# Educational Course - Imaging Informatics II
# CT Dose Reporting

# CTDI and Patient Size Effects on Radiation Dose

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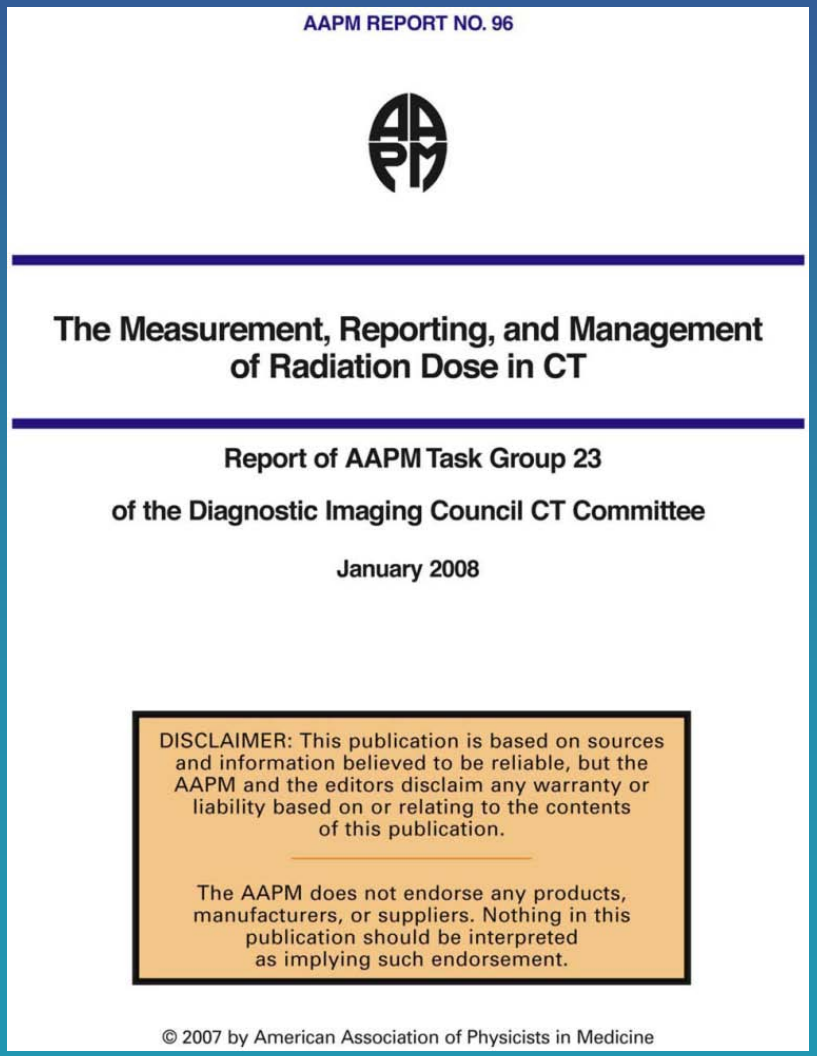
# Learning Objectives

- Understand how CTDIvol and DLP are determined for a clinical CT scanner.
- Learn how to estimate organ doses and effective dose from reports of CTDIvol and DLP
- Understand current limitation on effective dose estimates with respect to patient size and sex.

# Best Reference – AAPM Report 96



AAPM REPORT NO. 96

The Measurement, Reporting, and Management of Radiation Dose in CT

Report of AAPM Task Group 23

of the Diagnostic Imaging Council CT Committee

January 2008

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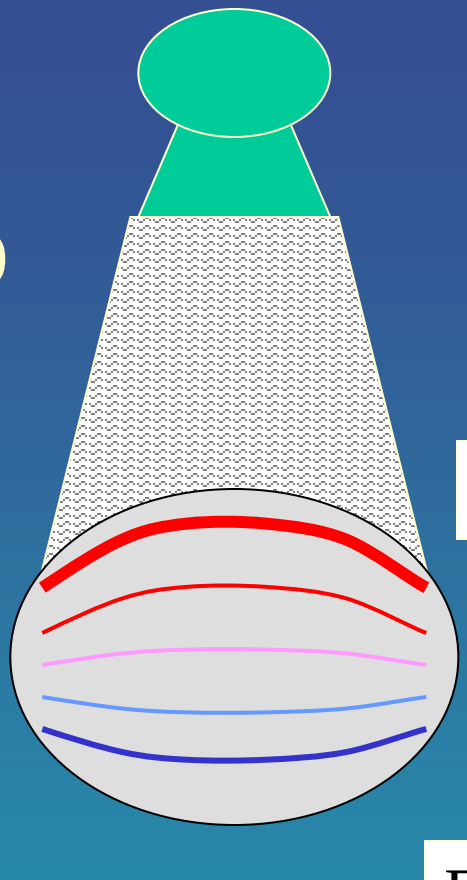
**RADIOGRAPHIC EXPOSURE**
(single tube position)

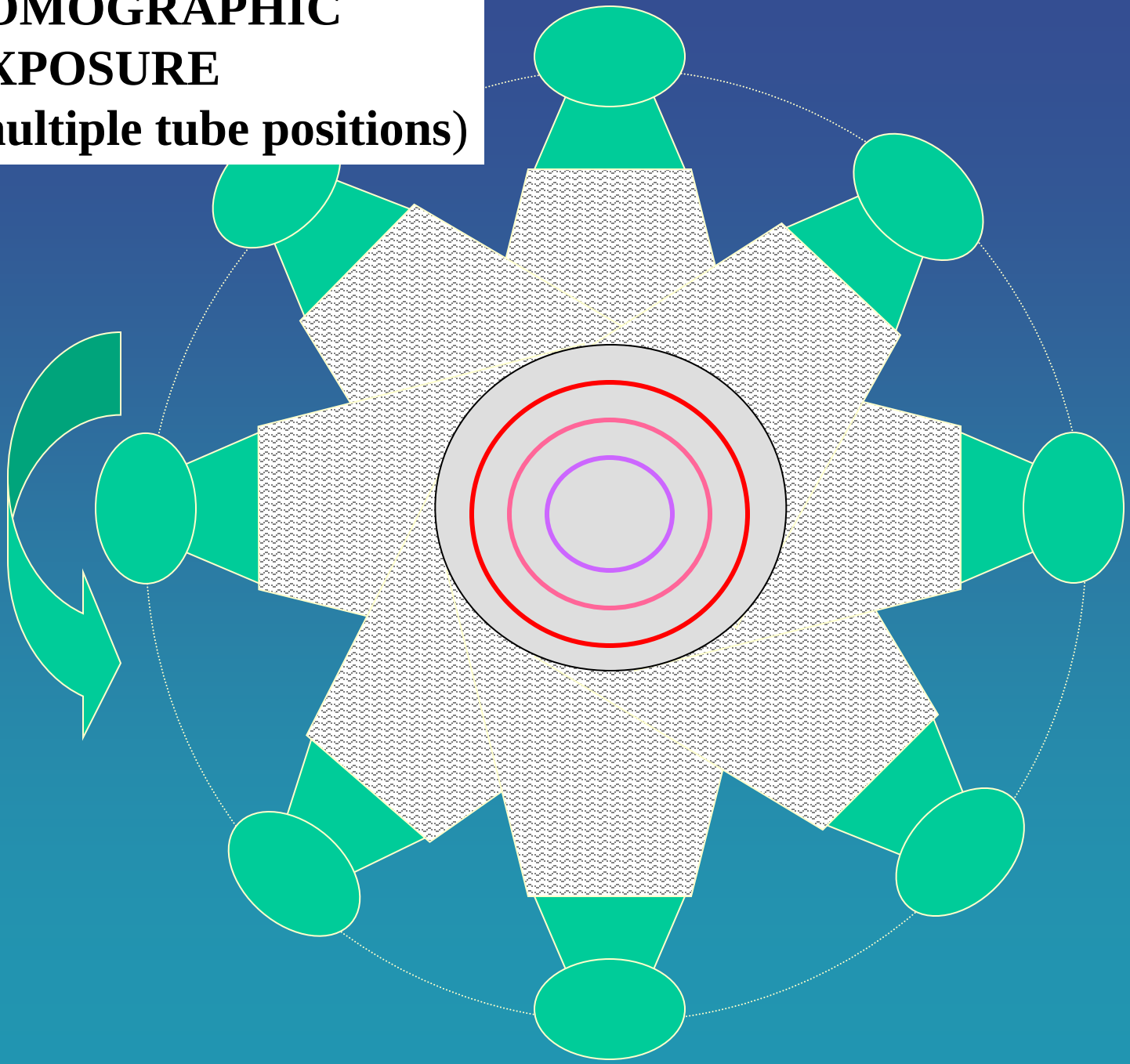


Dose Gradient

Entrance Skin Exposure (ESE)

