Bismuth Shielding: Helpful or Harmful

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DISCLOSURES

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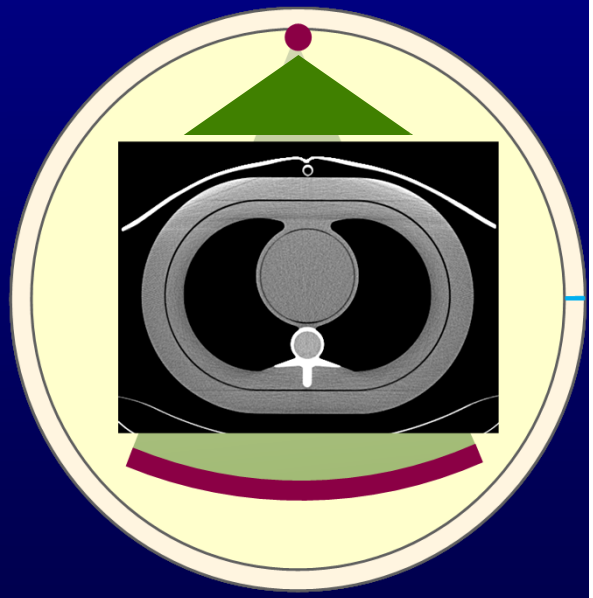
DK 090728	
AR 057902	
RR 018898	

Off Label Usage

None

Introduction

- Bismuth shielding has been used to reduce the dose from CT to superficial radiosensitive organs, such as the breast, lens of the eye, and thyroid.
- Concerns include an adverse effect on image quality and absorption of photons exiting the patient and on their way to the detector
- Clinical studies did not control for noise level; primarily assessed whether “clinically acceptable”



Motivation

- To quantitatively assess the dose reduction and image quality in controlled experiments:
  - Standard clinical protocol
  - Bismuth shielding
  - Organ-based TCM
  - Globally decreasing the tube current to achieve the same dose reduction as bismuth shielding

Bismuth Eye Shielding

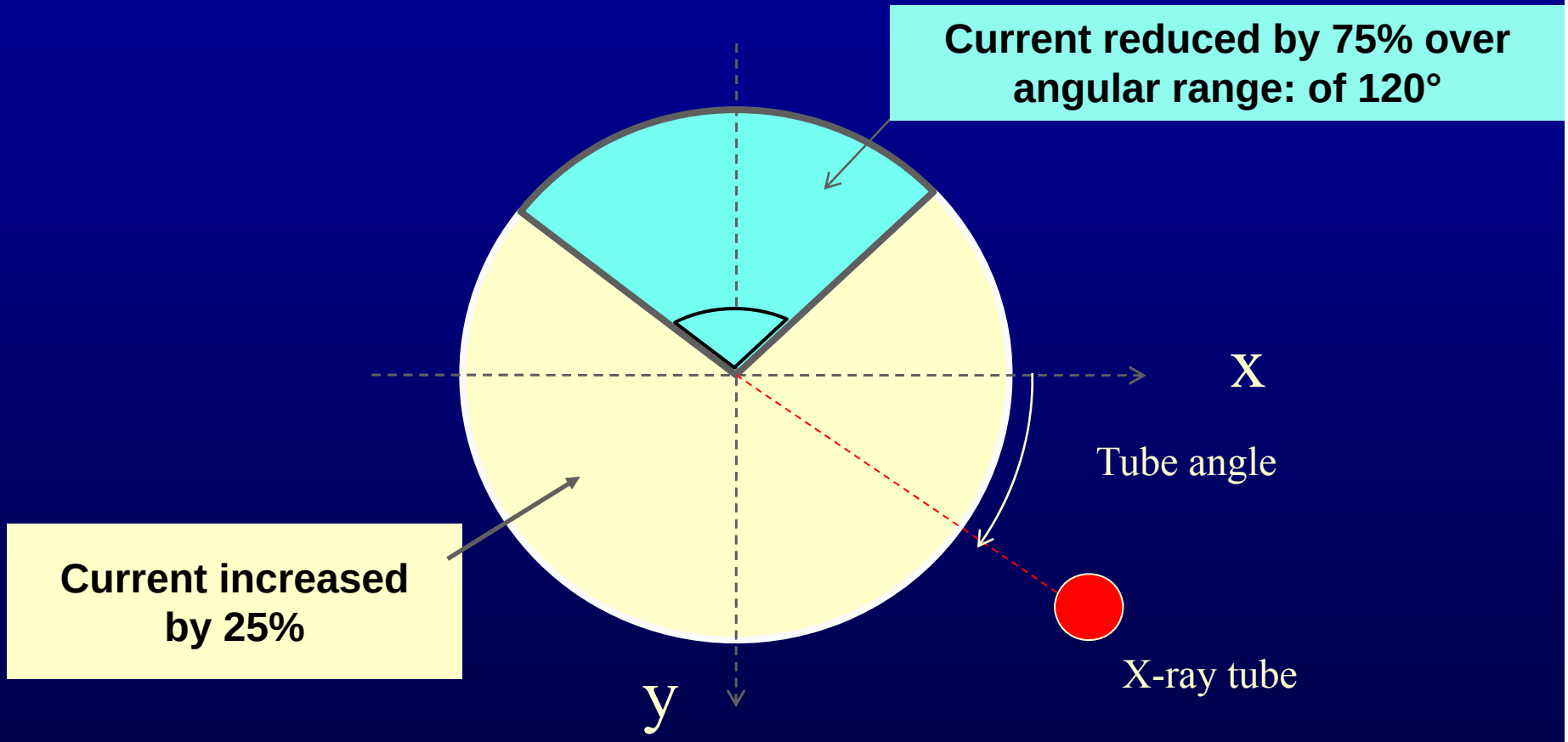
Courtesy of Jia Wang

Scanning parameters

- Reference scan parameters were chosen from our standard spiral head scanning protocol
  - 120 kV, 1s rotation, 5 mm image thickness, 300 mm FOV
- Chose a reduced effective mAs ["Low-mAs"] to yield the same dose reduction to the eye as bismuth shield:

  Low-mAs = Ref-mAs * Bi_Dose / Ref_Dose
- Bi_Dose and Ref_Dose are the doses measured at the eye with and without bismuth shielding, respectively.

