Eye lens dose from brain perfusion CT exams

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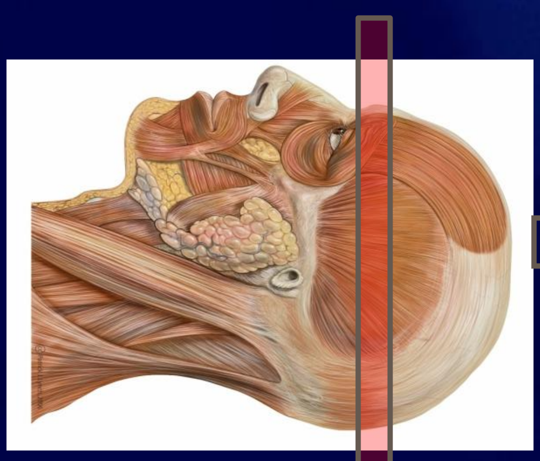
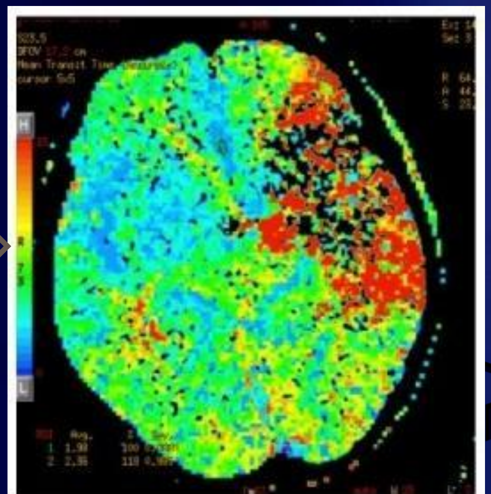
Disclosure

- Current employee of Toshiba America Medical Systems

CT brain perfusion

- Evaluate cerebral perfusion defects for suspected stroke patients
- Important tool to monitor blood-brain barrier
- Repeatedly exposing one location of the head to monitor contrast uptake and wash-out



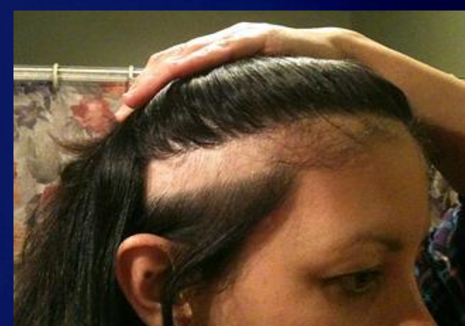


Concern about deterministic effects

- Radiation dose
- Peak skin dose:
  - Erythema (skin reddening) and epilation (hair loss) complications
- Eye lens dose:
  - Cataractogenesis

Concern about deterministic effects

- Started from medias
  - Hospitals in Los Angeles, Altanta, etc



Eye lens dose management is important

- Retrospective estimation
- Correlation with existing CT dose metrics
- Reduction strategies

Eye lens dose management

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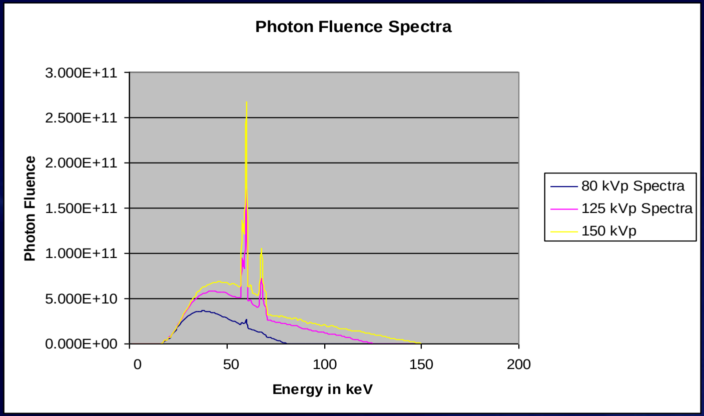
- Reduction strategies

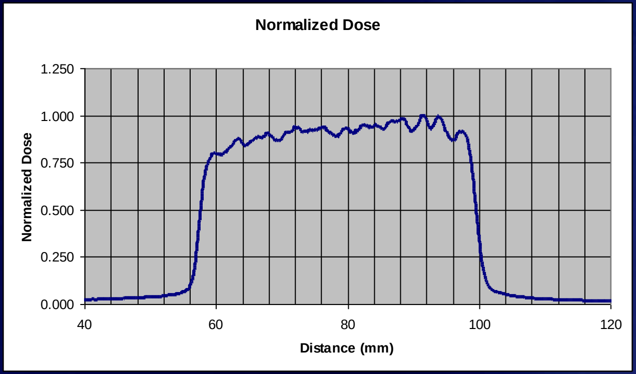
Estimating eye lens dose

- Monte Carlo simulations
  - CT source model
  - Patient model

CT source model

- Spectra
  - Function of beam energy
- Geometry
  - Fan angle, beam profile
- Filtration
  - Bowtie filter (typically proprietary)
  - Other added filtration (also proprietary)





