3RD CT DOSE SUMMIT:
STRATEGIES FOR CT SCAN PARAMETER OPTIMIZATION
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TUBE CURRENT MODULATION

Mark P. Supanich, PhD

Henry Ford Health System

Detroit, MI

DISCLOSURES

- Research Support
  - Siemens AG
- Patient images used with IRB approval
  - All PHI information removed

OUTLINE

- Automatic Exposure Control Fundamentals
- Potential Pitfalls in the Implementation of AEC
- Vendor Specific Implementations
- Additional Topics for Consideration

AUTOMATIC EXPOSURE CONTROL (AEC)

- AEC is implemented on CT scanners to meet a particular image quality level along a scan length and amongst patients
- AEC systems determine the patient attenuation and prescribe changes to the scanner output tailored to the specific patient and body region to meet the desired image quality
- AEC systems are particularly useful for non-homogenous scan regions or for body parts that are not uniform in size

DOSE MODULATION

- Many CT scanners automatically adjust the technique parameters (and as a result the $CTDI_{vol}$) to achieve a desired level of image quality and/or to reduce dose
- Dose Modulation and Reduction techniques vary by scanner manufacturer, model and software version

AUTOMATIC EXPOSURE CONTROL (AEC)

- Automatically adapts the Tube Current or Tube Potential (kVp) according to patient attenuation to achieve a specified image quality
  - Automatic adjustment of Tube Current may not occur when Tube Potential (kVp) is changed
  - **Centering the patient in the gantry is VITAL for most AEC systems**
- AEC aims to deliver a specified image quality across a range of patient sizes. It tends to increase $CTDI_{vol}$ for large patients and decrease it for small patients relative to a reference patient size

The use of Automatic Exposure Control may decrease or increase $CTDI_{vol}$ depending on the patient size and body area imaged and image quality requested

IMAGE QUALITY REFERENCE PARAMETER

- Is the AEC parameter that is set by the user to define the desired level of image quality
- Changing the Image Quality Reference Parameter will affect the $CTDI_{vol}$

The effect on $CTDI_{vol}$ when changing the Image Quality Reference Parameter is vendor dependent

IMAGE QUALITY REFERENCE PARAMETER

- A change in the Image Quality Reference Parameter will affect the $CTDI_{vol}$
- Setting the parameter for “increased” image quality (e.g., lower noise) will result in more dose
- Setting the parameter for “decreased” image quality (e.g., more noise) will result in less dose

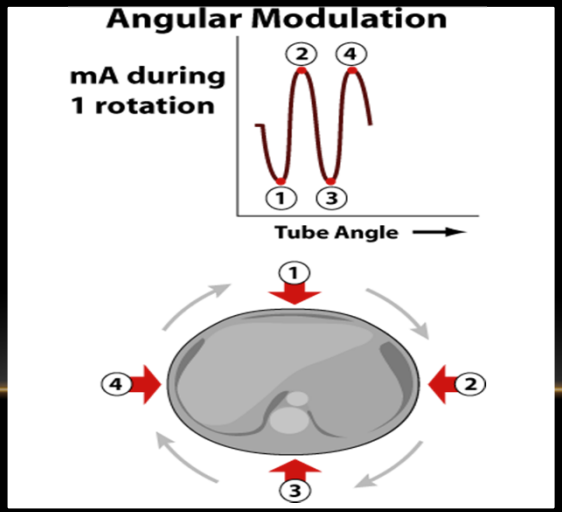
ANGULAR TUBE CURRENT MODULATION

- Is an AEC feature that adjusts the Tube Current as the x-ray tube rotates around the patient to compensate for attenuation changes with view angle
- Angular Tube Current Modulation is used to adjust the Tube Current to attempt to deliver similar dose to the detector at all view angles

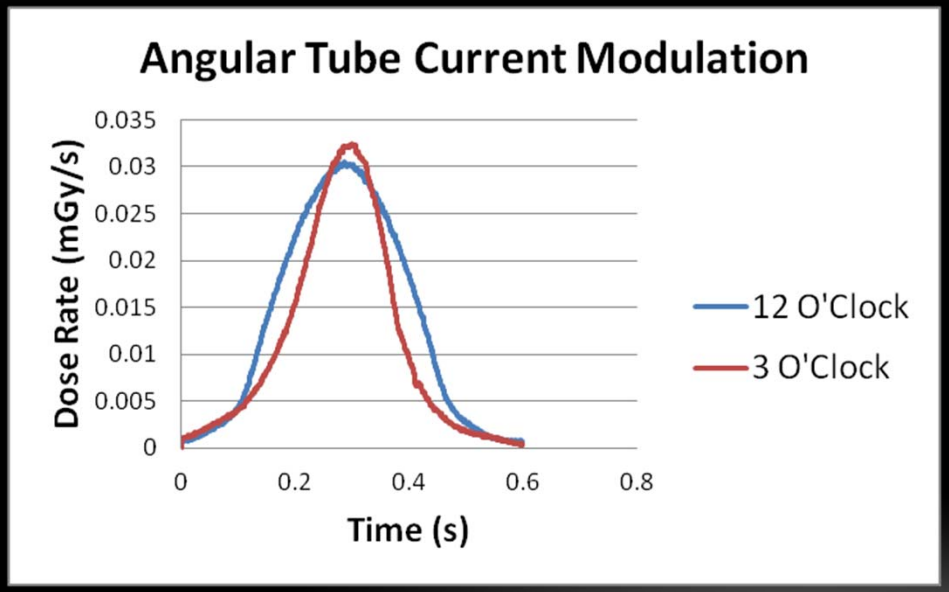
The use of Angular Tube Current Modulation may decrease or increase $CTDI_{vol}$ depending on the patient size and body area imaged and image quality requested

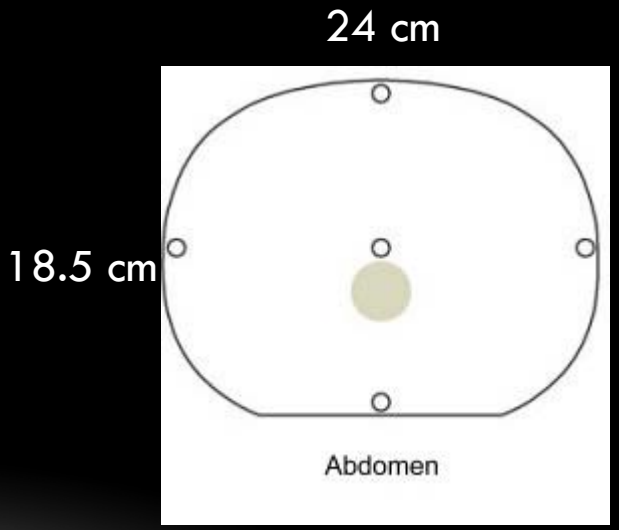
ANGULAR TUBE CURRENT MODULATION

- Angular Tube Current Modulation uses information from one or two view localizers



ANGULAR TUBE CURRENT MODULATION (CIRS PHANTOM)





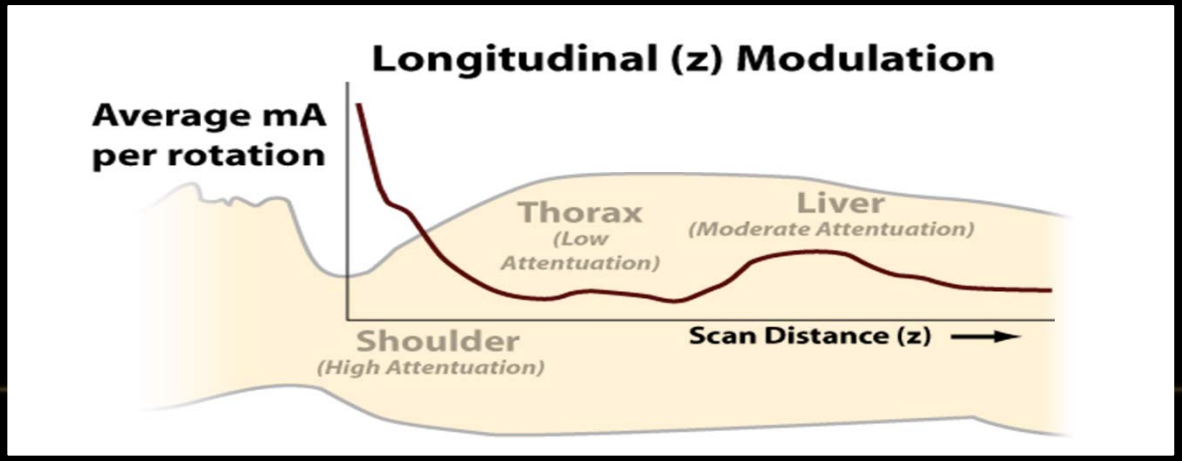
LONGITUDINAL TUBE CURRENT MODULATION

- Is an AEC feature that adjusts the Tube Current as patient attenuation changes in the longitudinal direction
- The CT Localizer Radiograph is used to estimate patient attenuation

The use of Longitudinal Tube Current Modulation may decrease or increase $CTDI_{vol}$ depending on the patient size and body area imaged and image quality requested

LONGITUDINAL TUBE CURRENT MODULATION

- Longitudinal Tube Current Modulation uses information from one or two view localizers