Organ-based Tube Current Modulation

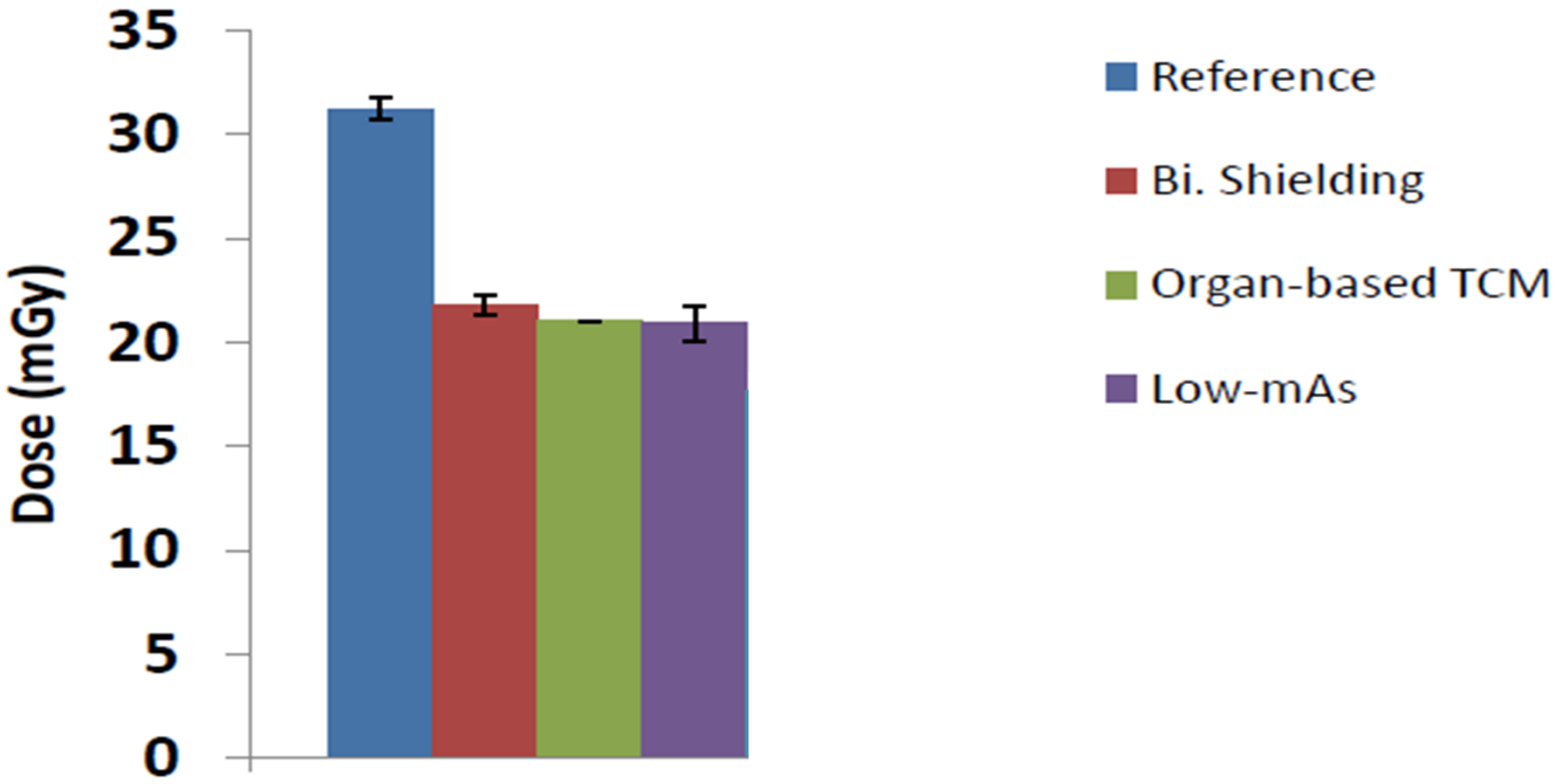


Duan et al, Dose Reduction to Anterior Surfaces With Organ-Based Tube-Current Modulation: Evaluation of Performance in a Phantom Study, AJR, 2011