- Data comes from:
  - Manufacturer
  - Equivalent Source Methods (e.g. Turner et al. Med Phys 2009)
    - Measured values (HVL, bowtie profile)
    - Calculations to get “equivalent” spectra and bowtie

Estimating eye lens dose

- Monte Carlo method based simulations (MCNPX)
  - CT source models for 64 slice scanners from all four manufactures
    - Toshiba Aquilion 64

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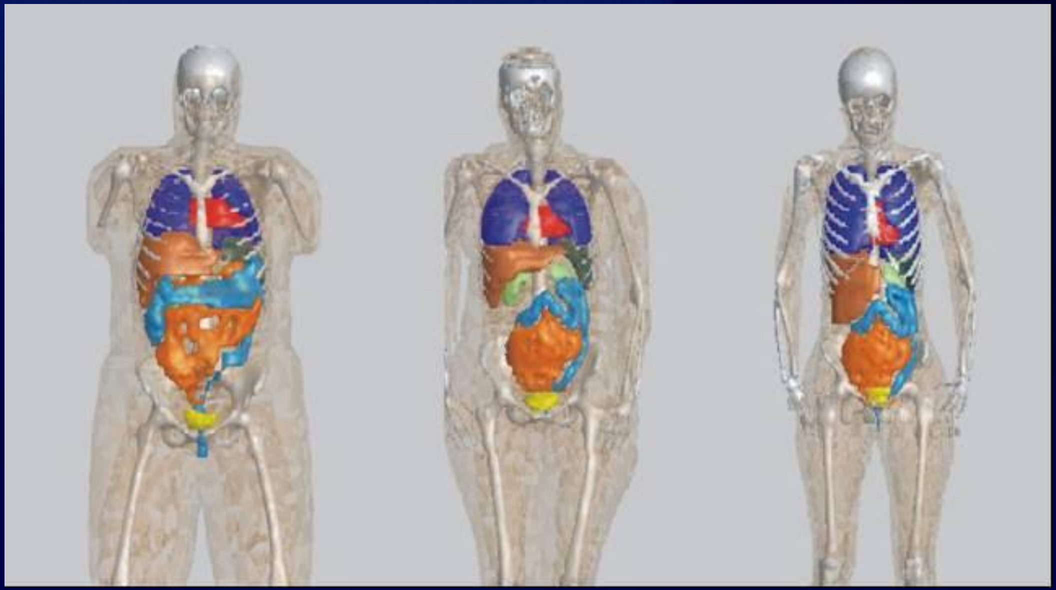
    - GE VCT 64
    - Phillips Brilliance 64

Patient model

- Voxelized Models
  - Based on actual patient images
  - Identify radiosensitive organs – usually manually
    - Location, size, composition, and density defined for each organ
- Different age, gender, and sizes

Patient model

- GSF models (Petoussi-Henss N, Zankl M et al, 2002)
  - 4 adults (Irene, Donna, Golem, and Frank)