LONGITUDINAL TUBE CURRENT MODULATION

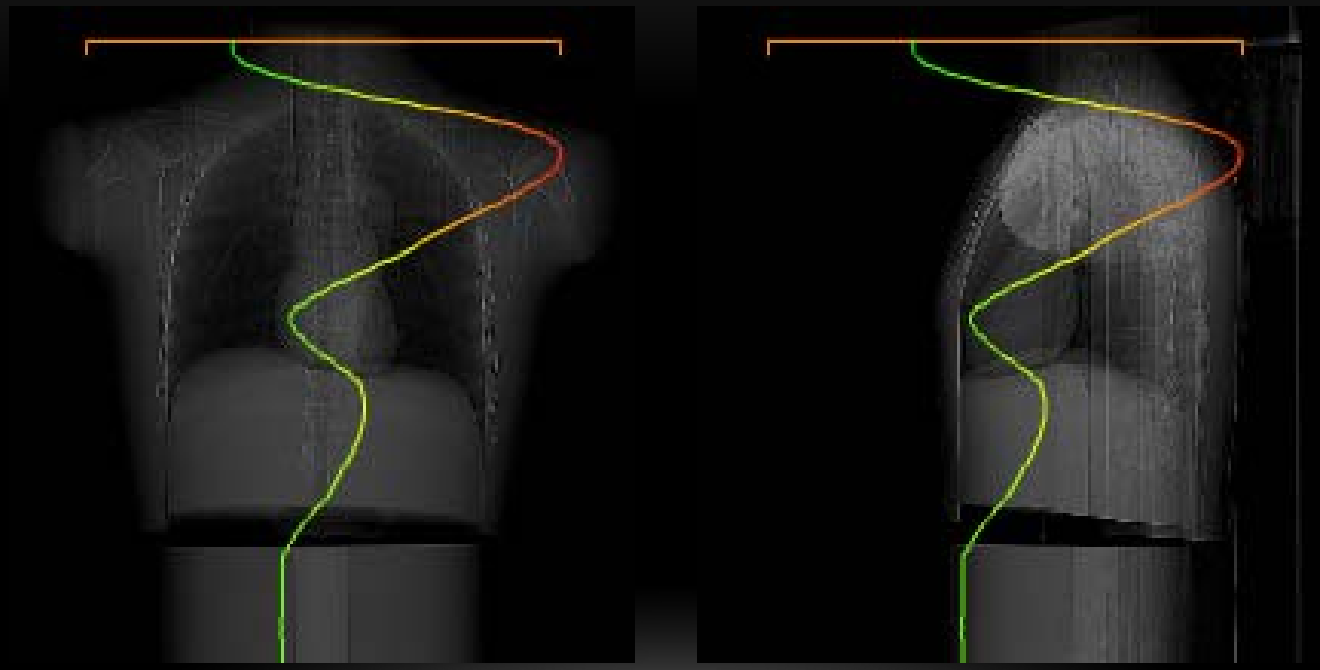


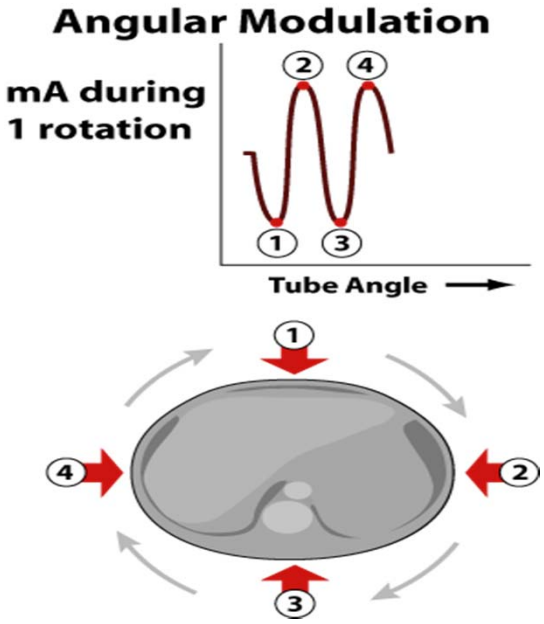
Image from Radimetrics' eXposure Software

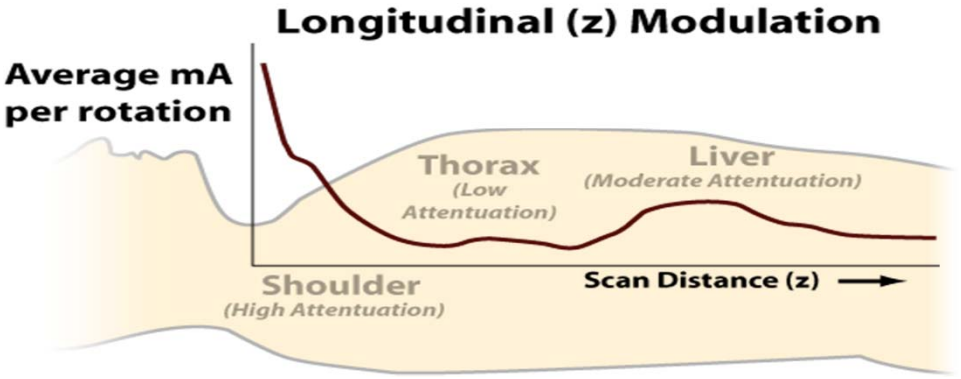
ANGULAR AND LONGITUDINAL TUBE CURRENT MODULATION

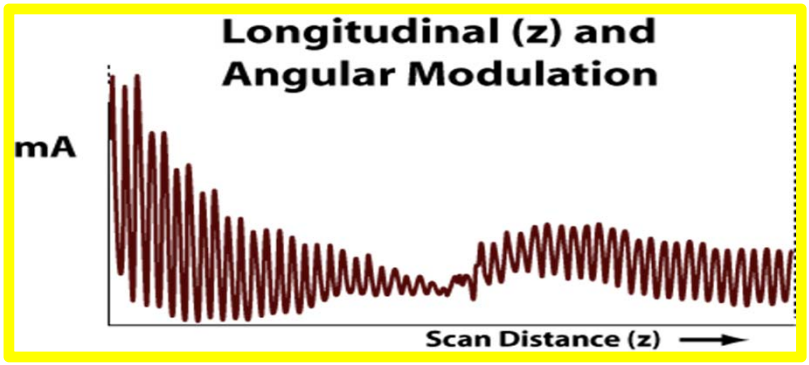
- Is an AEC feature that incorporates the properties of both Angular and Longitudinal Tube Current Modulation to
  - Adjust the Tube Current based on the patient's overall attenuation
  - Modulate the Tube Current in the angular (X-Y) and longitudinal (Z) dimensions to adapt to the patient's shape

The use of Angular and Longitudinal Tube Current Modulation may decrease or increase $CTDI_{vol}$ depending on the patient size and body area imaged and image quality requested