Eye scanning parameters

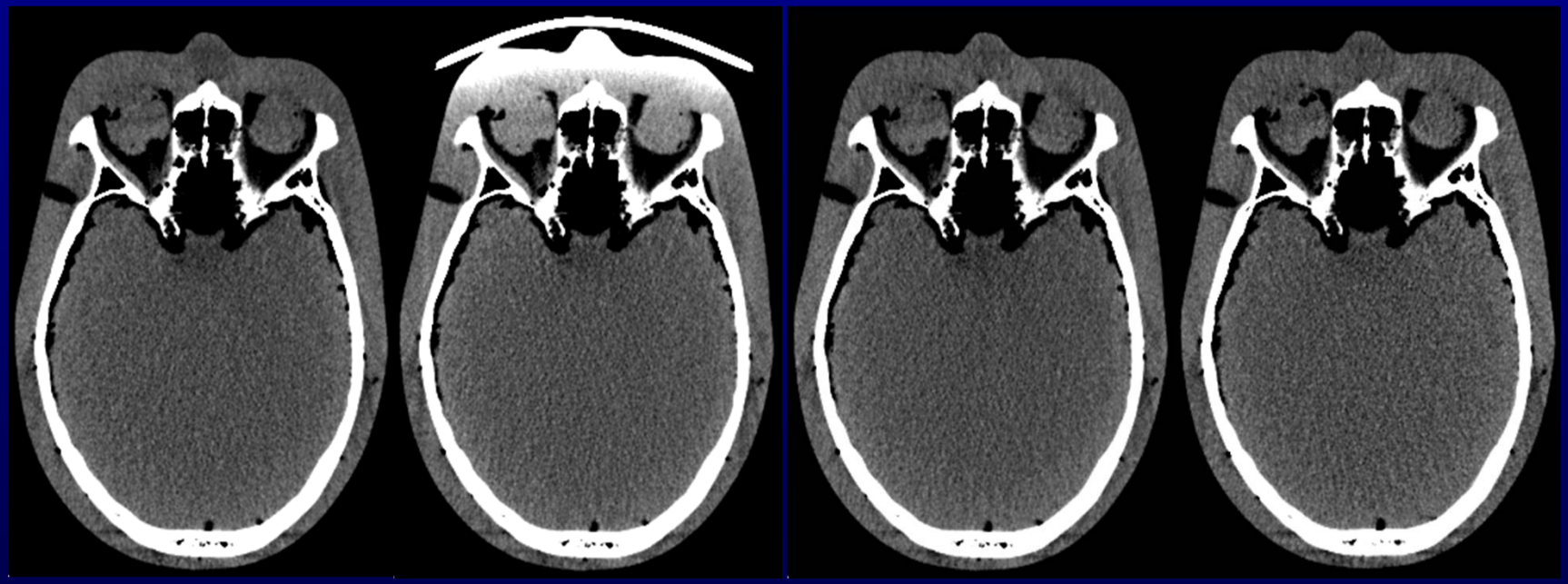
	Effective mAs	CTDIvol (mGy)
Reference	250	38.18
Bi. Shielding	250	38.18
Organ-based TCM	250	37.57
Low-mAs	177	27.19

Dose reduction to the eye lens



Wang et al, ***Bismuth Shielding, Organ-based Tube Current Modulation and Global Reduction of Tube Current for Dose Reduction to the Eye in Head CT,*** **Radiology, In Press**

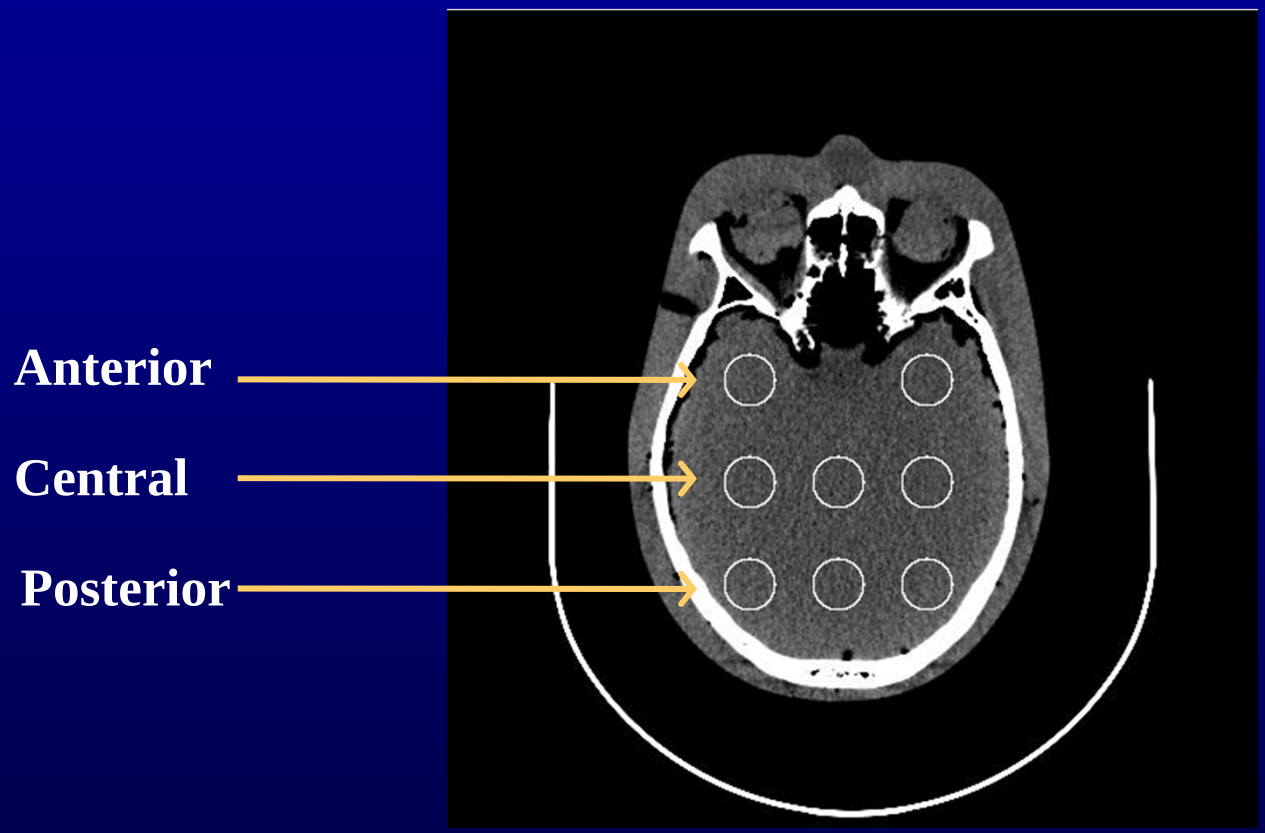
Reference | Bismuth shielding (one layer) | Organ-based TCM | Low-mAs