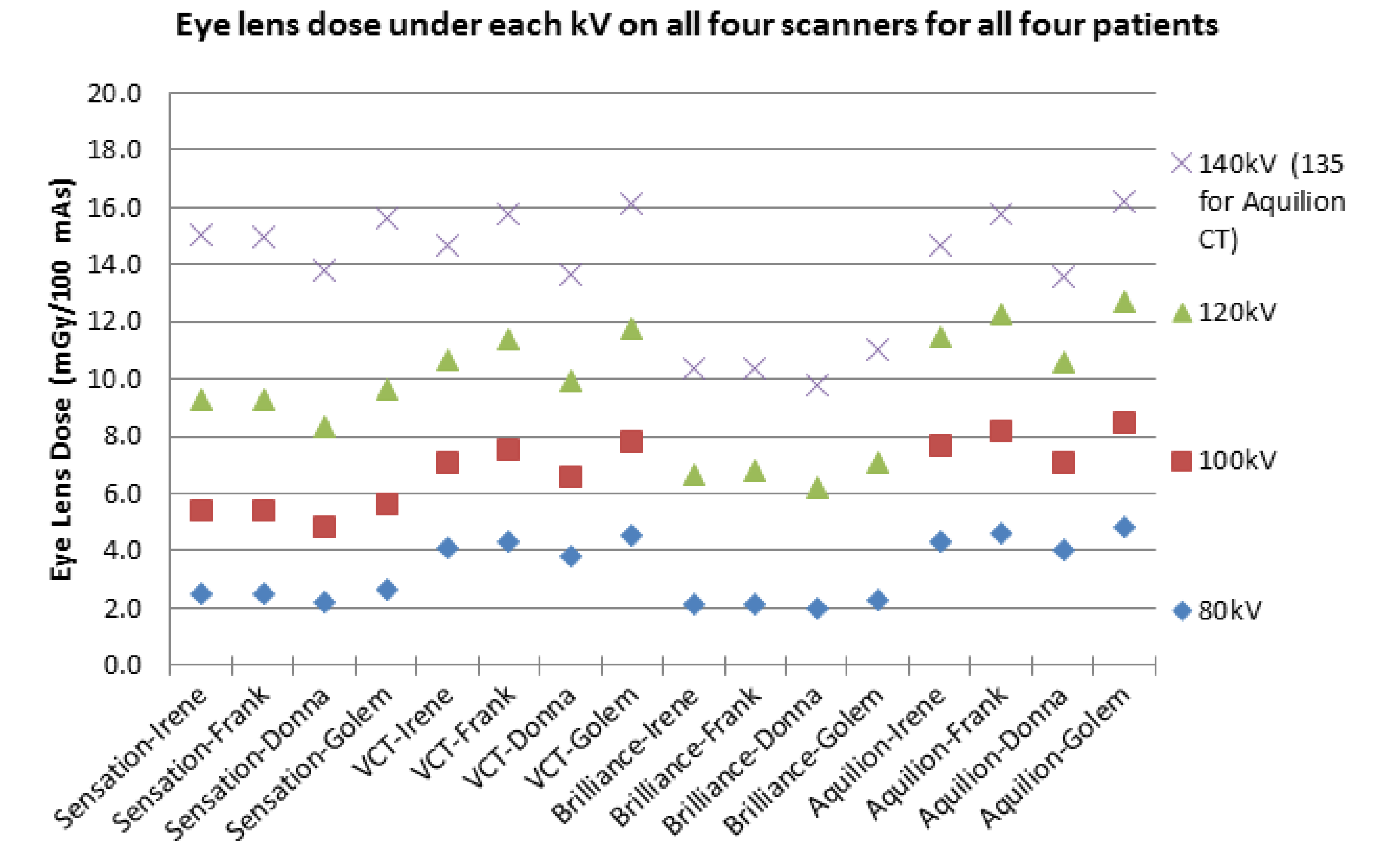


Simulation experiments

- To estimate eye lens dose from brain perfusion scan:
  - All 4 scanners, all 4 patients
  - at all 4 tube voltage settings (4 x 4 x 4 simulations)
  - Using the widest collimation
  - Cover the eye lenses
  - No table movement

Results

- Eye lens dose (mGy/100mAs)



Di Zhang, et al, Med Phys, 40 (9), 2013

So……?

- Estimate scanner and protocol specific eye lens dose for CT brain perfusion exams

- For example, AAPM brain perfusion protocols

AAPM protocols

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CT SCAN PROTOCOLS

Purpose	FDA Award	Questions	Role of the QMP	CT Dose-Check	Protocols	Lexicon	Education Slides

Available Protocols

Adult Protocols

- Lung Cancer Screening CT (updated 07/03/2015) [Give Feedback]
- Routine Adult Chest-Abdomen-Pelvis CT (added 02/20/2014) [Give Feedback]
- Routine Adult Chest CT (added 11/20/2012) [Give Feedback]
- Routine Adult Abdomen/Pelvis CT (added 10/17/2012) [Give Feedback]
- Routine Adult Head CT (added 06/01/2012) [Give Feedback]
- Routine Adult Brain Perfusion (updated 05/22/2012) [Give Feedback]

AAPM protocols

Scanner/Mode	kVp	bowtie	Nominal collimation (total) in mm	mAs/rotation	No. of rotations	total mAs
Siemens Sensation 64	80	general	24 x 1.2 (28)	270	40	10800
GE VCT axial mode	80	head	64 x 0.625 (40)	150	22	3300
GE VCT cine mode	80	head	64 x 0.625 (40)	150	45	6750
Philips Brilliance 64 Non-Jog mode	80	general	32 x 1.25(40)	125	30	3750

AAPM protocols

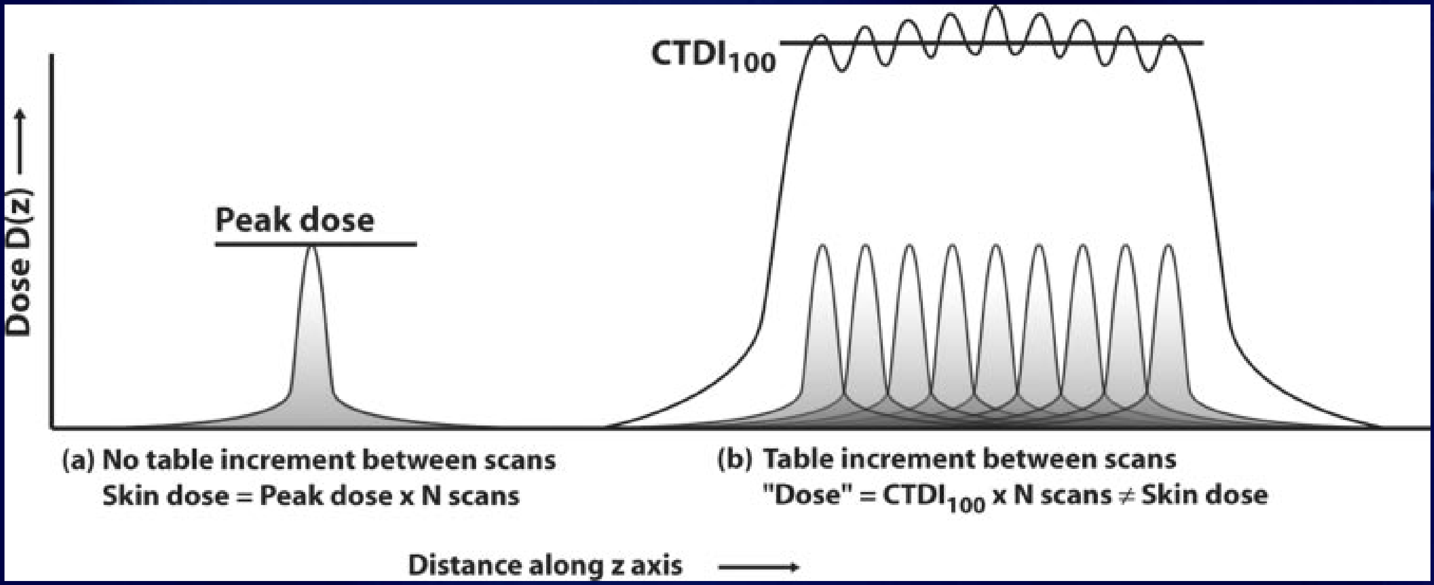
Scanner/ mode	Siemens Sensation 64	GE VCT axial mode	GE VCT cine mode	Philips Brilliance 64
Eye lens dose (mGy)	256	137	279	81

