAFIRE configuration



SAFIRE images



Example 1: CT enterography at 80 kV. Images were reconstructed at 2-mm slices using the B40 kernel for the full-dose and half-dose exam. The corresponding I40 kernel was utilized for reconstructing the half-dose SAFIRE images.

Thank you for your attention!