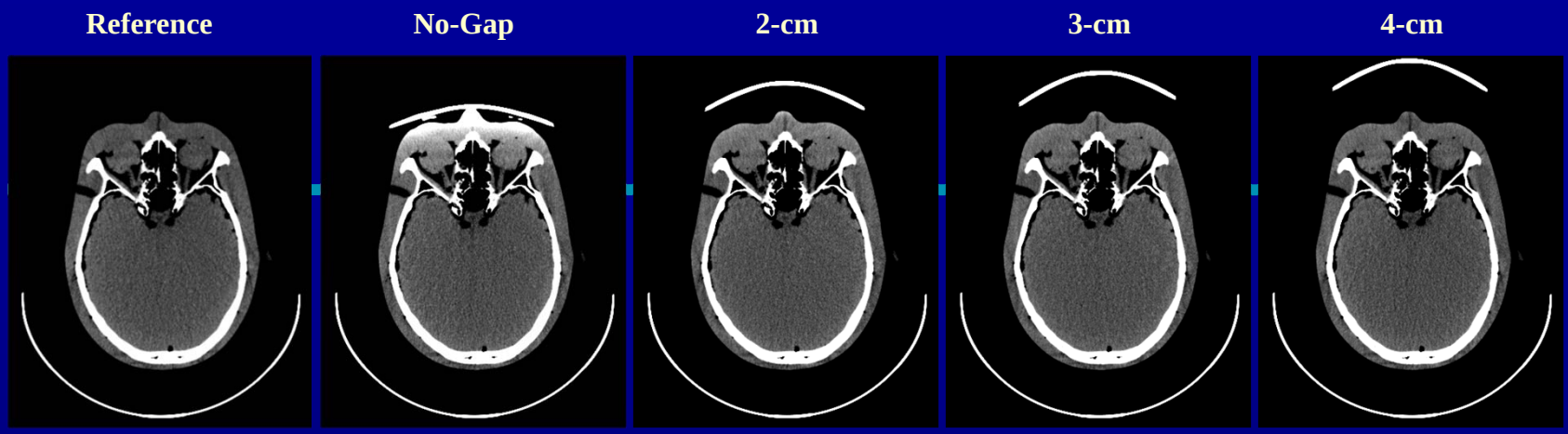


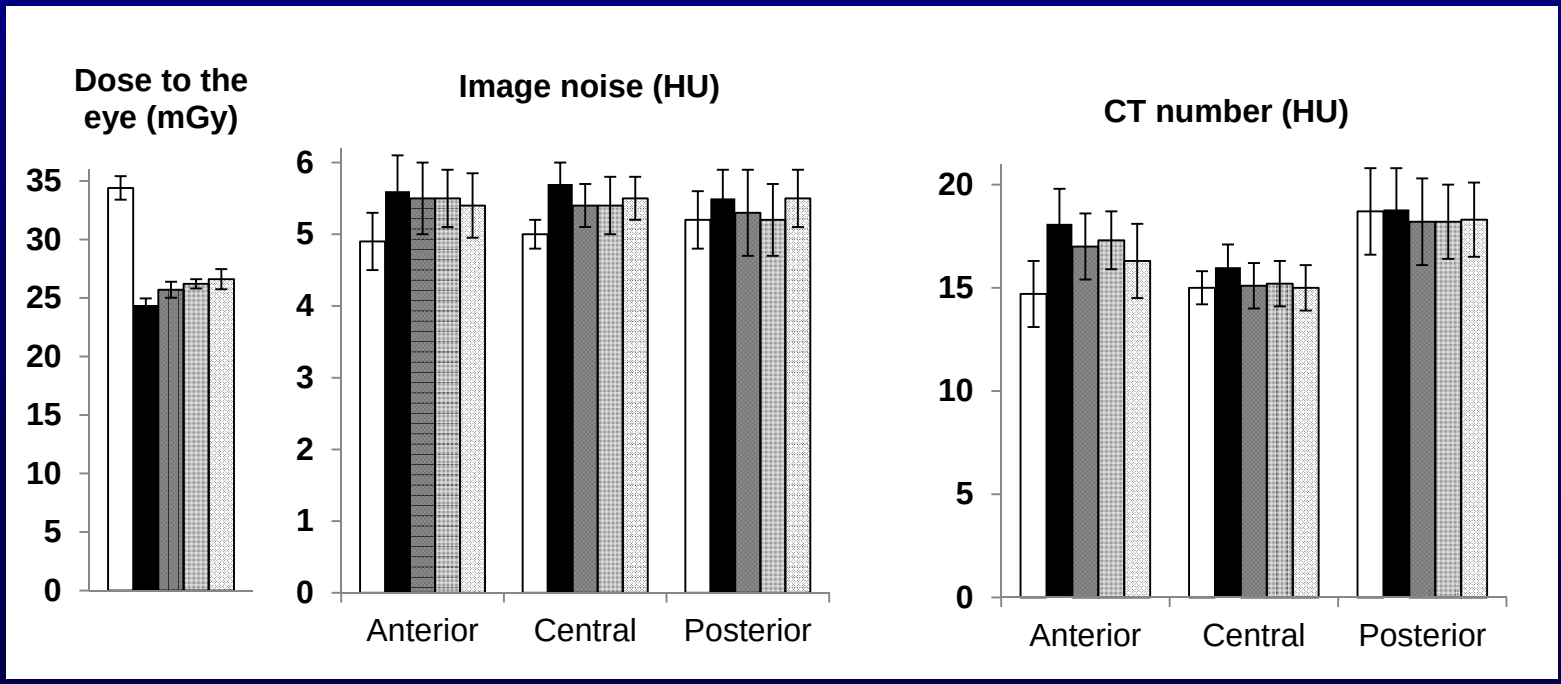
(ww/wl = 120/40)

Courtesy of Jia Wang

Image quality evaluation




Reference
No-Gap
2-cm
3-cm
4-cm


Dose to the eye (mGy)
35
30
25
20
15
10
5
0
Image noise (HU)
6
5
4
3
2
1
0
Anterior
Central
Posterior
CT number (HU)
20
15
10
5
0
Anterior
Central
Posterior
Reference
No-Gap
2-cm
3-cm
4-cm

Summary – Lens of Eye

	Bismuth	Organ-based TCM	Low mAs
Dose Reduction	~ 26%	~ 30%	~ 30%
Noise Increase - Central - Posterior	 ~ 1HU None	 ~ 1 HU None	 ~ 1 HU ~ 1 HU
CT Number Increase	~ 1-3 HU	None	None
Streak Artifacts	Yes	No	No