Eye lens dose management is important

- Retrospective estimation
- Correlation with existing metrics
- Reduction strategies

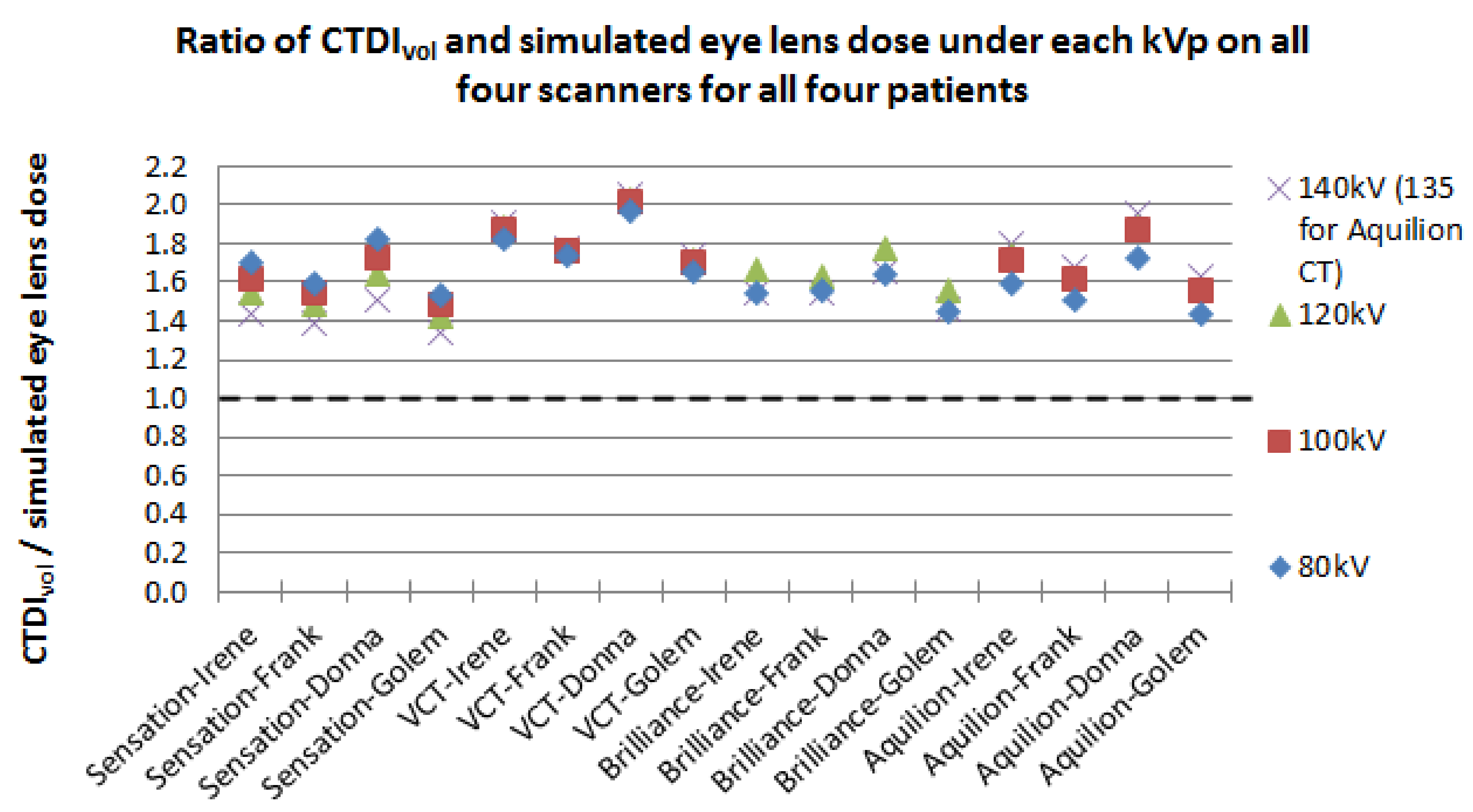
CT dose metrics

- $CTDI_{vol}$
  - Assume continuous scans with table incrementations
  - Overestimate dose to a point



Bauhs, J.A., Vrieze, T.J., Primak, A.N., Bruesewitz, M.R. & McCollough, C.H. CT dosimetry: comparison of measurement techniques and devices. *Radiographics* **28**, 245-253 (2008).