ANGULAR AND LONGITUDINAL TUBE CURRENT MODULATION



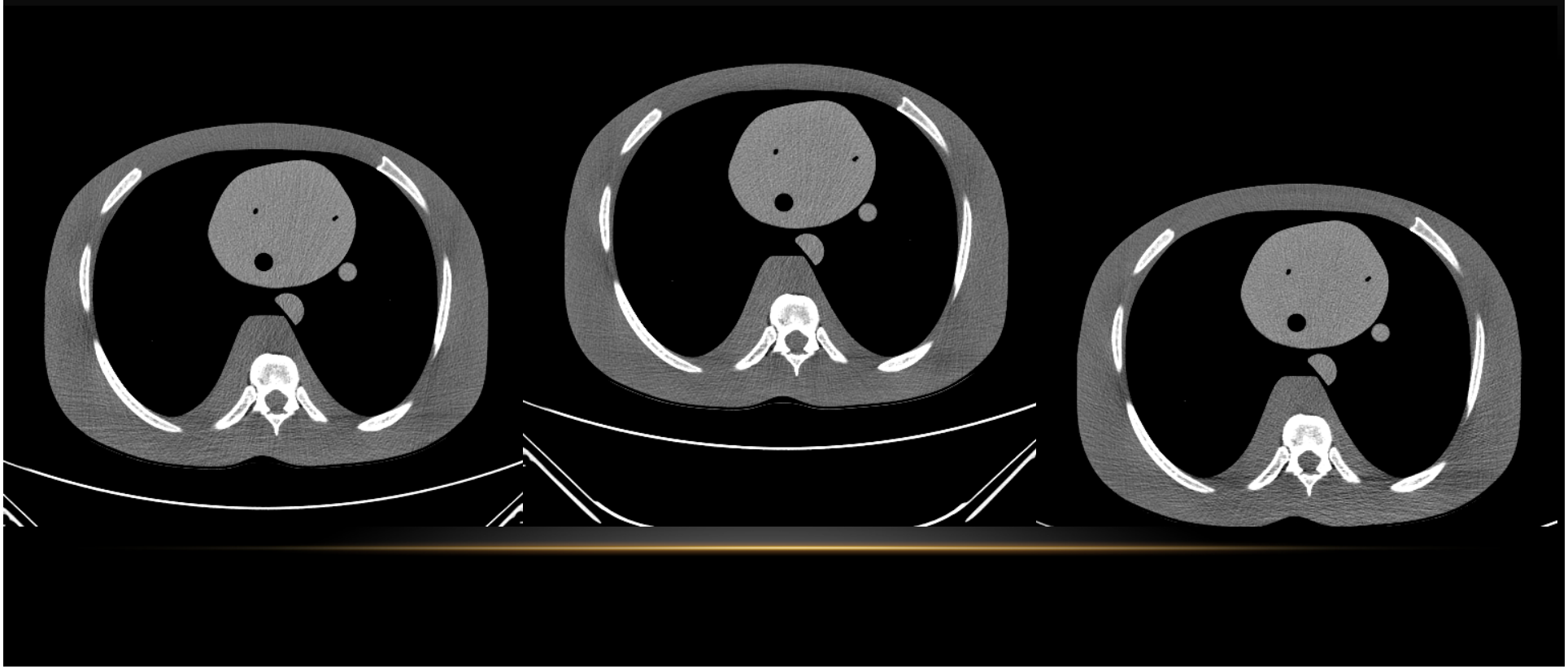




POTENTIAL PITFALLS IN IMPLEMENTATION

- Patient centering

PATIENT CENTERING



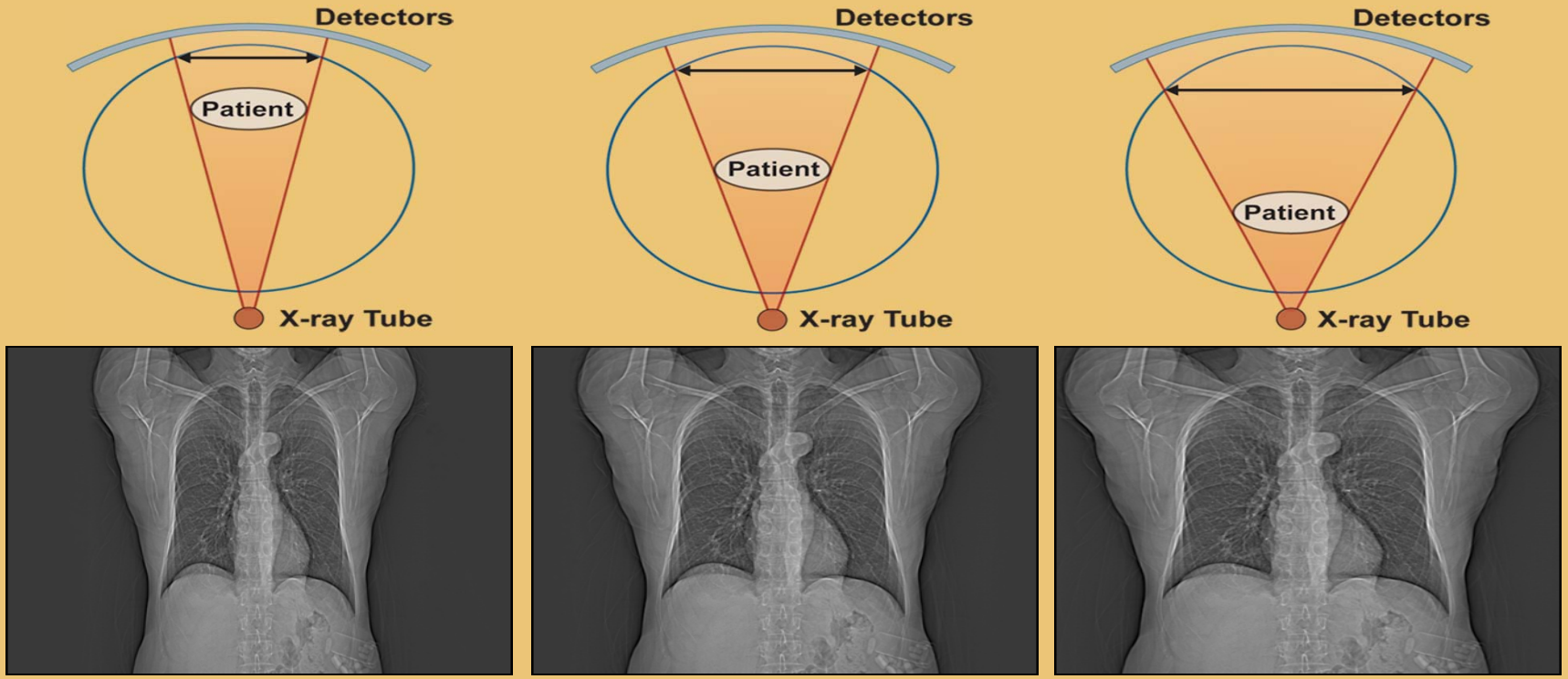
PATIENT CENTERING

- Patient attenuation calculated assuming positioning at isocenter
- Patient positioned above or below isocenter can affect calculation of attenuation and impact implementation of AEC
- Patient mispositioning to the left or right of isocenter will result in one side of body receiving more radiation dose than the other

Philips Brilliance 64	Centered	Table Raised 4 cm	Table Lowered 4 cm
CTDIvol In Chest	7.8	8.2	7.5
CTDIvol in Shoulders	14.4	15.4	15.0

mA Modulation Scout Scans

Jim Kofler, Ph.D.



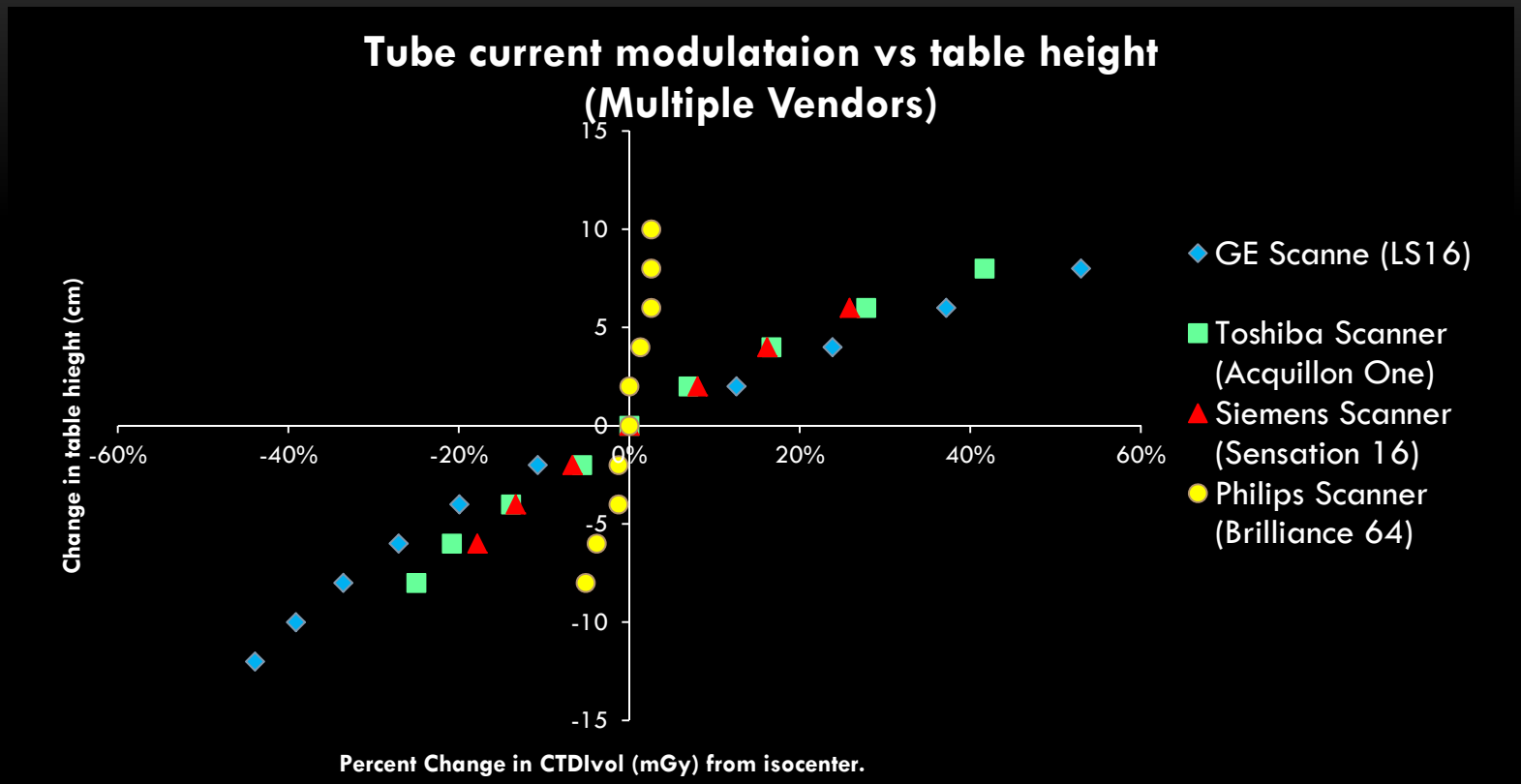
Same patient – vertical table height can affect size-shape model!

Slide courtsey of Rong, Travis and Cody (MD Anderson)

TABLE HEIGHT IMPACT ON TCM

- Chest & Abdomen anthropomorphic phantoms
- Carefully centered in gantry
- Planned routine scans with TCM
- Recorded predicted CTDIvol
- Changed table height
- Planned identical scan
- Recorded predicted CTDIvol
- Etc…

Slide courtsey of Rong, Travis and Cody (MD Anderson)



Slide courtsey of Rong, Travis and Cody (MD Anderson)

BOTTOM LINE

- Tube current modulation REQUIRES CAREFUL CENTERING OF THE PATIENT IN THE GANTRY
- ALL scanners appear sensitive to magnification and minification process in localizer views (with exception of Philips scanners perhaps – requires confirmation)
- Be generous with localizers (repeat if needed and be sure ALL anatomy to be covered is included in the localizer) and be stingy with helical images

Slide courtsey of Rong, Travis and Cody (MD Anderson)

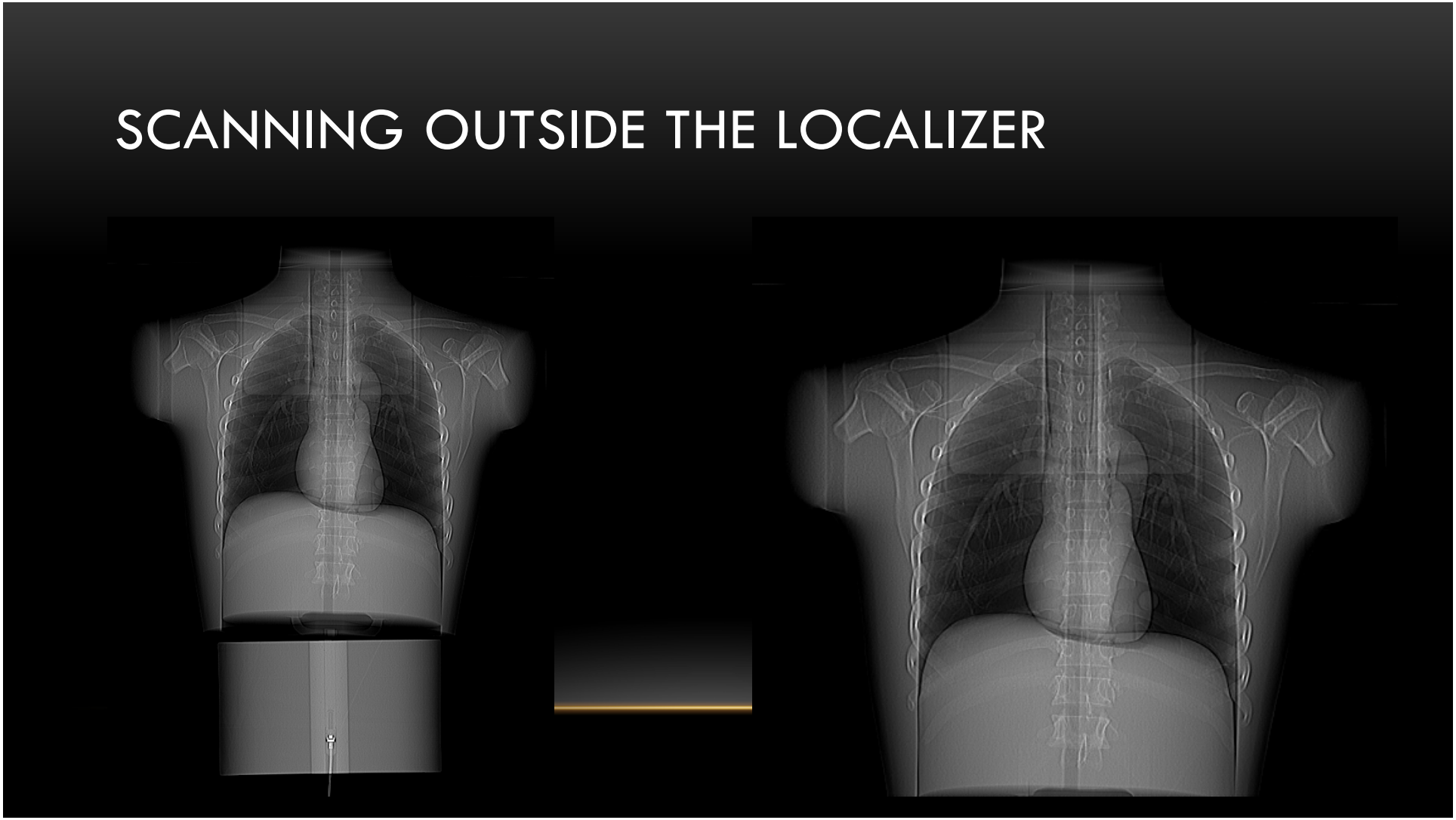
POTENTIAL PITFALLS IN IMPLEMENTATION

- Patient centering
- Scanning outside the localizer

SCANNING OUTSIDE THE LOCALIZER

- Tube Current Modulation is implemented using knowledge of patient attenuation from localizers
- If scan region extends outside of localizer then there is no information to base modulation off of
- Four possible outcomes in scan region not covered by localizer
  - Tube Current goes to maximum
  - Tube Current goes to minimum
  - Tube Current stays what it was at edge of localizer
  - Tube Current goes to manual setting