Anterior vs. global dose reduction

- Bismuth shielding
  - reduces dose to only the anterior surface by ≈ 26%
  - total scanner output (CTDIvol) unchanged
- Organ based tube current modulation
  - reduces dose to anterior surface
  - increases dose to lateral and posterior surfaces
  - total scanner output (CTDIvol) unchanged
- Globally reducing tube current
  - reduces dose to all surfaces by ≈ 30%
  - total scanner output (CTDIvol) decreased ≈ 30%

Thorax phantoms

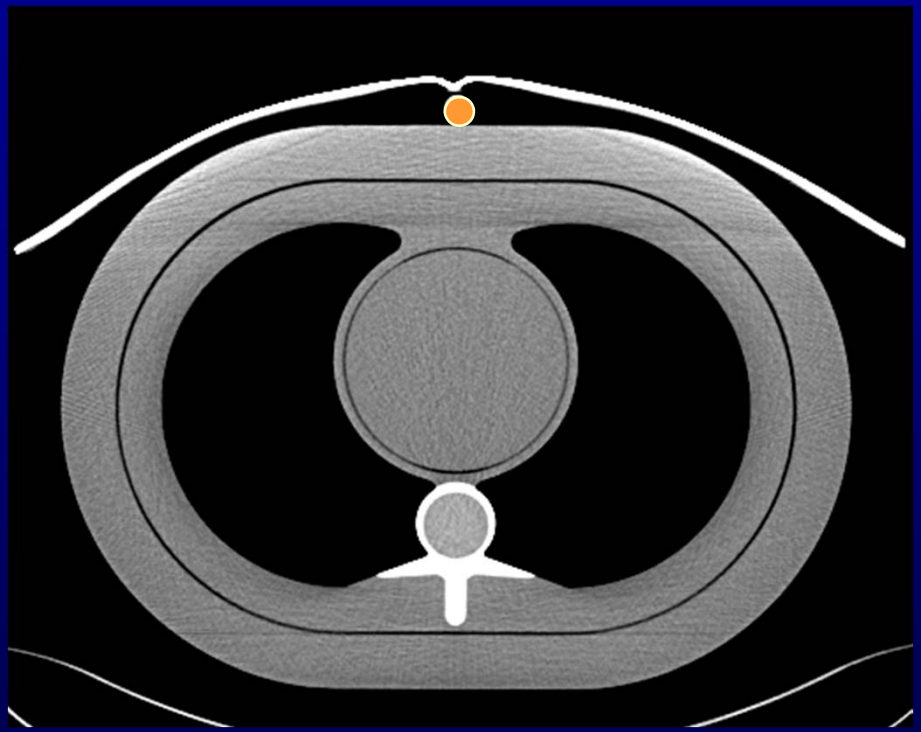
- Semi-anthropomorphic thorax phantoms (Cardio CT, QRM, Moehrendorf, Germany)

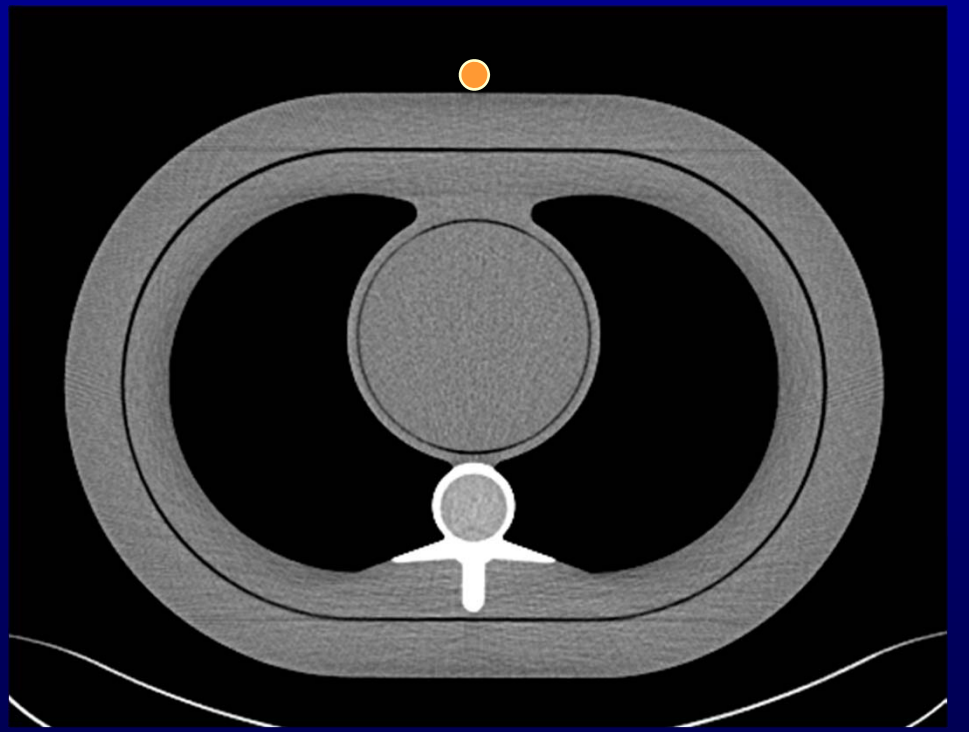
Lateral (cm)	AP (cm)	Bismuth shields
15	11	Pediatric (2-ply)
30	20	Adult (4-ply)
35	25	Adult (4-ply)
40	30	Adult (4-ply)

Scanning Parameters

- Tube voltage:
  - 100kV for 15-cm phantom,
  - 120kV for three adult phantoms
- Collimation: 12 x 0.6 mm, Rotation time: 0.28s
- Automatic Exposure Control (CareDose4D, Siemens Healthcare, Forchheim, Germany)
- The bismuth shield was placed on the phantom ***after the topogram***.
- $CTDI_{vol}$ was same for the reference scan as with bismuth or organ-based TCM