CTDI$_{vol}$ normalized by true eye lens dose



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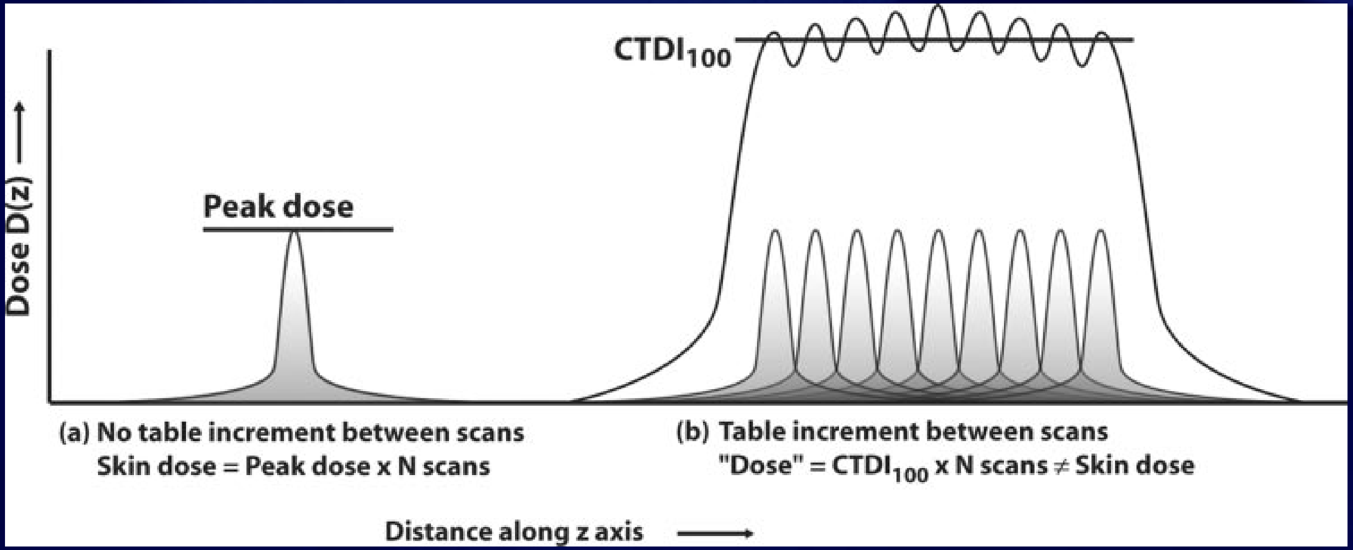
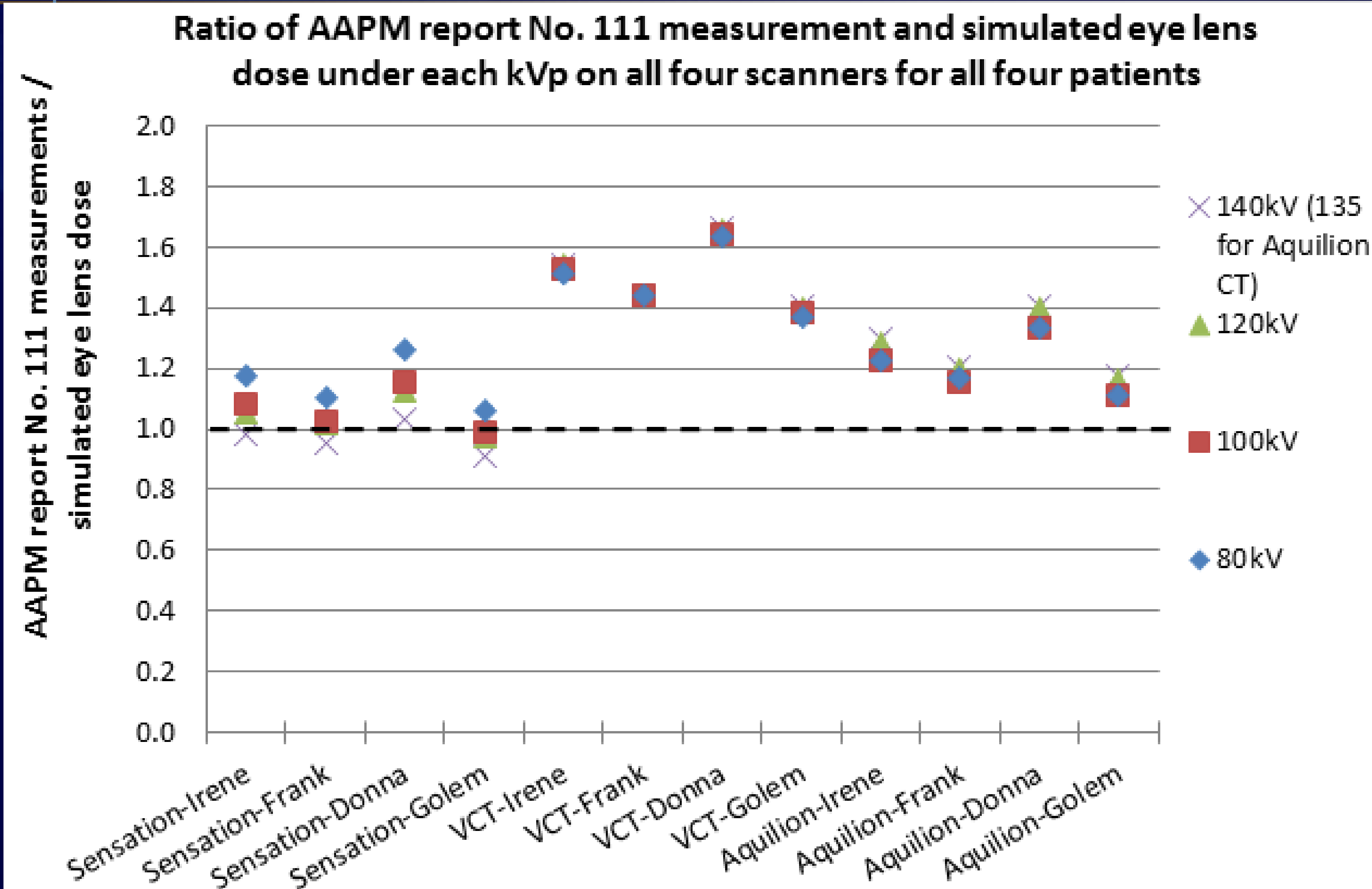
CT dose metrics