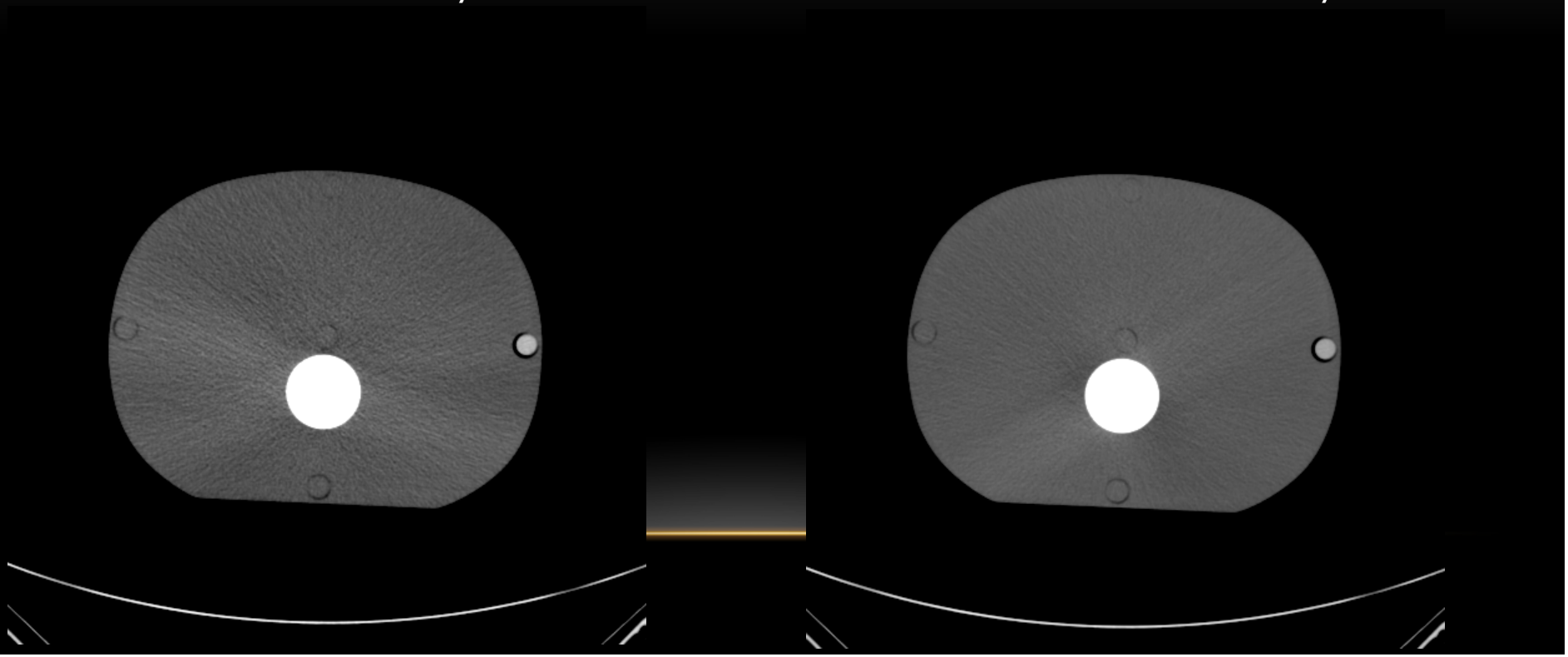
SCANNING OUTSIDE THE LOCALIZER



PHILIPS BRILLIANCE 64: TUBE CURRENT GOES TO MAXIMUM

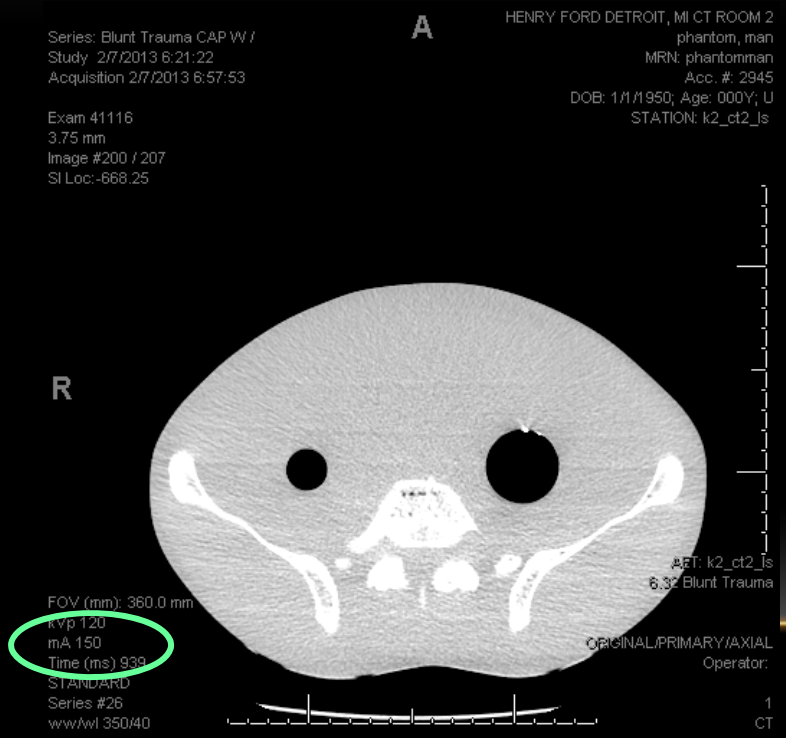
CTDIvol = 7.34 mGy

CTDIvol = 19.35 mGy

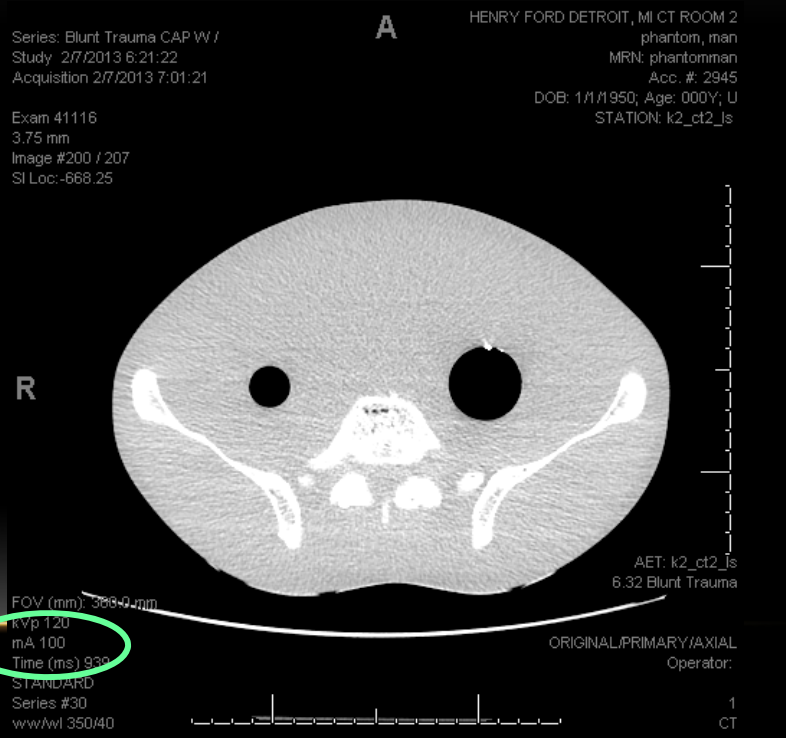


GE: TUBE CURRENT GOES TO MINIMUM SETTING FOR THAT PROTOCOL

Tube Current = 150 mA



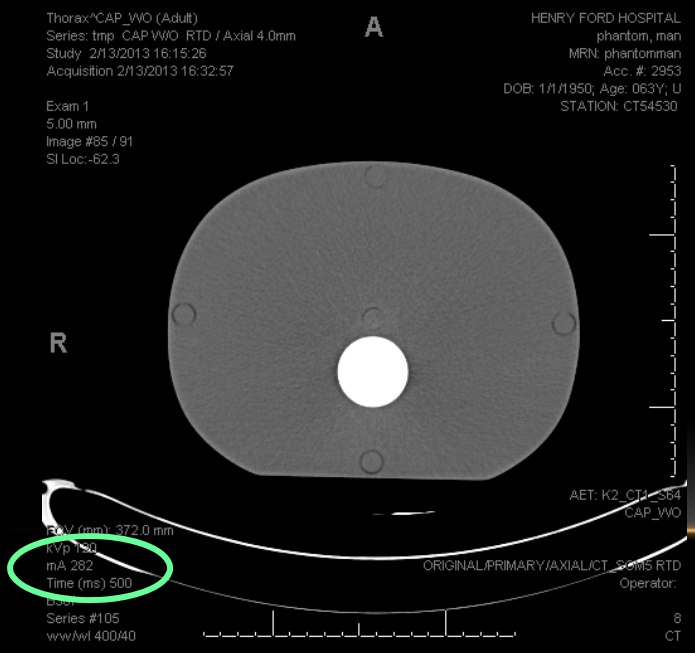
Tube Current = 100 mA



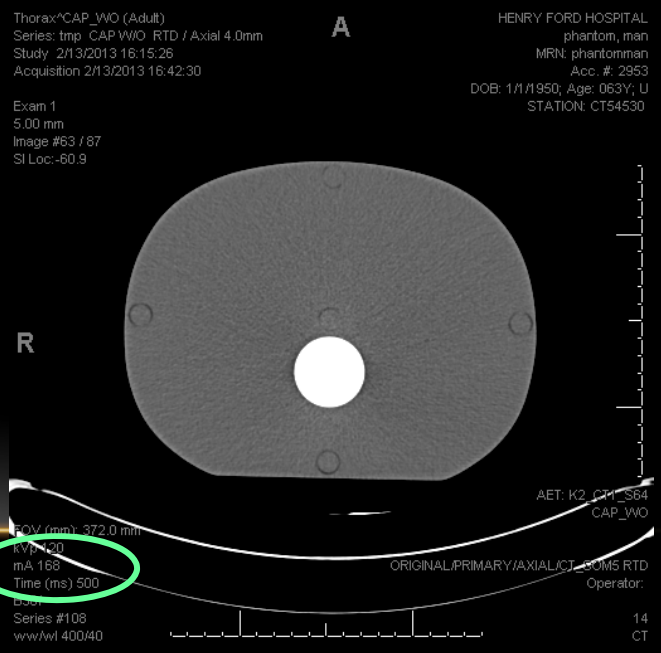
SIEMENS: TUBE CURRENT AT LAST KNOWN LOCATION USED