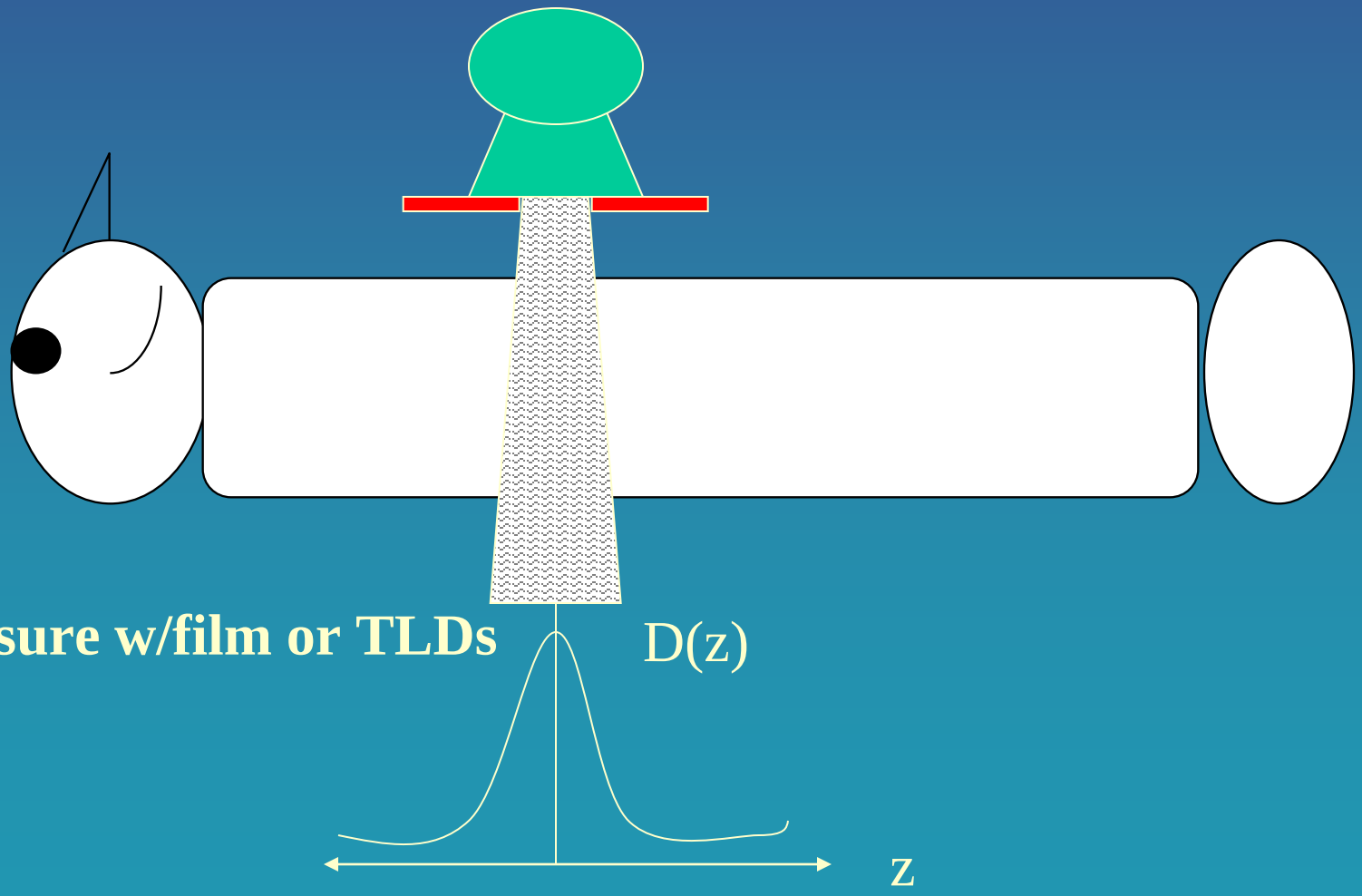
Exit Skin Exposure

# TOMOGRAPHIC EXPOSURE (multiple tube positions)



# CT Dose Distributions

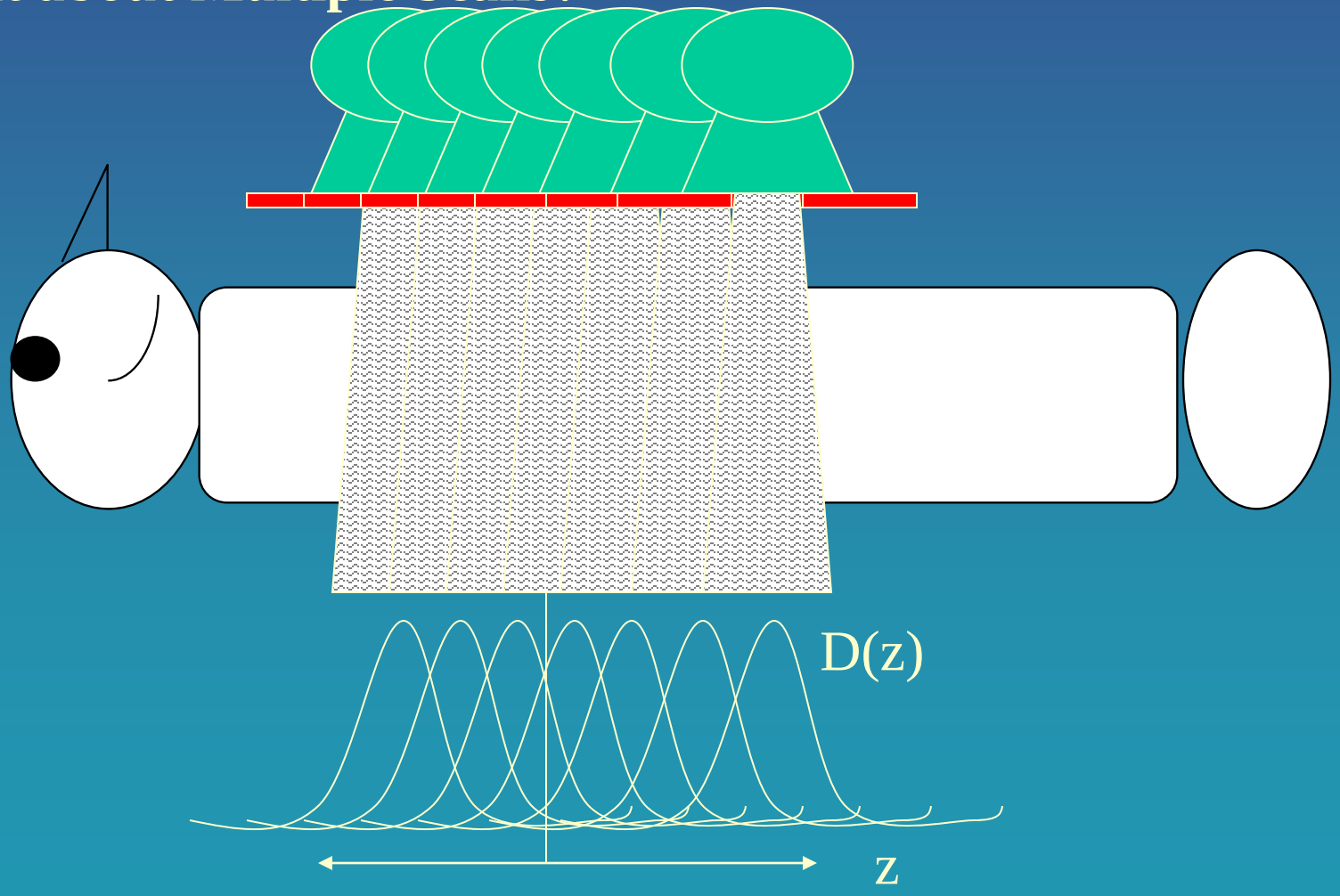
- **D(z) = dose profile along z-axis from a single acquisition**