- AAPM TaskGroup 111 (TG111) peak dose metric
  - Use a small chamber for point dose measurement
  - May provide better estimate to eye lens dose from brain perfusion scans



TG111 measurements normalized by true eye lens dose



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Outline

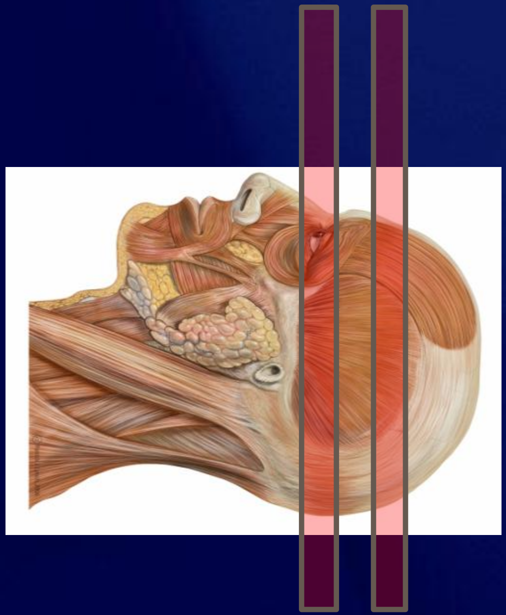
- Estimation
- Correlation with existing metrics
- Reduction strategies

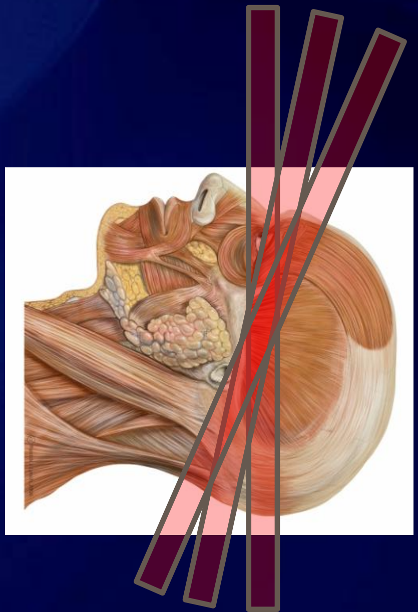
Explore dose reduction strategies

- Lowering kVp or mAs, IR (universal methods)
- Bismuth shielding
- Organ based tube current modulation

Explore dose reduction strategies

- Simply the geometry
  - Scan location
  - Gantry tilt

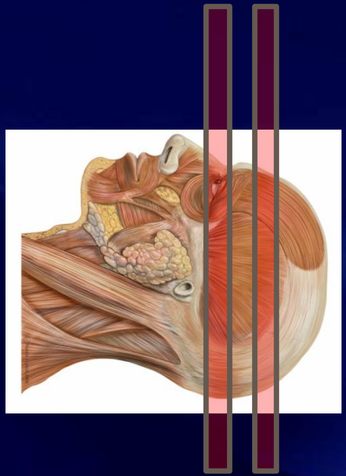




Explore dose reduction strategies

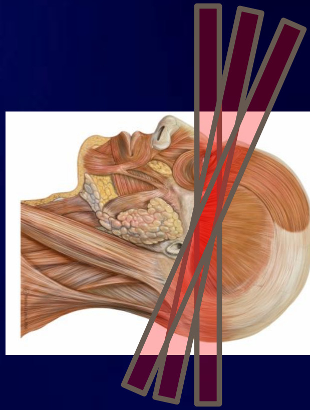
- Move scan location away

  scan location every 0.5 cm .