Globally Decreasing Tube Current

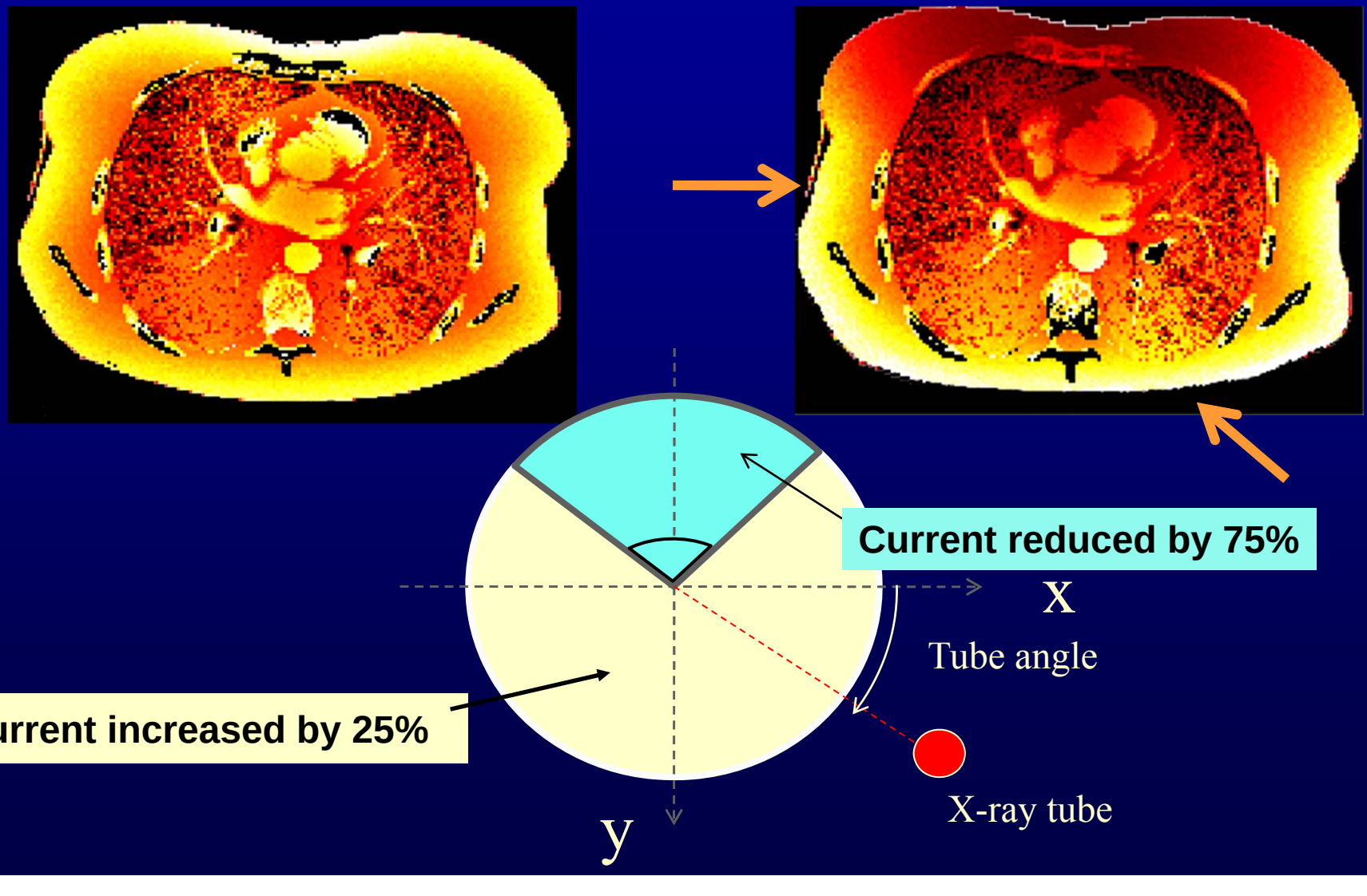




$$mAs_{Low} = mAs_{Ref} \times \frac{Dose_{Bismuth}}{Dose_{Reference}}$$

Courtesy of Jia Wang

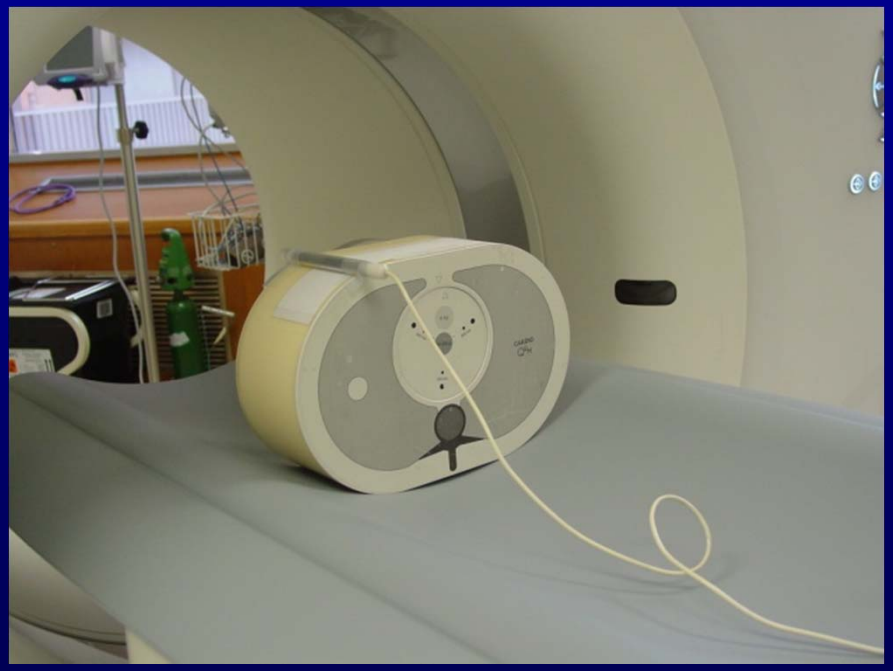
Organ-based tube current modulation

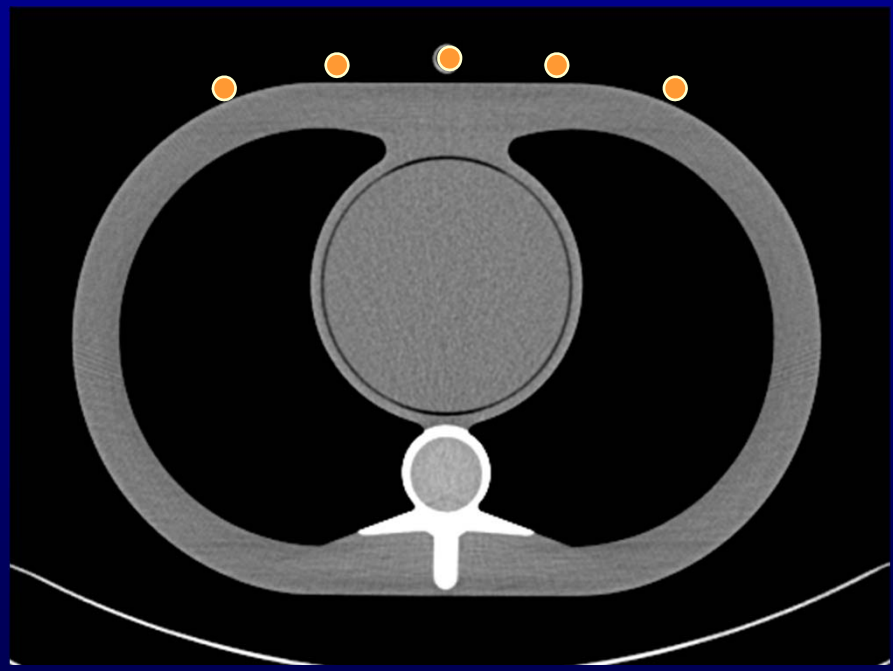


Thorax scanning parameters