- Offers warning that scan will extend past localizer limits

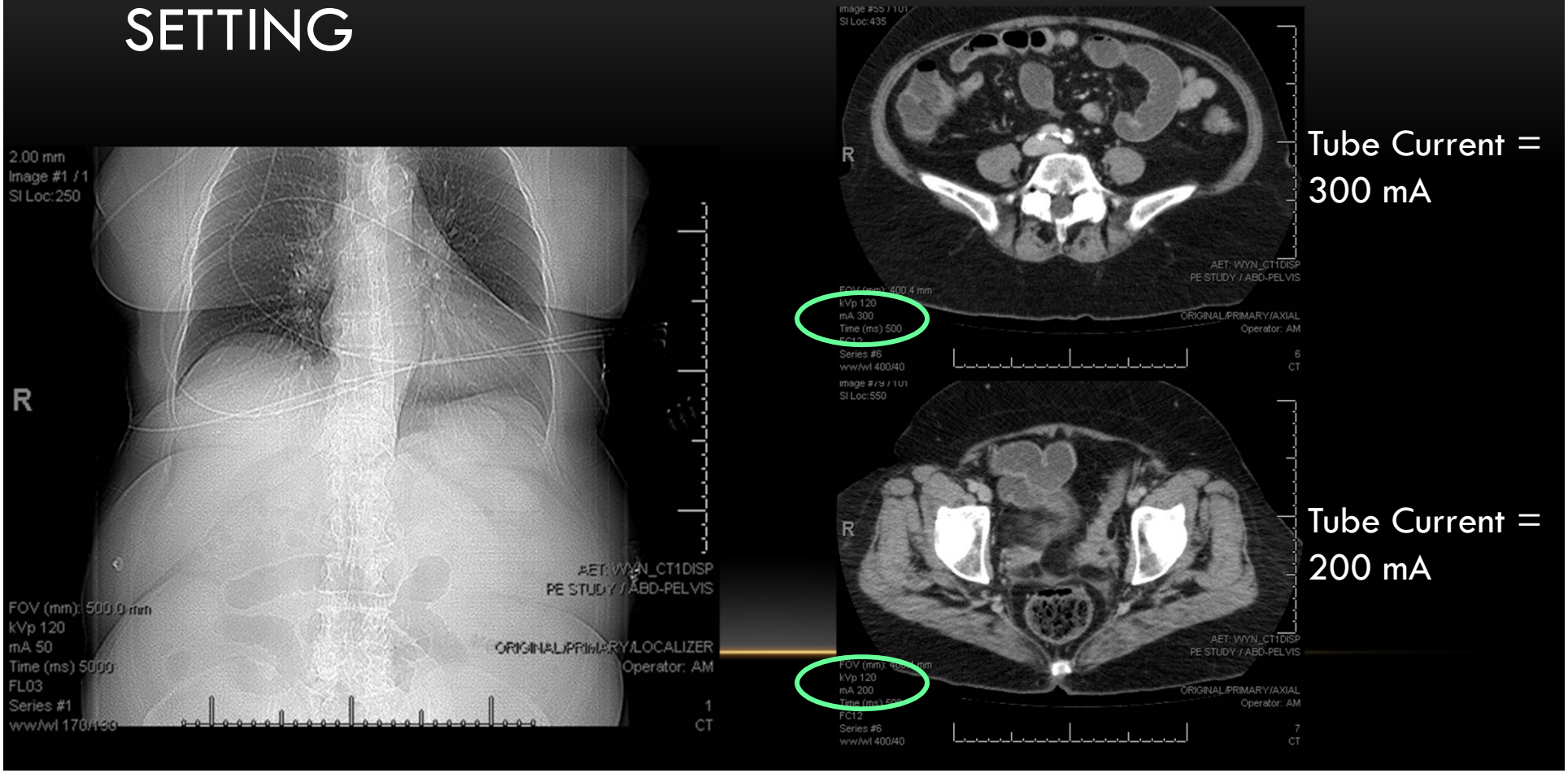
Tube Current = 282 mA



Tube Current= 168 mA



TOSHIBA – GOES TO DEFAULT MANUAL SETTING



Tube Current = 300 mA

Tube Current = 200 mA

POTENTIAL PITFALLS IN IMPLEMENTATION

- Patient centering
- Scanning outside the localizer
- Change in patient orientation

CHANGE IN PATIENT ORIENTATION

- A change in the selected patient orientation during a protocol may impact AEC
- Systems will assume that the localizer is no longer an accurate assessment of the scanning situation
- Some systems will require a new localizer before proceeding
- Other systems will set tube current to maximum
- Others will switch to the manual tube current settings

POTENTIAL PITFALLS IN IMPLEMENTATION

- Patient centering
- Scanning outside the localizer
- Change in patient orientation
- Image thickness dependence of reference parameter

IMAGE THICKNESS DEPENDENCE OF REFERENCE PARAMETER

- Changing the image thickness may automatically adjust the Image Quality Reference Parameter
  - GE Systems – changing image thickness will adjust Reference Noise Index and Noise Index
    - 1 scan at 1.25 mm image thickness for MPRs and a second phase at 3.75 mm need different Reference Noise Indices and different Noise Indices for same image quality
  - Siemens & Philipscsystems –acquisition image thickness will not change image quality reference parameter
  - Important to confirm that expected AEC behavior does not change when adjusting image thickness

POTENTIAL PITFALLS IN IMPLEMENTATION

- Patient centering
- Scanning outside the localizer
- Change in patient orientation
- Image thickness dependence of reference parameter
- Setting of minimum and maximum values where applicable

SETTING OF MINIMUM AND MAXIMUM VALUES WHERE APPLICABLE

- Some systems allow for minimum and maximum tube current values to be set when using AEC
- Limitations to tube currents may help in situations with metal implants or from going to high or too low at patient extremes
  - May limit image quality for extremely large patients
  - Care must be given to setting appropriate maximum and minimum values
- GE and Toshiba allow setting of maximum and minimum tube currents when using AEC

POTENTIAL PITFALLS IN IMPLEMENTATION

- Patient centering
- Scanning outside the localizer
- Change in patient orientation
- Image thickness dependence of reference parameter
- Setting of minimum and maximum values where applicable
- How localizers are used

HOW LOCALIZERS ARE USED

- Acquiring both AP and lateral localizers ensures proper patient positioning
- Manufacturers may use both, the last acquired or the localizer used to plan on for tube current modulation
- Consult the user manual to ensure a full understanding of how localizers are used in tube current modulation

POTENTIAL PITFALLS IN IMPLEMENTATION

- Patient centering
- Scanning outside the localizer
- Change in patient orientation
- Image thickness dependence of reference parameter
- Setting of minimum and maximum values where applicable
- How localizers are used
- AEC settings not easily displayed on PACS

AEC SETTINGS NOT DISPLAYED IN PACS

- No DICOM field for image quality reference parameter
- Information about AEC settings may be located in private DICOM metadata
- Display of AEC information in overlays on PACS is typically not available
  - Difficult to know if parameters have been changed unless checked on scanner
  - Frequent review of scanner protocols is important
- Occasional review of metadata to ensure proper AEC settings may be useful

IMPLEMENTATION FROM DIFFERENT MANUFACTURERS

- Implementation of AEC may vary amongst scanner models and software versions from the same manufacturer
- Detailed information on the AEC and Tube Current Modulation techniques are available in the scanner manual or from an applications specialist

GE TERMS: AUTO MA

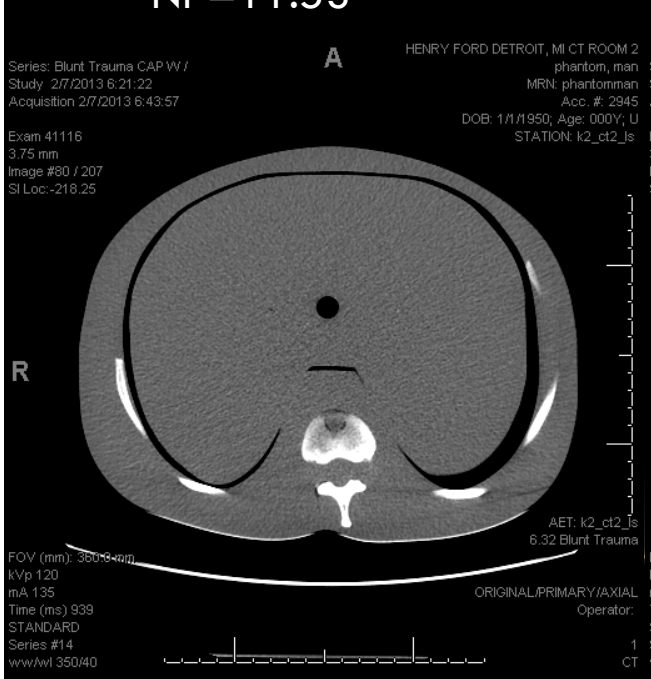
- Image Quality Reference Parameter: Noise Index
  - Increasing Noise Index increases image noise and decreases $CTDI_{vol}$
  - Decreasing Noise Index decreases image noise and increases $CTDI_{vol}$
  - Additional Parameter: Reference Noise Index
    - Default noise index for a protocol
- Longitudinal Tube Current Modulation: Auto mA
- Angular and Longitudinal Tube Current Modulation: Smart mA
- Allows maximum and minimum tube current settings
- Available for head protocols

GE EXAMPLE SCAN INFORMATION

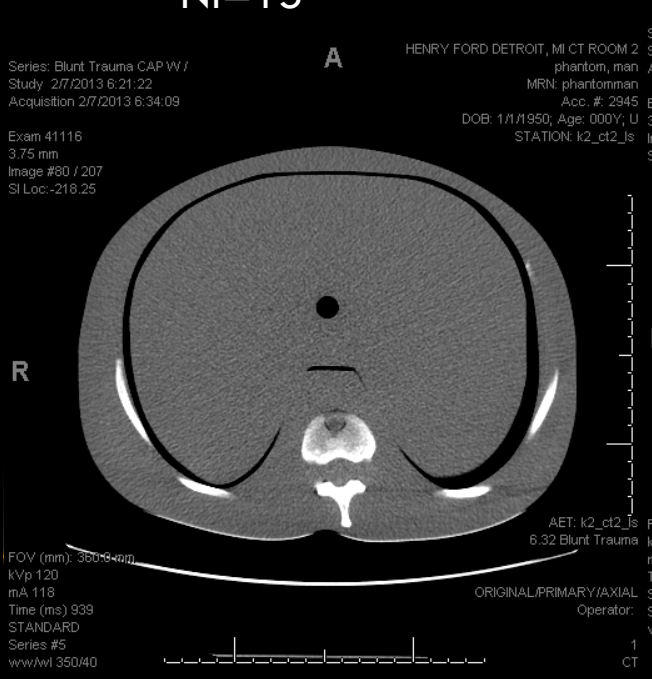
- Anthropomorphic Chest and Abdomen phantoms
- Clinical Chest-Abdomen Pelvis protocol on LightSpeed 16
- 32X1.25 mm collimation
- 3.75 mm Image Thickness
- Variety of Noise Indices used