- **Measure w/film or TLDs**

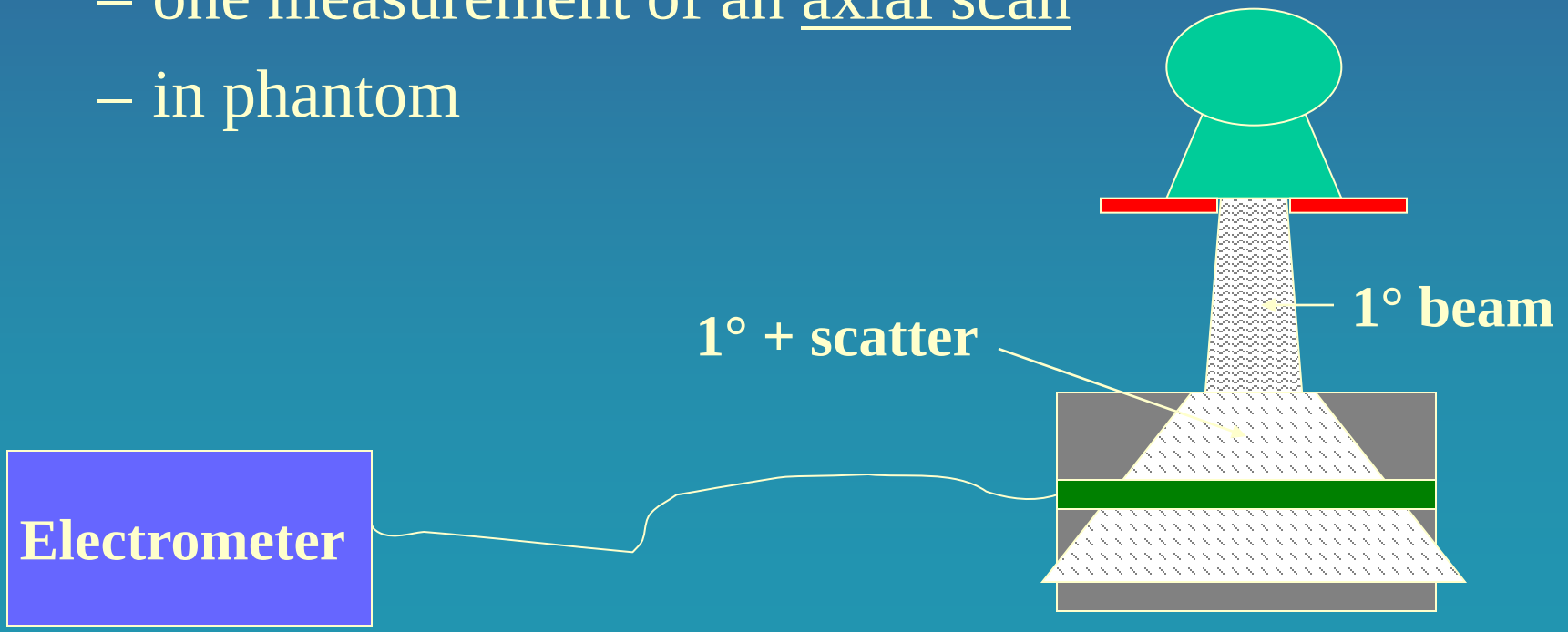
# CT Dose Distributions

- **What about Multiple Scans?**

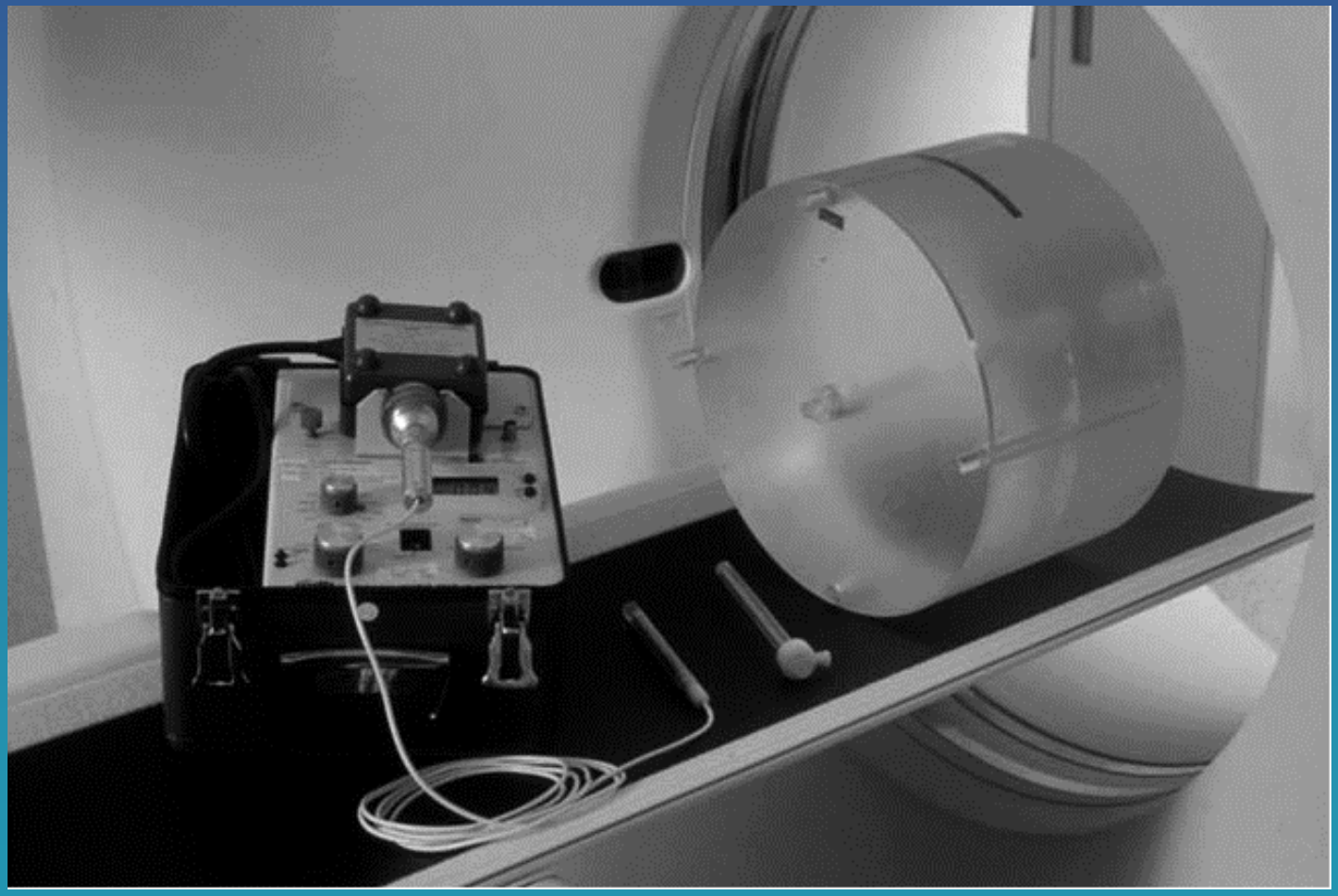


# (CTDI) – defined

- How to get area under single scan dose profile?
  - Using a pencil ion chamber
  - one measurement of an axial scan
  - in phantom