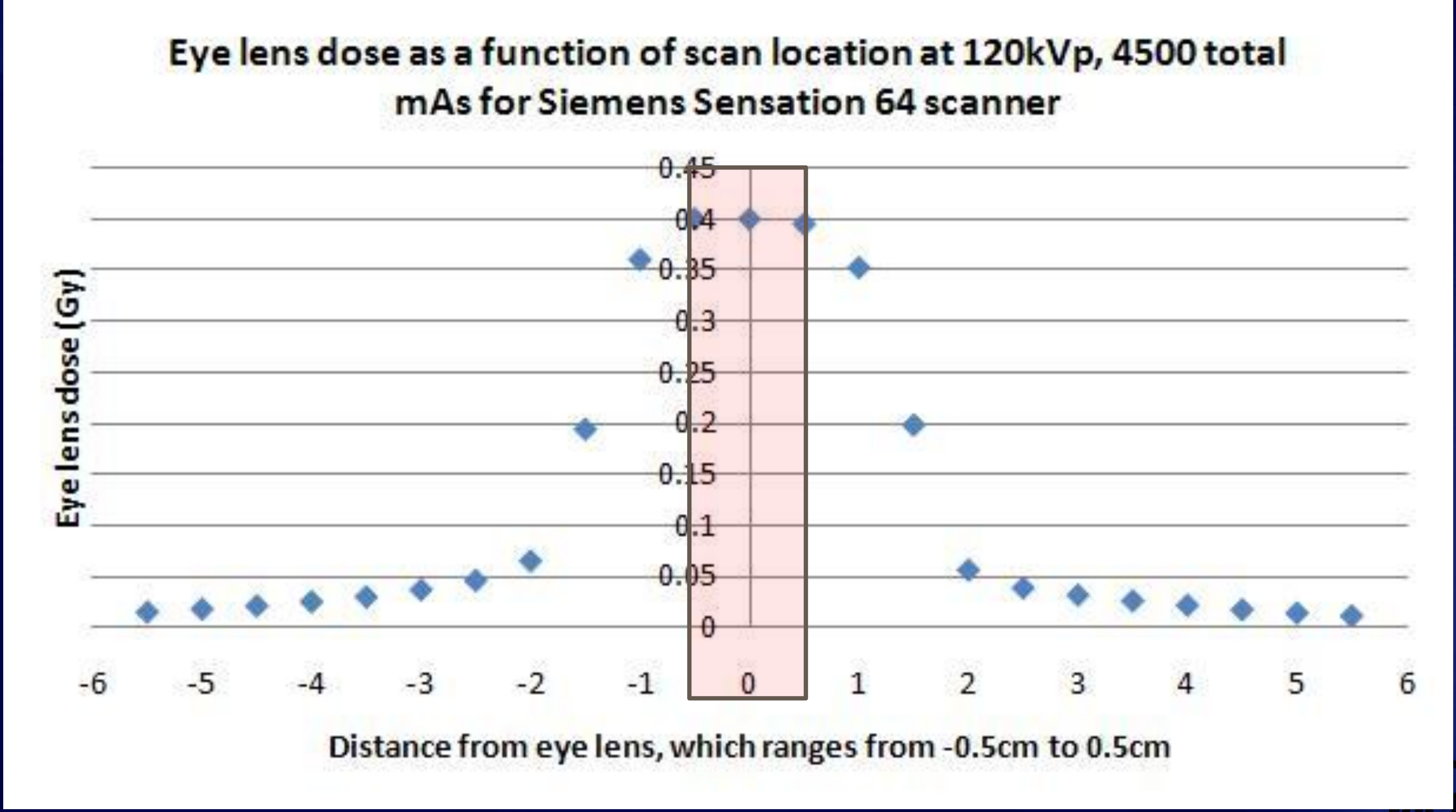
- Tilt gantry angle

  every 5 degree.