GE DIFFERENT NOISE INDEX SETTINGS

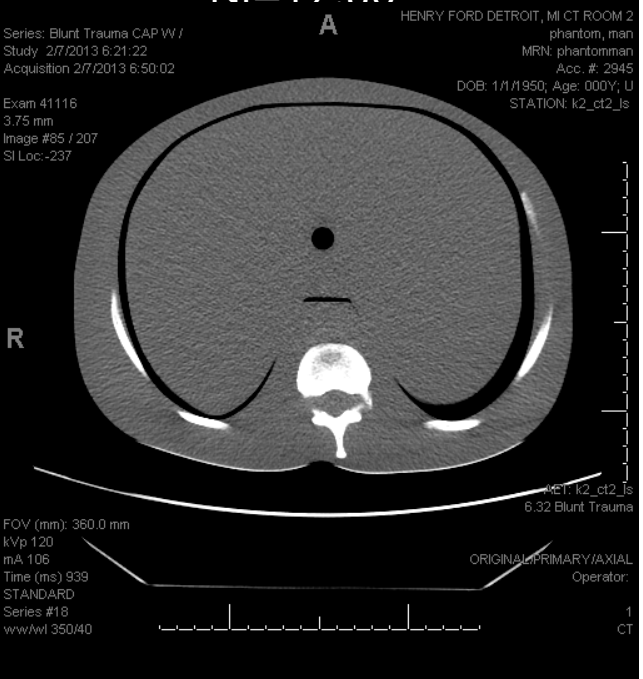
NI =11.53



NI=15



NI=17.80



GE DIFFERENT NOISE INDEX SETTINGS

	NI=11.53	NI=15	NI=17.89
CTDIvol	10.7	7.4	6.3
STD of HU	12.1	13.3	14.3

HITACHI TERMS: INTELLIEC

- Image Quality Reference Parameter: Standard Deviation (SD)
  - Increasing SD increases image noise and decreases $CTDI_{vol}$
  - Decreasing SD decreases image noise and increases $CTDI_{vol}$
- Angular and Longitudinal Tube Current Modulation: IntelliEC

NEUSOFT: DOSERIGHT

- Image Quality Reference Parameter: DoseSave Level
  - Increasing the DoseSave level will decrease the image noise and increase $CTDI_{vol}$
  - Decreasing the DoseSave level will increase image noise and decreases $CTDI_{vol}$
- Angular Tube Current Modulation: DOM (Dose Modulation)
- Longitudinal Tube Current Modulation: ACS (Automatic Current Selection)
- Angular and Longitudinal Tube Current Modulation: ACS + DOM

PHILIPS TERMS: DOSERIGHT

- Image Quality Reference Parameter: Dose Right Index
  - Increasing Dose Right Index decreases image noise and increases $CTDI_{vol}$
  - Decreasing Dose Right Index increases image noise and decreases $CTDI_{vol}$
- Angular Tube Current Modulation: 3D Modulation
- Longitudinal Tube Current Modulation: Z-Modulation
- Axial and Longitudinal Tube Current Modulation: Z-Modulation and 3D Modulation

PREVIOUS PHILIPS SOFTWARE TERMS

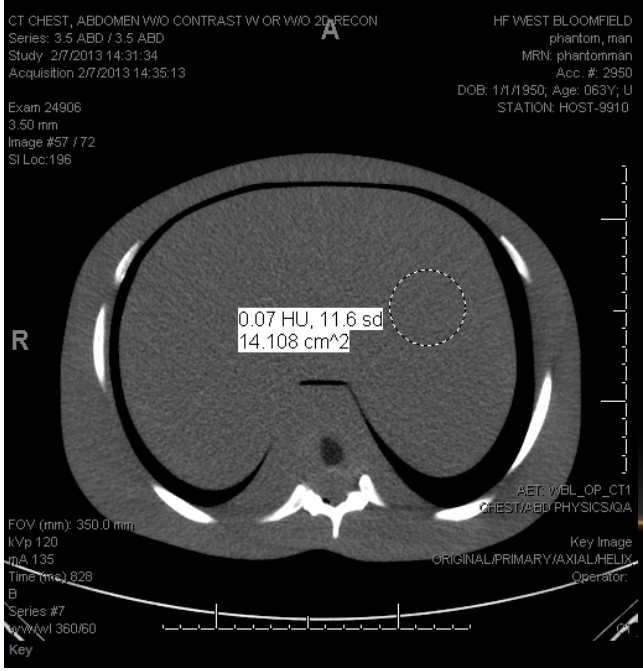
- Image Quality Reference Parameter: mAs/slice
  - Increasing mAs/slice decreases image noise and increases $CTDI_{vol}$
  - Decreasing mAs/slice increases image noise and decreases $CTDI_{vol}$
- Angular Tube Current Modulation: D-DOM
- Longitudinal Tube Current Modulation: Z-DOM
- Axial and Longitudinal Tube Current Modulation: Z-DOM and D-DOM
- Not available for head protocols
- Estimate of mean mAs/slice available after localizer

PHILIPS EXAMPLE SCAN INFORMATION

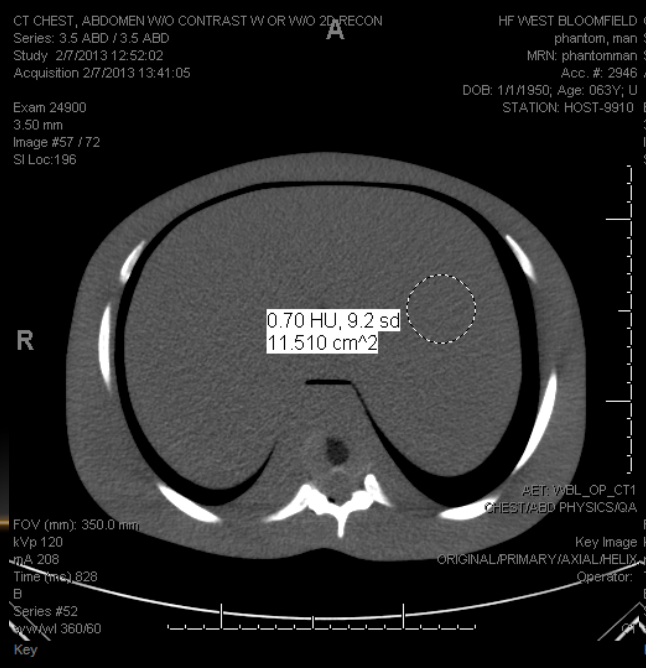
- Anthropomorphic Chest and Abdomen Phantoms
- Clinical Chest-Abdomen/Pelvis Protocol
- 3.5 mm Image Thickness
- 32X1.25 mm detector configuration
- Variable mAs/slice

PHILIPS DIFFERENT MAS/SLICE

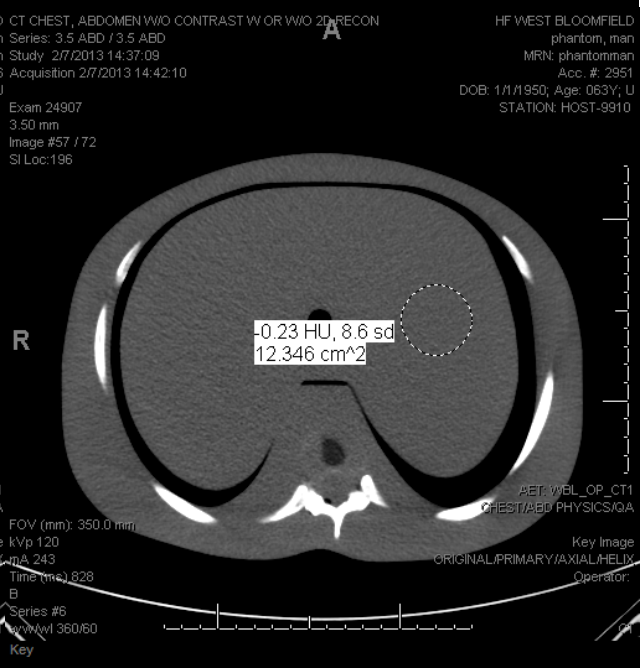
200 mAs/slice



300 mAs/slice



400 mAs/slice



PHILIPS DIFFERENT MAS/SLICE LEVELS

	200 mAs/slice	300 mAs/slice	400 mAs/slice
CTDIvol (mGy)	7.2	11.1	13.0
STD of HU	11.6	9.2	8.6

SIEMENS: CARE DOSE 4D

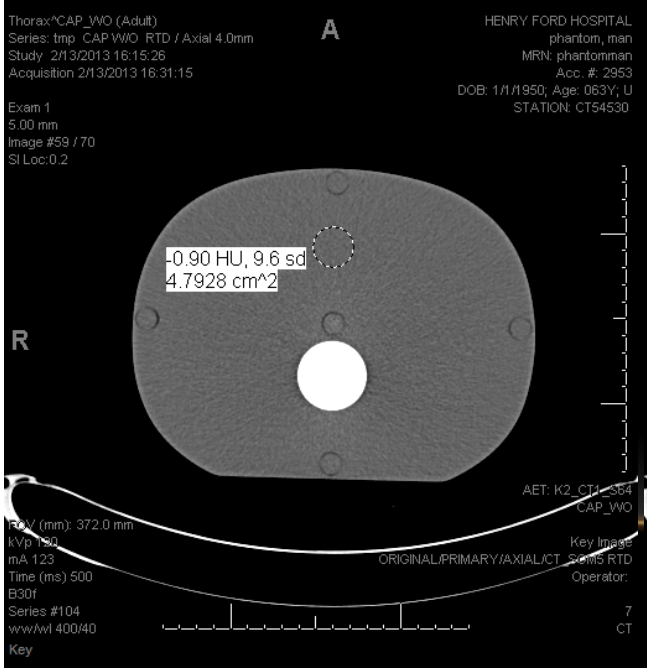
- Image Quality Reference Parameter: Image Quality Reference mAs
  - Increasing Image Quality Reference mAs will decrease image noise and increases $CTDI_{vol}$
  - Decreasing Image Quality Reference mAs will increase image noise and decreases $CTDI_{vol}$
- Angular Tube Current Modulation: Angular Tube Current Modulation
- Longitudinal Tube Current Modulation : Axial Tube Current Modulation
- Axial and Longitudinal Tube Current Modulation: Care Dose 4D
- Only longitudinal tube current modulation available for head protocols
- Estimate of mean effective mAs available following localizer