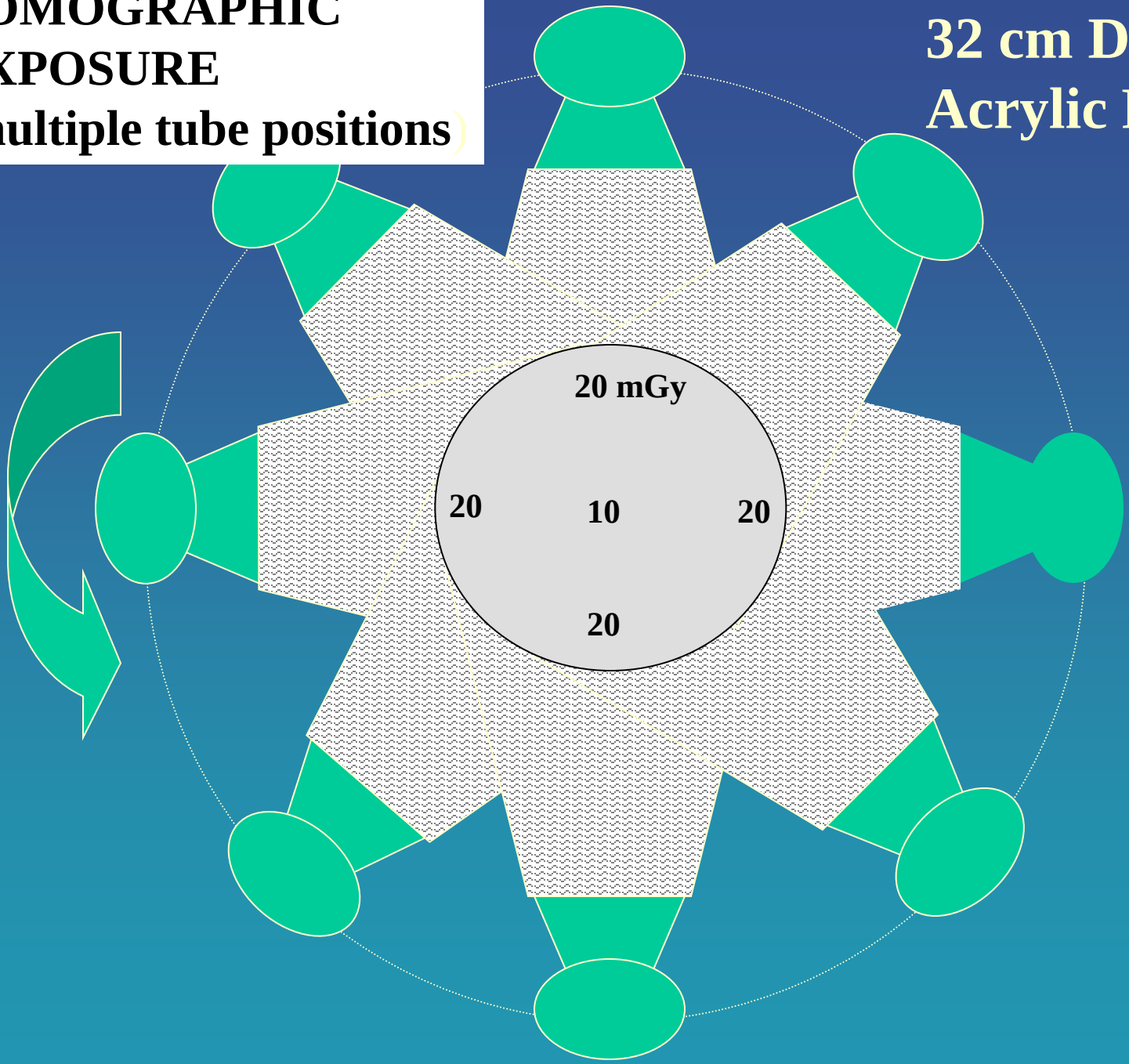


# (CTDI) – defined



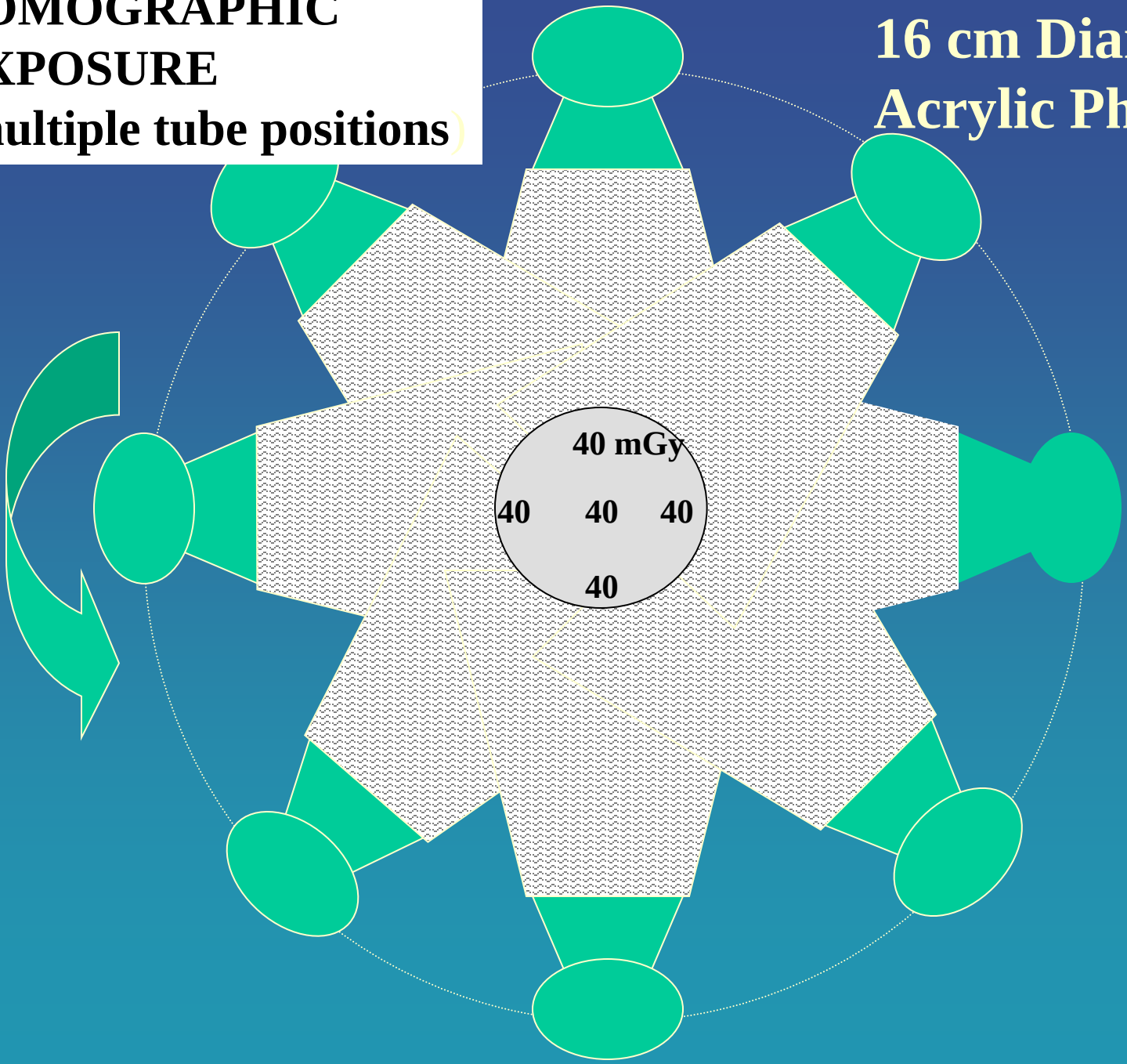
**TOMOGRAPHIC EXPOSURE (multiple tube positions)**

**32 cm Diam (Body) Acrylic Phantom**



**TOMOGRAPHIC EXPOSURE (multiple tube positions)**

**16 cm Diam (Head) Acrylic Phantom**



# (CTDI) – defined

- CTDI Represents
  - **Average dose** along the z direction
  - at a given **point (x,y)** in the scan plane
  - over the **central scan of a series of scans**
  - when the series consists of a **large number of scans**
  - **separated by the slice thickness** (contiguous scanning)

# $CTDI_{100}$

- Measurement is made w/100 mm chamber:
- $CTDI_{100} = (1/NT) \int_{-5cm}^{5cm} D(z)\, dz$

$= (f*C*E*L)/(NT)$

f = conversion factor from exposure to dose in air, use 0.87 rad/R

C = calibration factor for electrometer (typical= 1.0, 2.0 for some)

E = measured value of exposure in R

L = active length of pencil ion chamber
(typical= 100 mm, 160 mm for some)

N = *actual* number of data channels used during one axial scan

T = nominal slice width of one axial image (scan collimation)

# Radiation Dose Basics: How do we currently measure dose in CT?

Conventional Computed Tomography Dose Index (CTDI)

- Measure exposure in ***phantom*** (16 or 32 cm diameter) in 100 mm long pencil ionization chamber
- Using an axial scan (even if protocol is helical scan)
- Calculate

$$CTDI_{100} = \frac{fCEL}{NT}$$

$$CTDI_{w} = [(\frac{1}{3} CTDI_{center}) + (\frac{2}{3} CTDI_{periphery})]$$

$$CTDI_{vol} = \frac{CTDI_{w}}{p}$$

# DLP – Dose Length Product

- Dose Length Product is:
  - $CTDI_{vol}$* length of scan (in mGy*cm)

# Effective Dose

| Tissue | ICRP 60 weighting factor ($w_T$) | ICRP 103 $w_T$ |
|---|---|---|
| Gonads | 0.20 | .08 |
| Red Bone Marrow | 0.12 | .12 |
| Colon | 0.12 | .12 |
| Lung | 0.12 | .12 |
| Stomach | 0.12 | .12 |
| Bladder | 0.05 | .04 |
| Breast | 0.05 | .12 |
| Liver | 0.05 | .04 |
| Esophagus | 0.05 | .04 |
| Thyroid | 0.05 | .04 |
| Skin | 0.01 | .01 |
| Bone Surface | 0.01 | .01 |
| Brain | (Remainder) | .01 |
| Salivary Glands | (Remainder) | .01 |
| Remainder (Adrenals, etc.) | 0.05 | .12 |

# Estimating Effective Dose

- *E (mSv) = k x DLP*

  *= k *CTDIvol*Length*

*K factors for Adults:*

- Head and neck 0.0031
- Head 0.0021
- Neck 0.0059
- Chest 0.014
- Abdomen & pelvis 0.015

# What Do These Numbers Mean?

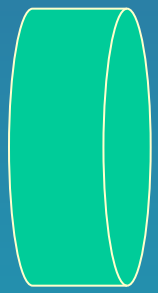
# $CTDI_{vol}$ and DLP

- $CTDI_{vol}$ currently reported on the scanner
  - (though not required in US)
- Is Dose to one of two phantoms
  - (16 or 32 cm diameter)
- Is NOT dose to a specific patient
- Does not tell you whether scan was done “correctly” or “Alara” without other information (such as body region or patient size)
- MAY be used as an index to patient dose with some additional information (later)