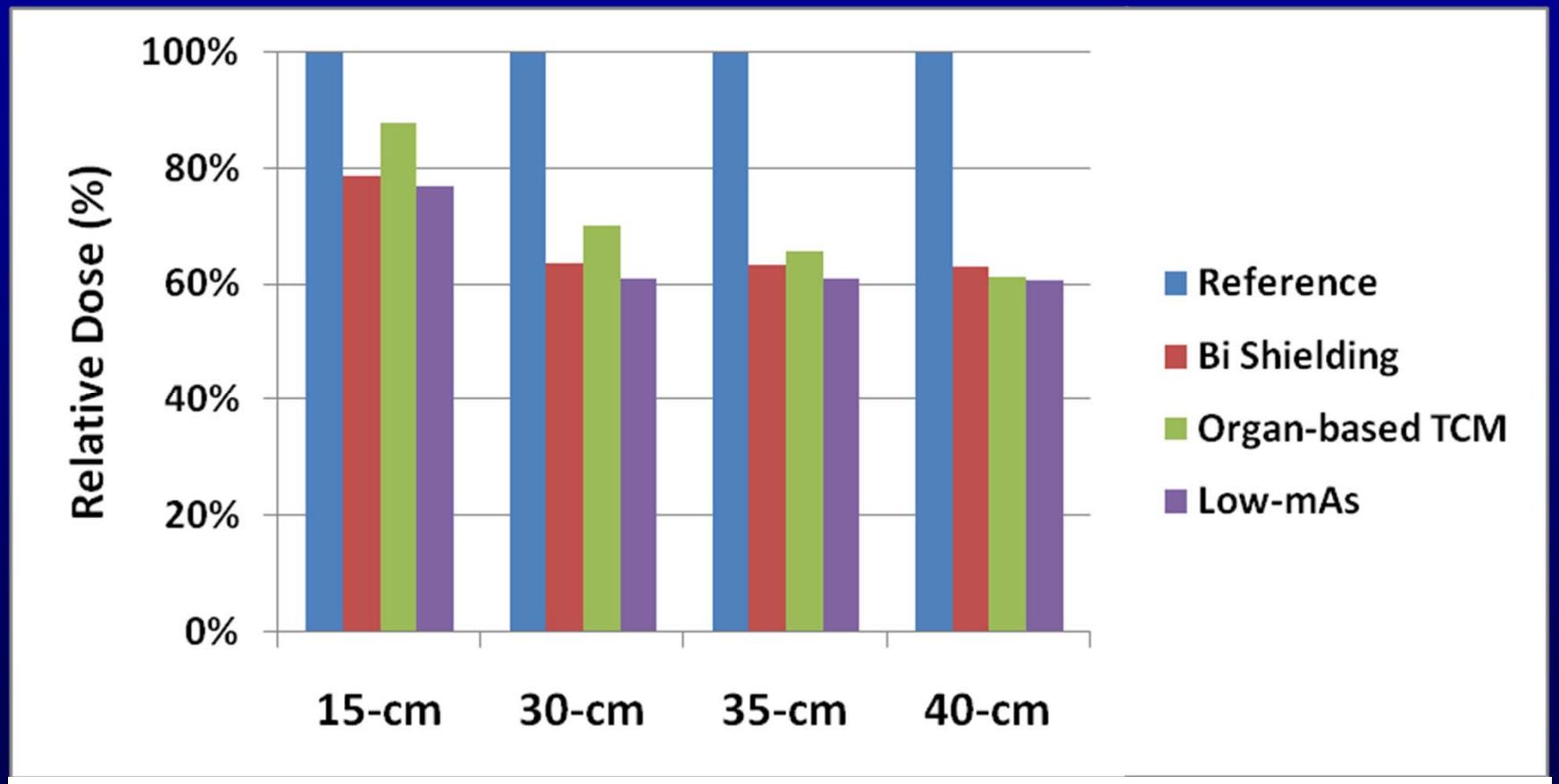
	15-cm		30-cm		35-cm		40-cm	
	Eff.mAs	$CTDI_{vol}$	Eff.mAs	$CTDI_{vol}$	Eff.mAs	$CTDI_{vo}$	Eff.mAs	$CTDI_{vo}$
Reference	32	1.06	67	4.54	126	8.53	139	9.41
Bi Shielding	31	1.05	66	4.51	126	8.51	141	9.52
Organ-based TCM	32	1.08	66	4.45	128	8.62	139	9.41
Low-mAs	26	0.84	56	2.76	76	5.13	83	5.67