SIEMENS EXAMPLE SCAN INFORMATION

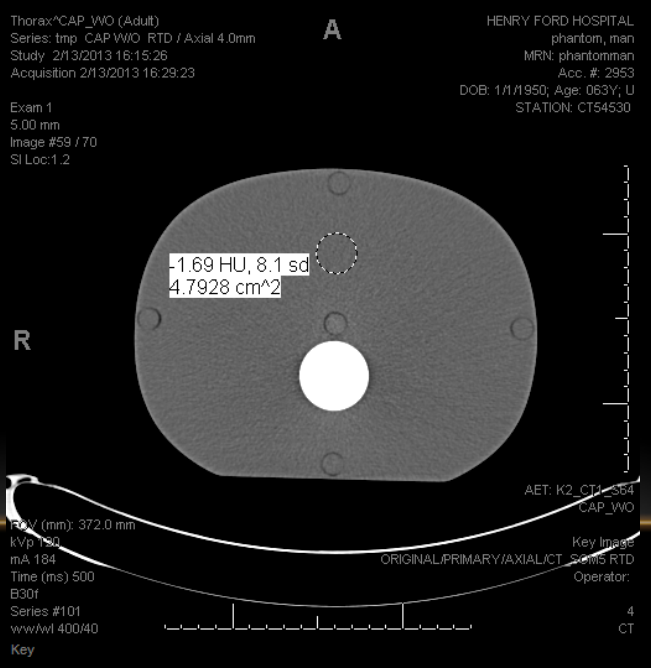
- Anthropomorphic Chest and Abdomen Phantoms
- Clinical Chest-Abdomen/Pelvis Protocol
- 5 mm Image Thickness
- 24X1.2 mm detector configuration
- Variable reference mAs levels

SIEMENS DIFFERENT IMAGE QUALITY REFERENCE MAS

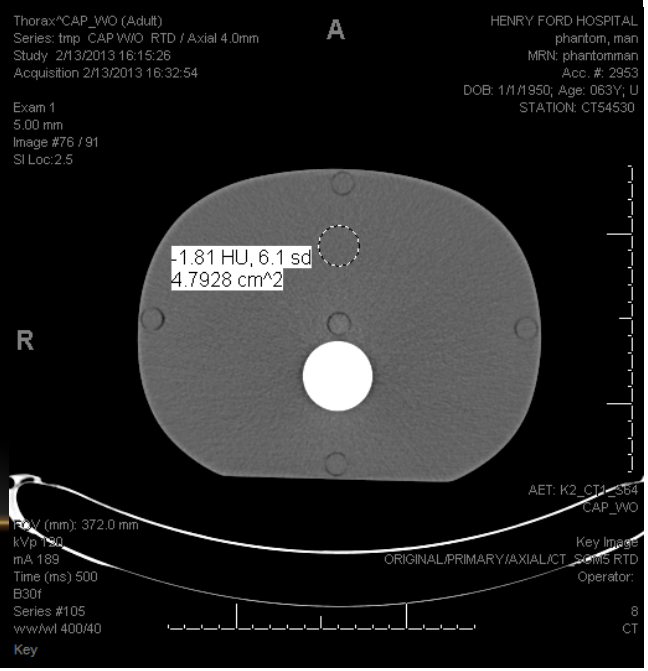
200 mAs



300 mAs



400 mAs



SIEMENS DIFFERENT REFERENCE MAS LEVELS

	200 mAs	300 mAs	400 mAs
CTDIvol (mGy)	9.0	13.4	17.5
STD	9.6	8.1	6.1

TOSHIBA: SURE EXPOSURE 3D

- Image Quality Reference Parameter: SD
  - Increasing SD will increase image noise and decreases $CTDI_{vol}$
  - Decreasing SD will decrease image noise and increases $CTDI_{vol}$
  - Angular Tube Current Modulation: XY-Modulation
- Longitudinal Tube Current Modulation : Always on
- Axial and Longitudinal Tube Current Modulation: ^{Sure}Exposure 3D
- Allows maximum and minimum tube current settings

CHANGING IMAGE QUALITY REFERENCE PARAMETER

- Siemens
  - How tube current adjusts with patient attenuation can be modified
- Philips
  - For some software versions – adjusting mAs/slice while planning a scan may impact future studies

CHANGING IMAGE QUALITY REFERENCE PARAMETER

	25% Increase in Image Quality Reference Parameter	Change in $CTDI_{vol}$
GE	NI from 10 to 12.5	Decrease ~ 10 %
Hitachi	SD from 10 to 12.5	Decrease ~ 10%
Neusoft	DoseSave Level from 20 to 25	Increase ~ 25%
Philips Newer Software	DoseRight Index from 20 to 25	Increase ~ 25%
Philips Older Software	mAs/slice from 400 to 500	Increase ~ 25%
Siemens	Reference mAs from 200 to 250	Increase ~ 25%
Toshiba	SD from 10 to 12.5	Decrease ~ 10%

Change in mAs/slice from 400 mAs/slice (left) to 300 mAs/slice (right) for Abdomen/Pelvis Protocol Philips Brilliance 64