# Scenario 1: **No adjustment** in technical factors for patient size

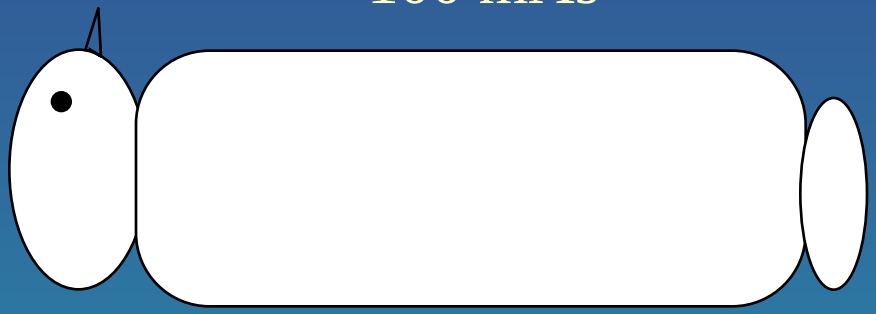
100 mAs

32 cm phantom

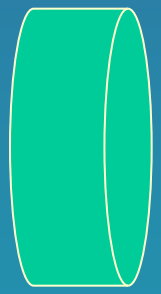


$CTDI_{vol}$ = 20 mGy

100 mAs



32 cm phantom

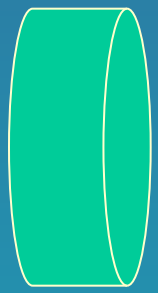


$CTDI_{vol}$ = 20 mGy

The $CTDI_{vol}$ (dose to phantom) for these two would be the same

# Scenario 2: **Adjustment** in technical factors for patient size

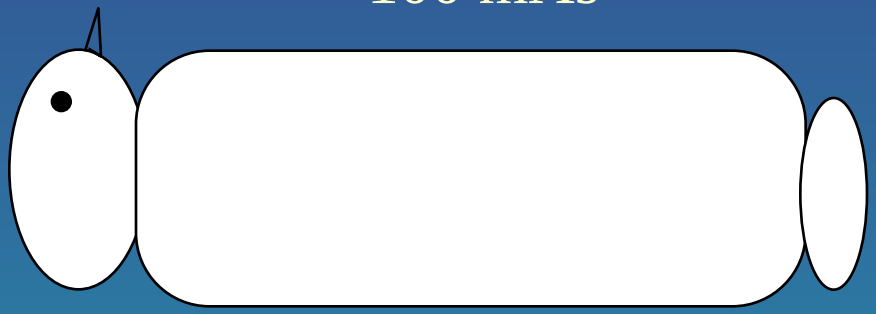
50 mAs

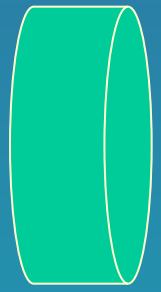


32 cm phantom

$CTDI_{vol}$ = 10 mGy

100 mAs





32 cm phantom

$CTDI_{vol}$ = 20 mGy

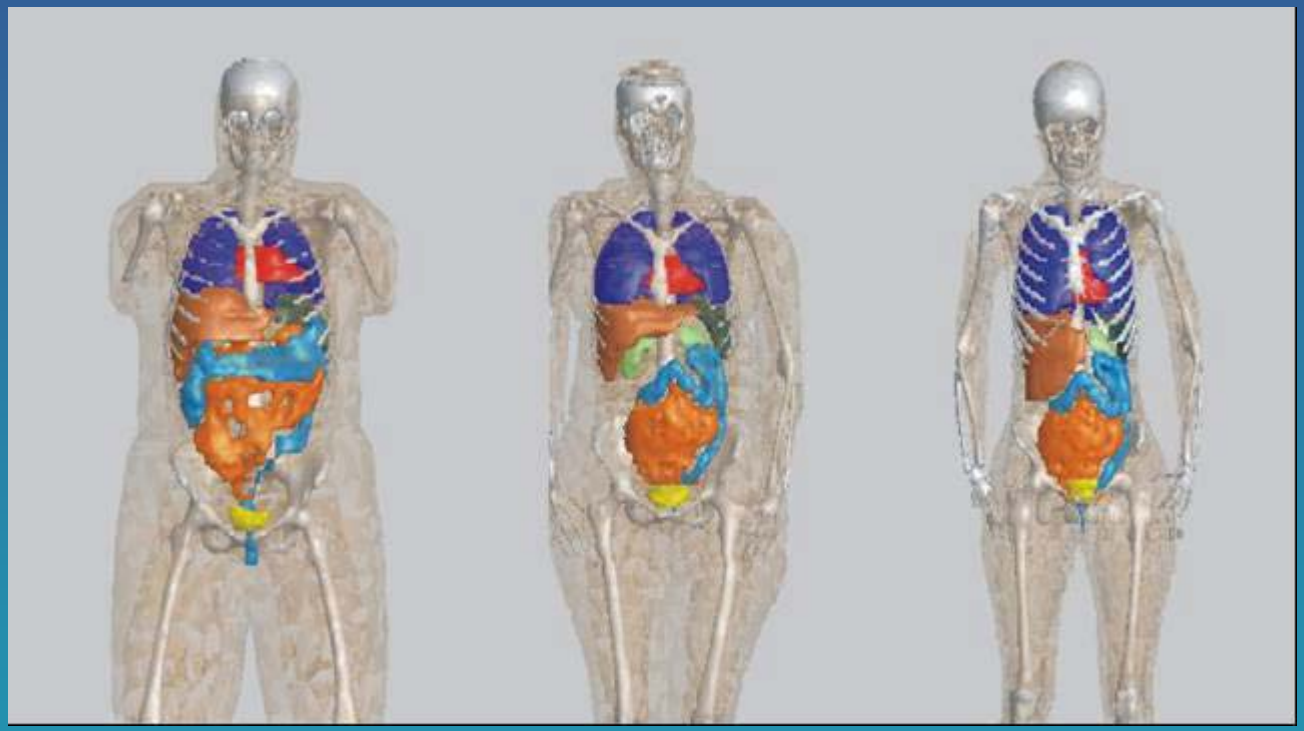
The $CTDI_{vol}$ (dose to phantom) indicates larger patient received 2X dose

# Did Patient Dose Really Increase ?

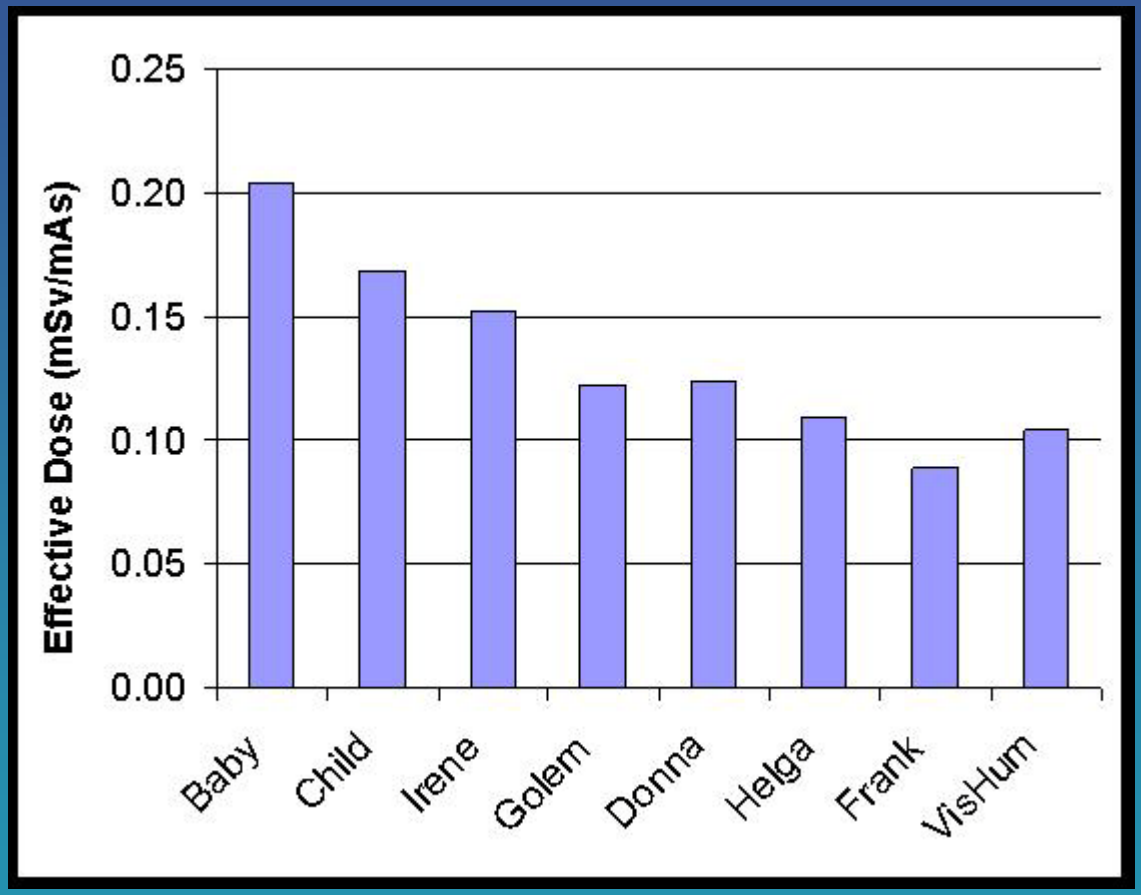
For same tech. factors, smaller patient absorbs more dose

- Scenario 1: CTDI is same but smaller patient's dose is higher
- Scenario 2: CTDI is smaller for smaller patient, but patient dose is closer to equal for both.