Dose measurement



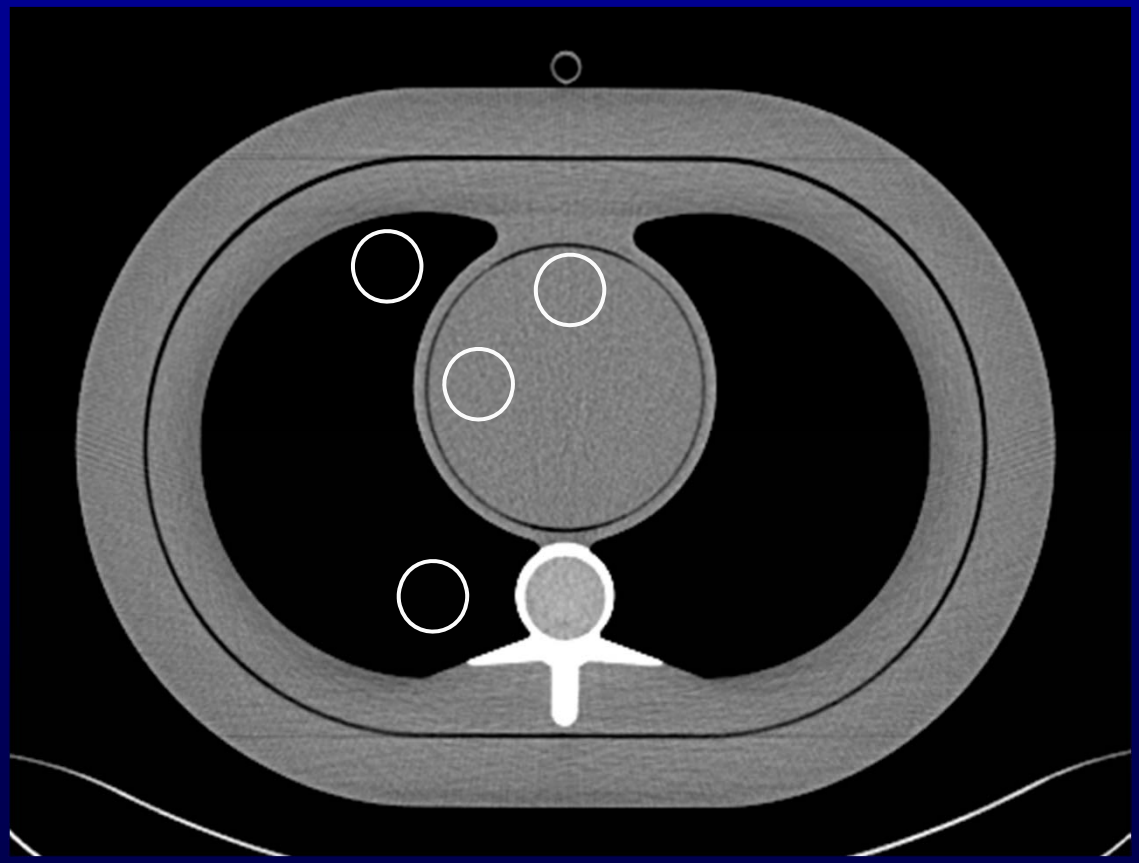


Dose reduction to the anterior surface



Wang et al, 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, Medical Physics, In Press

Image quality evaluation



Courtesy of Jia Wang

Summary - Thorax

	Bismuth	Organ-based TCM	Low mAs
Dose Reduction			
-Adult	~ 40%	~ 40%	~ 40%
-Pediatric	~ 20%	~ 12%	~ 20%
Noise Increase			
-Adult	~ 2-4 HU	None	~ 2-5 HU
-Pediatric	~ 1 HU	None	~ 1 HU
CT # Increase			
-Adult	~ 10-20 HU	None	None
-Pediatric	~ 2-6 HU	None	None
Streak Artifacts			
-Adult	Yes	No	No
-Pediatric	Yes	No	No

Anterior vs. global dose reduction

- Bismuth shielding
  - reduces dose to only the anterior surface by ≈ 40% (adults)/20% (ped)
  - total scanner output (CTDIvol) unchanged
- Organ based tube current modulation
  - reduces dose to anterior surface
  - increases dose to lateral and posterior surfaces
  - total scanner output (CTDIvol) unchanged
- Globally reducing tube current
  - reduces dose to all surfaces by ≈ 40% (adults)/ 20% (ped)
  - total scanner output (CTDIvol) decreased ≈ 40%/ 20% (ped)

Bismuth Shielding Summary

Useful

- Reduces dose to anterior surface
- Limits effects on image quality to a specific range, vs. over the whole scan
- Patients feel protected
- Straightforward to use

Disadvantages

- Not efficient way to reduce dose
  - Only anterior dose reduction
  - Attenuates photons exiting patient
- Affects image quality
  - Decreases CT number accuracy
  - Increases noise and artifacts
  - Should not be used over liver
- Pitfalls with tube current modulation
  - Image quality is not as prescribed
- Placement/disinfection needed

Conclusions

- Alternative approaches to reduce anterior dose should be considered (e.g. those mentioned or z-specific mAs)
- Organ-based tube current modulation can achieve the same anterior dose reduction as bismuth shielding
  - No artifacts, CT Number unaffected, no noise increase
  - Moves "saved" does to posterior
- Globally lowering tube current can match anterior dose reduction by bismuth shielding, at same noise level
  - Medical Physicists should assist in determining appropriate scan parameters (e.g. Noise Index)
  - Adapt for different patient sizes (Noise Index technique chart)

Thank you!

CT Clinical Innovation Center

http://mayoresearch.mayo.edu/ctcic