Dose reduction strategies

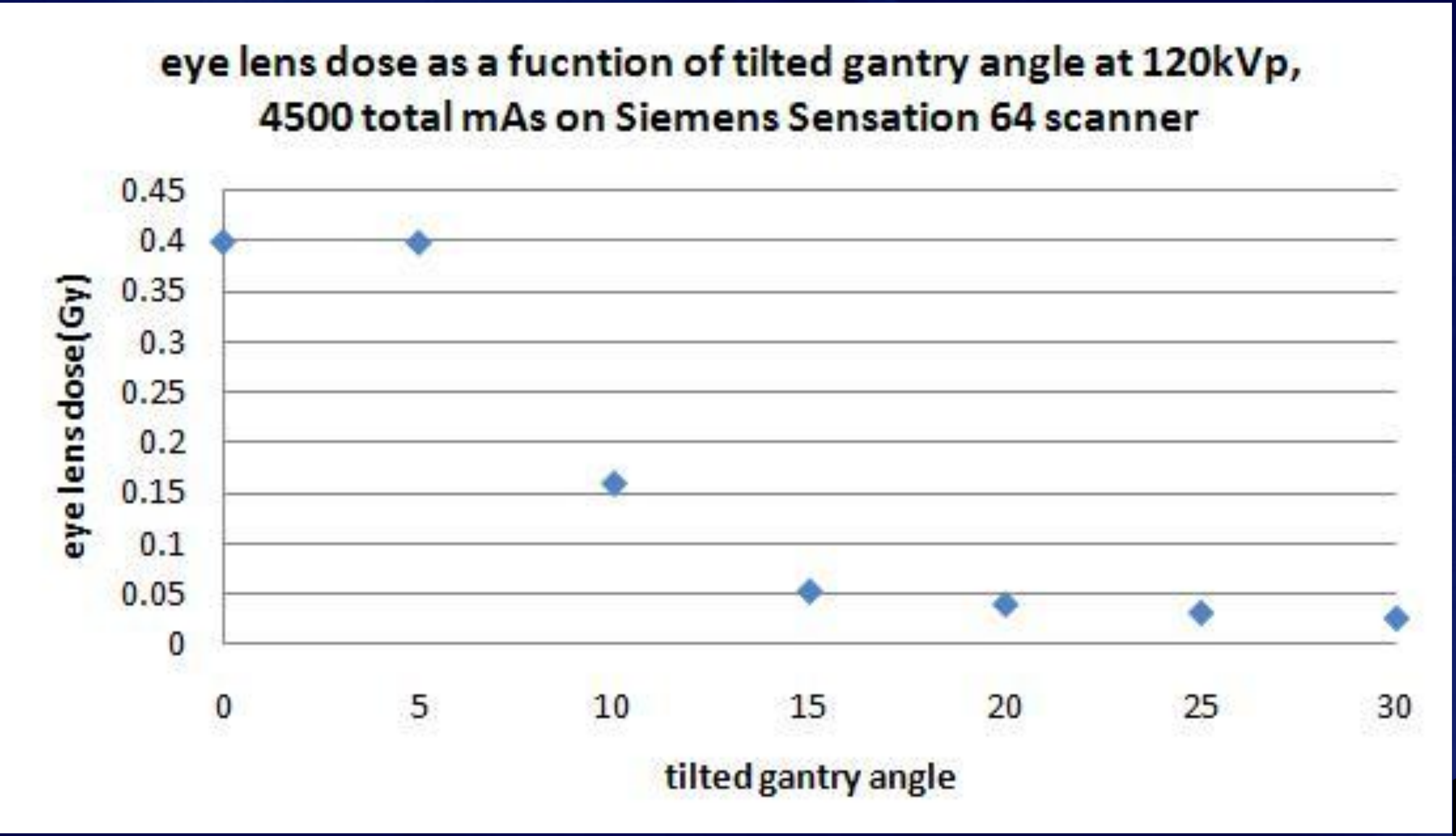
- Moving scan location away (half beam width 1.6 cm)



Di Zhang, et al, AJR, 198:412-417, 2012

Dose reduction strategies

- Tilting gantry angle



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Conclusions

Conclusion (1)

- Accurately estimate eye lens dose from CT brain perfusion exam
  - Protocol design
  - Dose estimate

Conclusion (2)

- Understand the performance of common tools in terms of estimating eye lens dose
  - CTDI overestimates dose, conservative estimation
  - TG111 is more accurate, but not currently available on console
  - Still not dose to patient

Conclusion (3)

- Strategies to reduce eye lens dose
  - Moving the scan location away
  - Tilting the gantry angle

CT perfusion imaging requires repeatedly exposing one location of the head in order to:

8%	1.	Improve low contrast resolution within the brain parenchyma
0%	2.	Maximize the spatial resolution within the brain parenchyma
2%	3.	Monitor brain tumor growth over a short period of time
14%	4.	Monitor the flow of cerebrospinal fluid
76%	5.	Monitor the uptake and wash-out of iodinated contrast

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Ref: “Peak skin and eye lens radiation dose from brain perfusion CT based on Monte Carlo simulation”. D Zhang et al, AJR Am J Roentgenol. 2012 Feb;198(2):412-7

The scanner reported CTDIvol values for the Brain Perfusion protocols posted on the AAPM website range actually:

62%	1.	Overestimate the patient eye lens dose by at least 20%
15%	2.	Overestimate the patient eye lens dose by just under 10%
15%	3.	An accurate estimate of patient eye lens dose to within 10%
6%	4.	Underestimate the patient eye lens dose by just under 10%
2%	5.	Underestimate the patient eye/ lens dose by at least 20%

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4. Underestimate the patient eye lens dose by just under 10%
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Ref: “Estimating peak skin and eye lens dose from neuroperfusion examinations: Use of Monte Carlo based simulations and comparisons to CTDIvol, AAPM Report No. 111, and ImPACT dosimetry tool values”, D Zhang, et al, Med Phys, 40 (9), 2013