# What is the Effect of Patient Size?

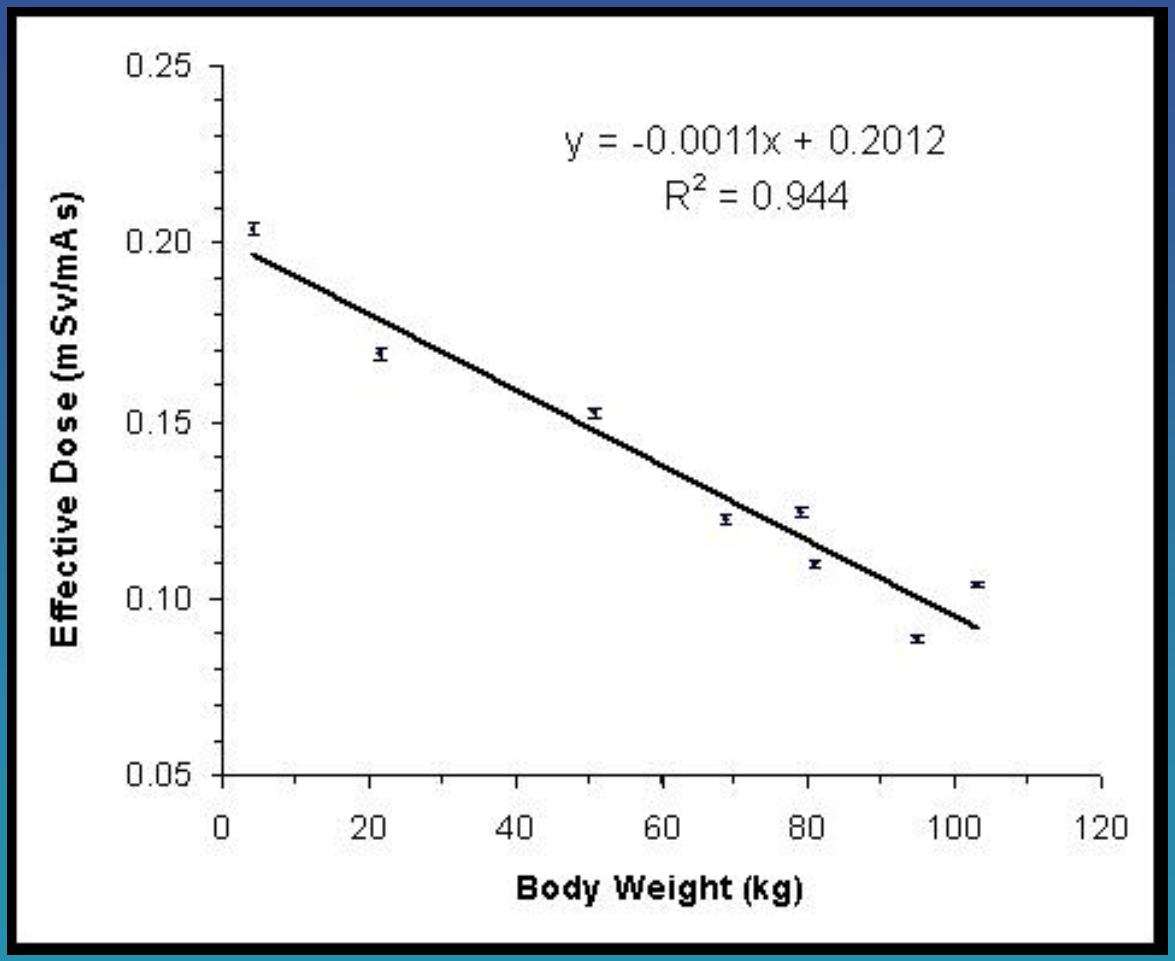


# DeMarco et al, PMB 2007



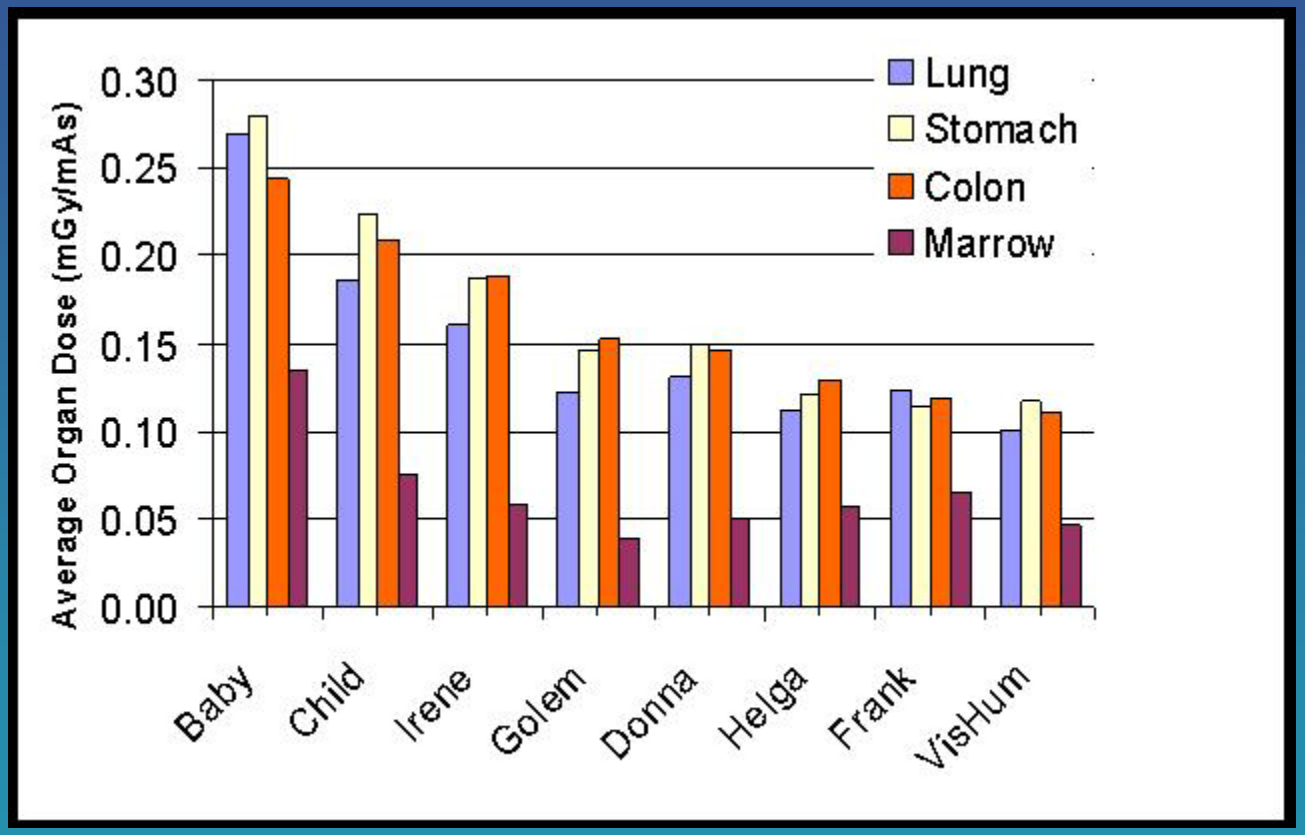

Normalized effective dose (mSv/mAs) for each GSF models resulting from whole body scan. Patient size increases from L to R.

# DeMarco et al, PMB 2007



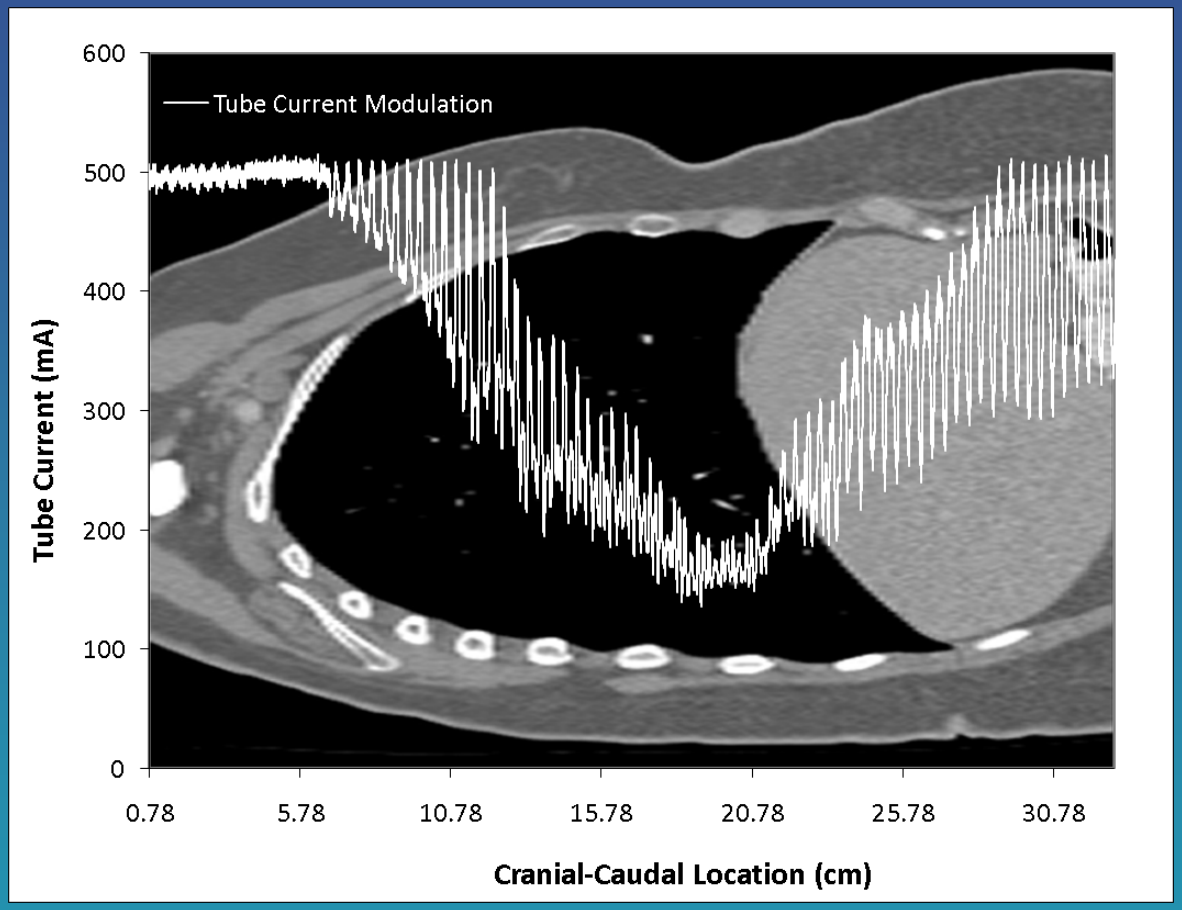

Normalized effective dose (mSv/mAs) for each GSF model by body weight resulting from whole body scan.