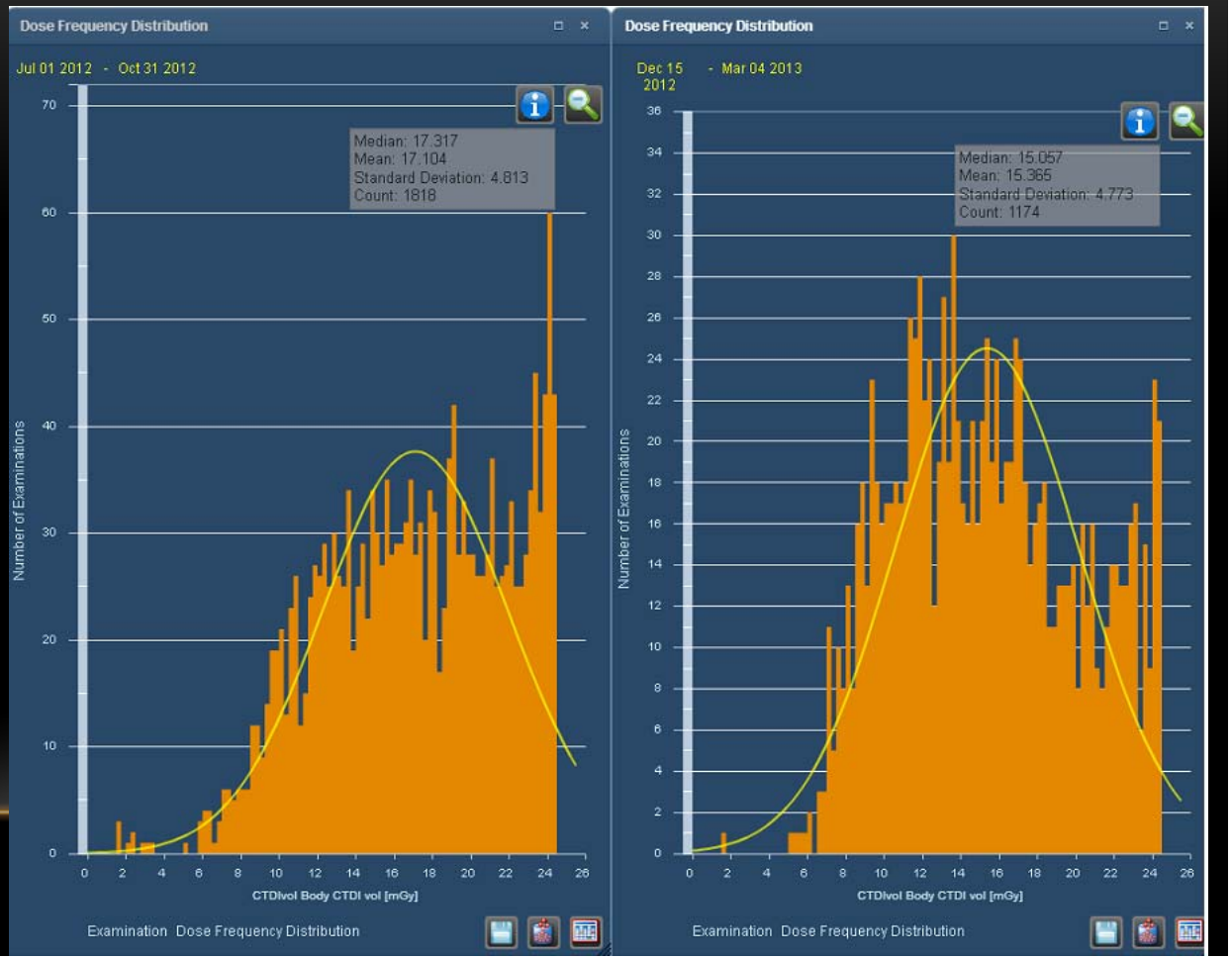


Image from Radimetrics' eXposure Software

Change in NI from

24 (left) to

30 (right) for

Abdomen/Pelvis Protocol

GE VCT

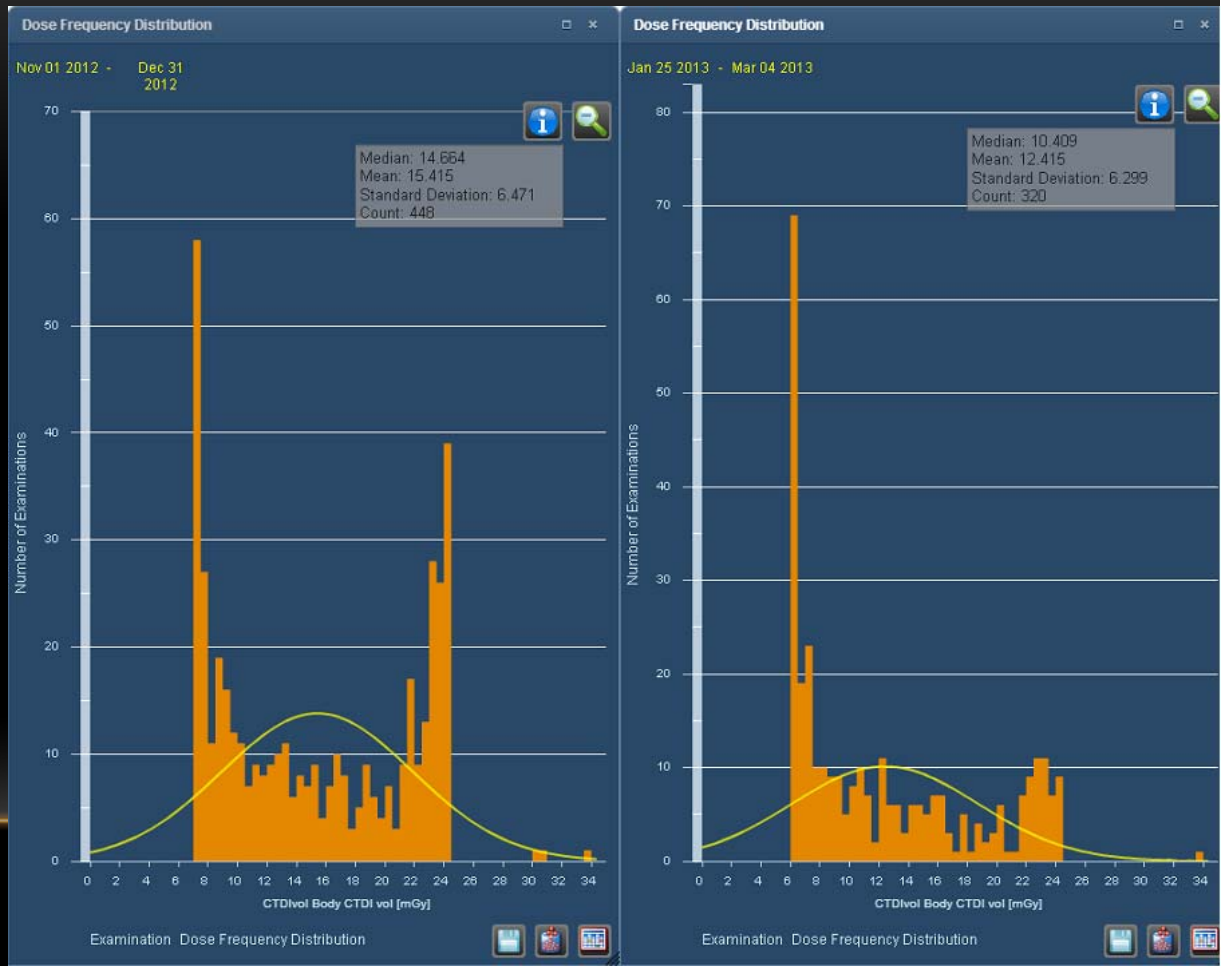
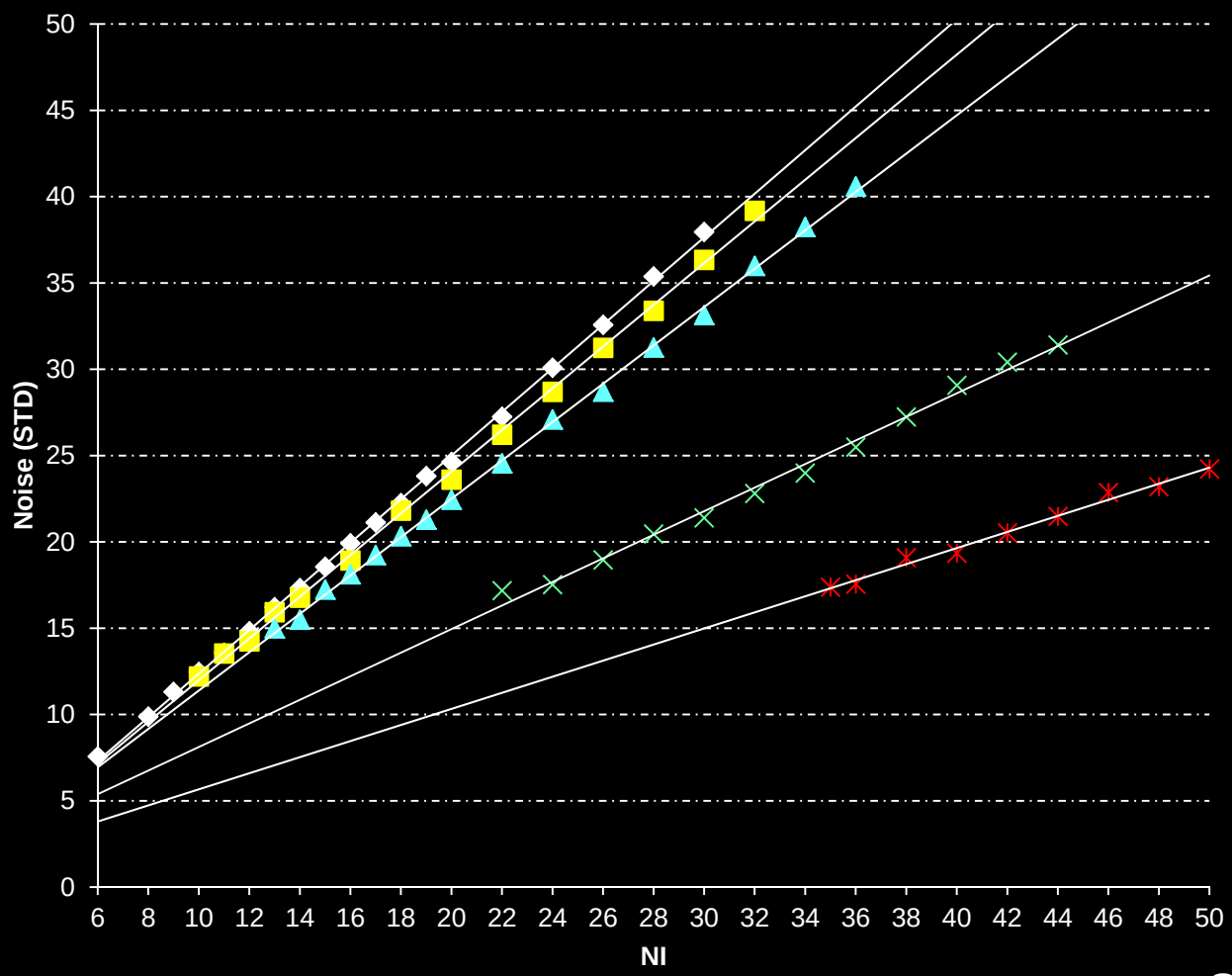


Image from Radimetrics' eXposure Software

ADDITIONAL TOPICS FOR CONSIDERATION

- Use of same image quality reference parameter for all patients
  - Adults of varying body habitus may produce different image quality results



Circumference (Lateral dimension), cm

- 71 (24) 15 yr old
- 86 (30) Small Adult
- 96 (32.5) Medium Adult
- 116 (38.9) Large Adult
- 136 (45) Extra-Large Adult

Courtesy of John Rong, Ph.D.

ADDITIONAL TOPICS FOR CONSIDERATION

- Use of same image quality reference parameter for all patients
  - Adults of varying body habitus may produce different image quality results
  - Pediatric patients of different size may need different image quality

PEDIATRIC PATIENT INDICATIONS AND SIZES MAY NEED DIFFERENT IMAGE QUALITY

- Two 12 year old patients to rule out appendicitis both with diameter ~ 30 cm
  - One imaged with AEC, the other with fixed technique

TCM at 3.5 mm, CTDIvol: 20.8 mGy

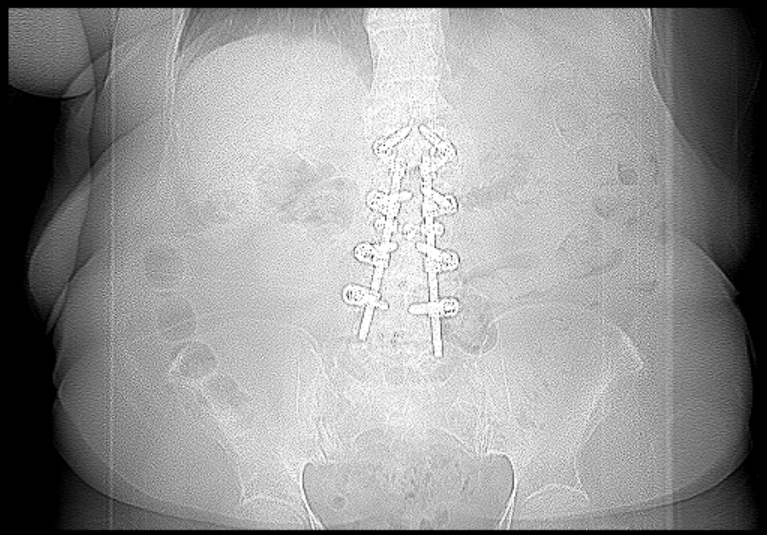
Fixed Technique at 5 mm, CTDIvol: 6.1 mGy

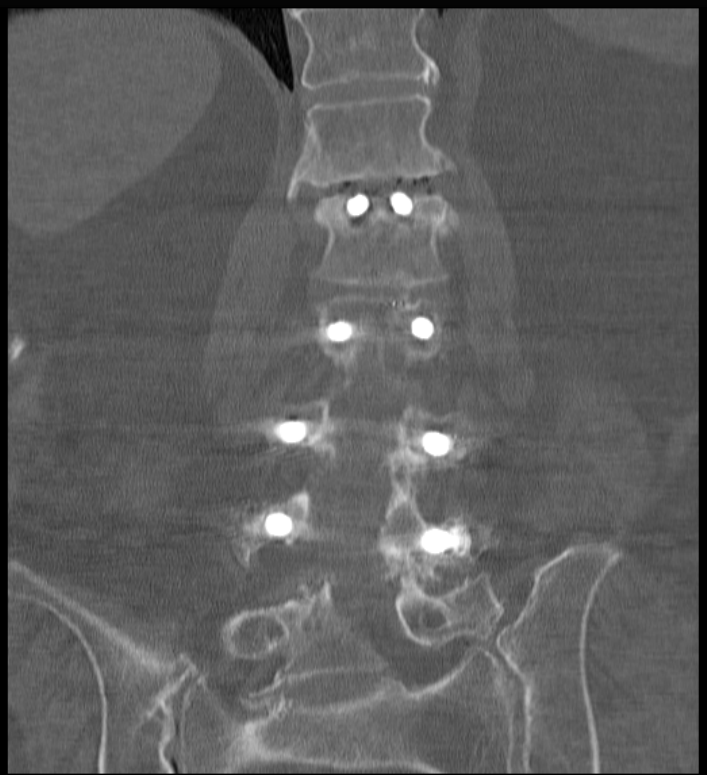
ADDITIONAL TOPICS FOR CONSIDERATION

- Use of same image quality reference parameter for all patients
  - Adults of varying body habitus may produce different image quality results
  - Pediatric patients of different size may need different image quality
- Should AEC be used for extremely large patients?
  - Are body CTDIvol values >80 mGy acceptable?

AEC WITH LARGE PATIENTS?

CTDIvol = 99.6 mGy





ADDITIONAL TOPICS FOR CONSIDERATION

- Use of same image quality reference parameter for all patients
  - Adults of varying body habitus may produce different image quality results
  - Pediatric patients of different size may need different image quality
- Should AEC be used for extremely large patients?
  - Are body CTDIvol values >80 mGy acceptable?
- Scans to not use all aspects of AEC on:
  - Perfusion
  - Extremities
  - Standard head without contrast
  - Pediatric patients? May be vendor specific recommendation

EXTREMITY STUDIES

Thank You!