# DeMarco et al, PMB 2007



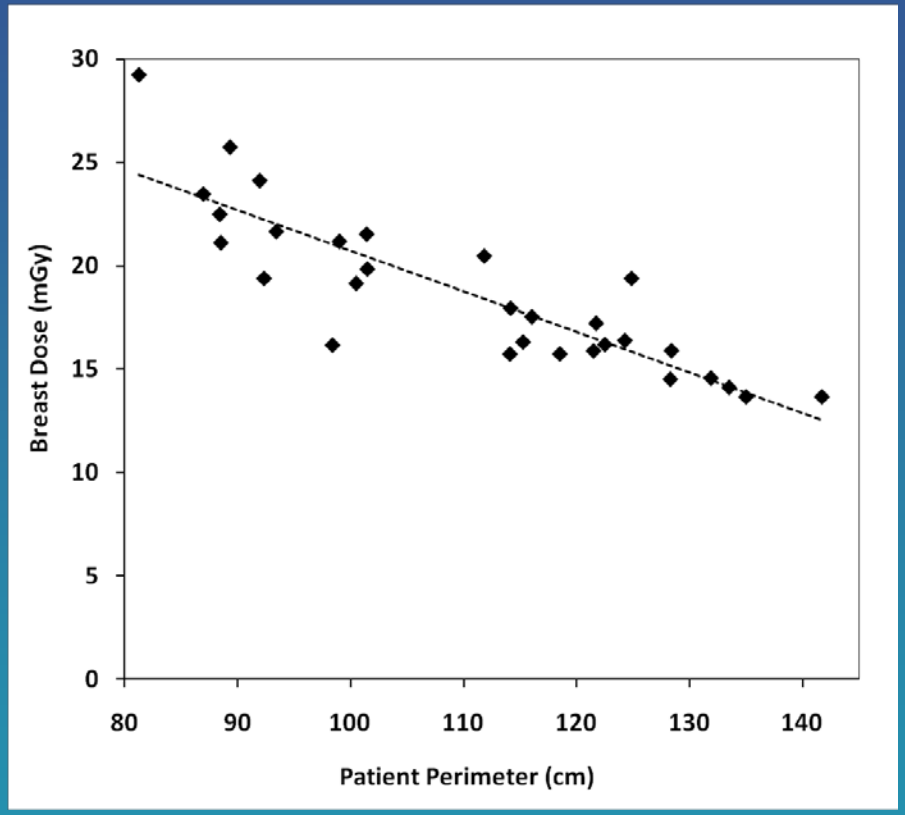

Normalized organ doses (mSv/mAs) for each GSF model resulting from whole body scan.

# Angel et al, PMB Feb 2009



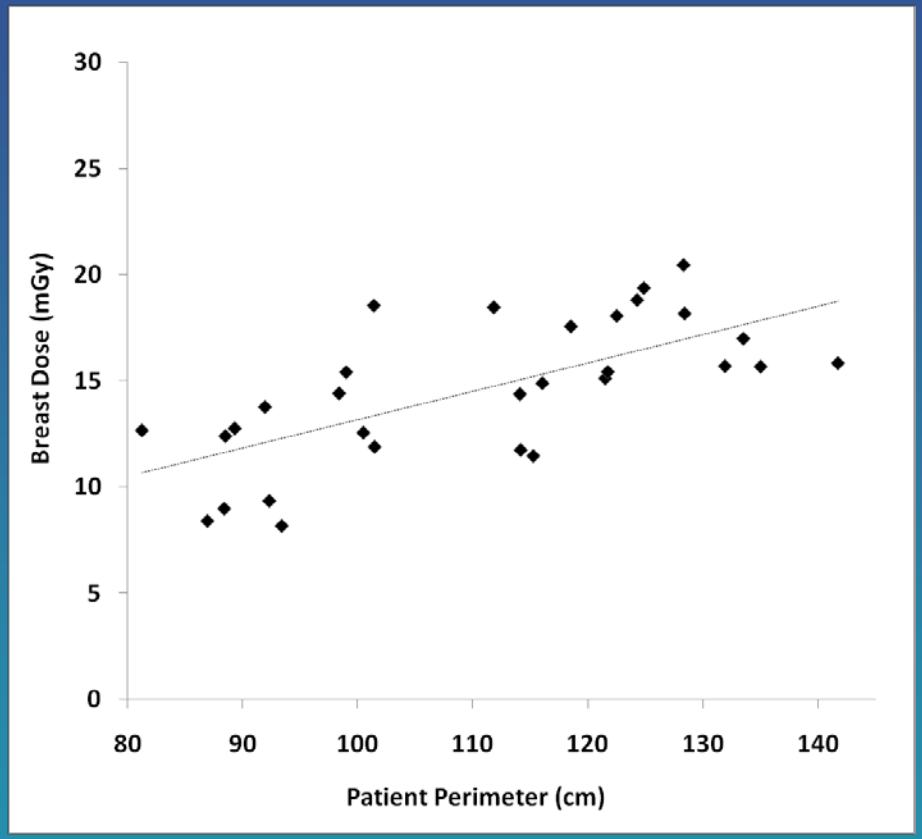

Tube current versus x-axis location of the TCM schema for a patient model with a perimeter of 125cm. Background is a sagittal view of the patient.

# Angel et al, PMB Feb 2009




Breast dose versus patient perimeter for all 30 patient models in the fixed tube current simulations. Breast dose decreases linearly with an increase in patient perimeter (R2=0.76).

# Angel et al, PMB Feb 2009

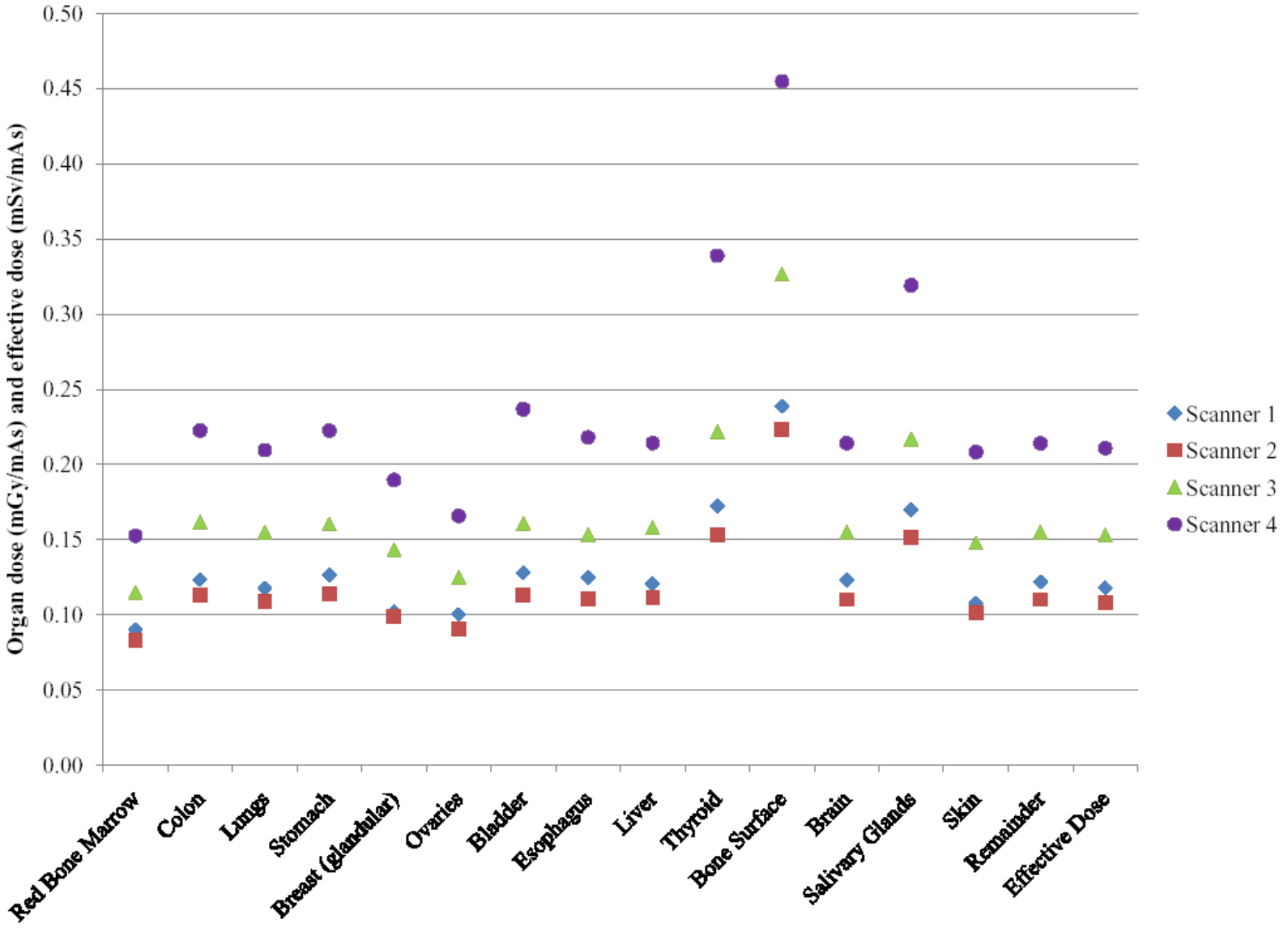



Breast dose versus patient perimeter for all 30 patient models in the TCM simulations. Breast dose increases linearly with an increase in patient perimeter (R2=0.46).

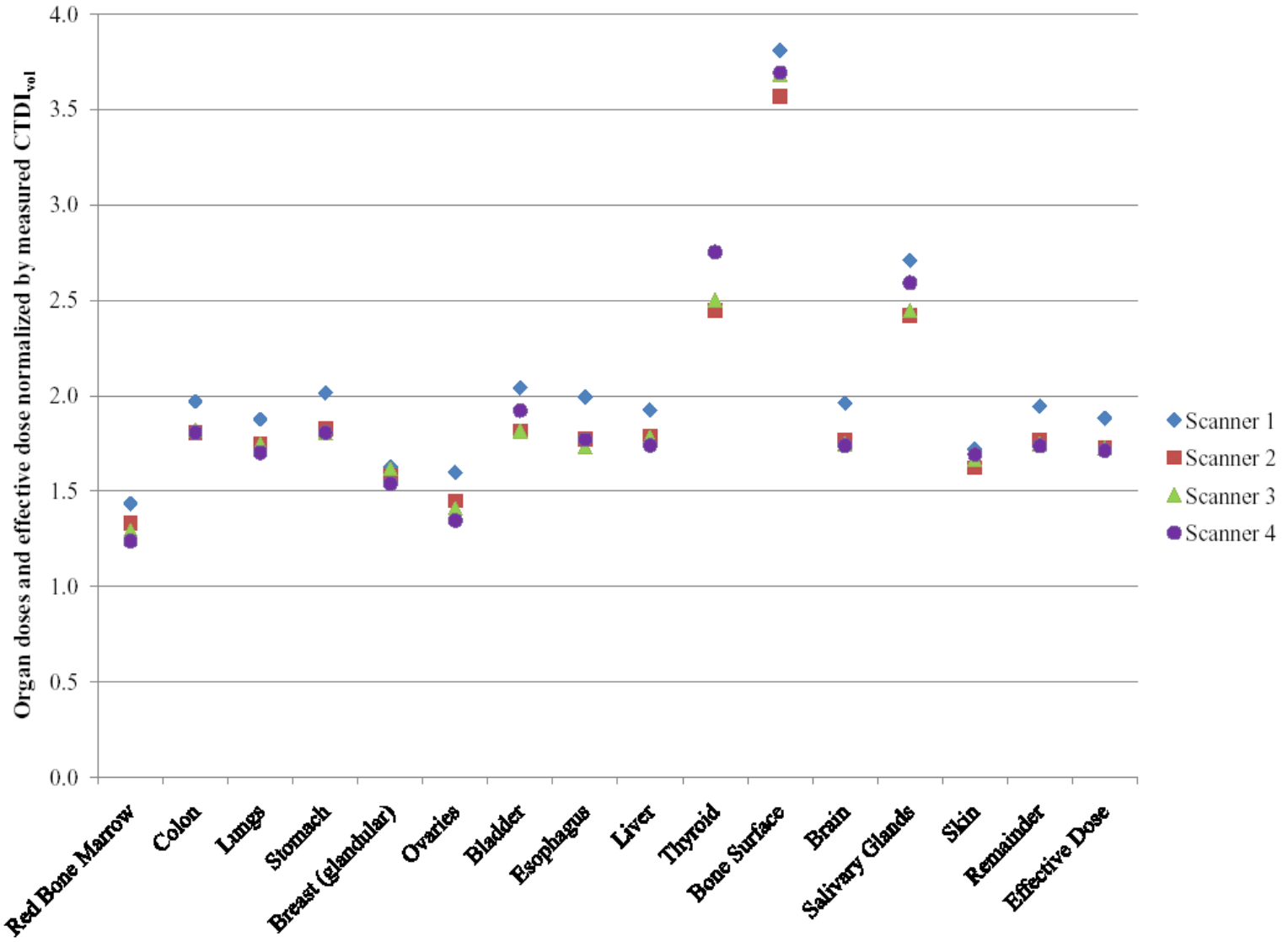
# Possible to Account for Scanner Differences? Patient Differences?

- What do I do with those CTDI numbers?

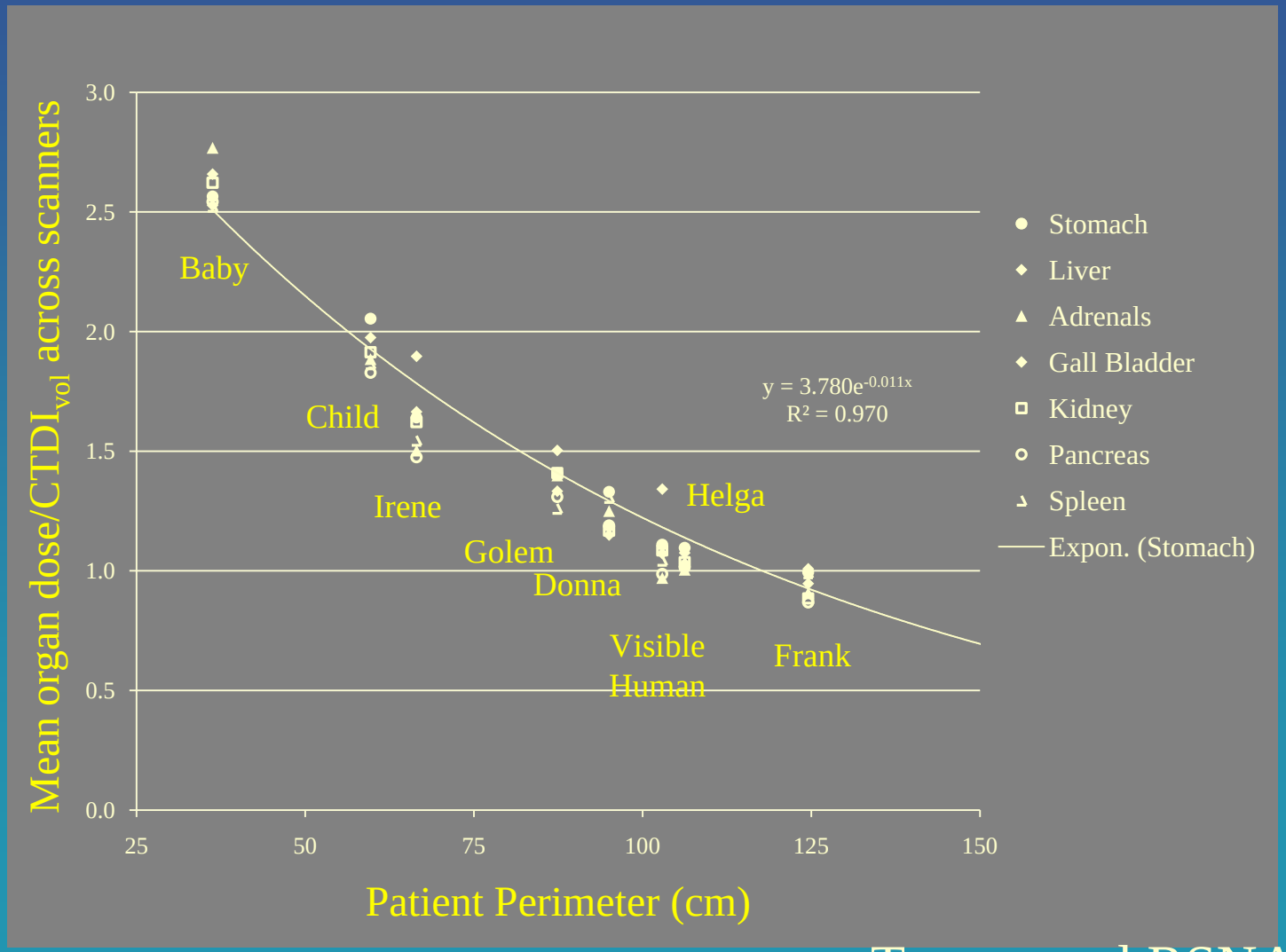
# Organ dose (in mGy/mAs) and effective dose (in mSv/mAs) for GSF model Irene resulting from a whole body scan with similar parameters for each scanner



# Organ dose and effective dose normalized by measured CTDIvol for GSF model Irene resulting from a whole body scan.

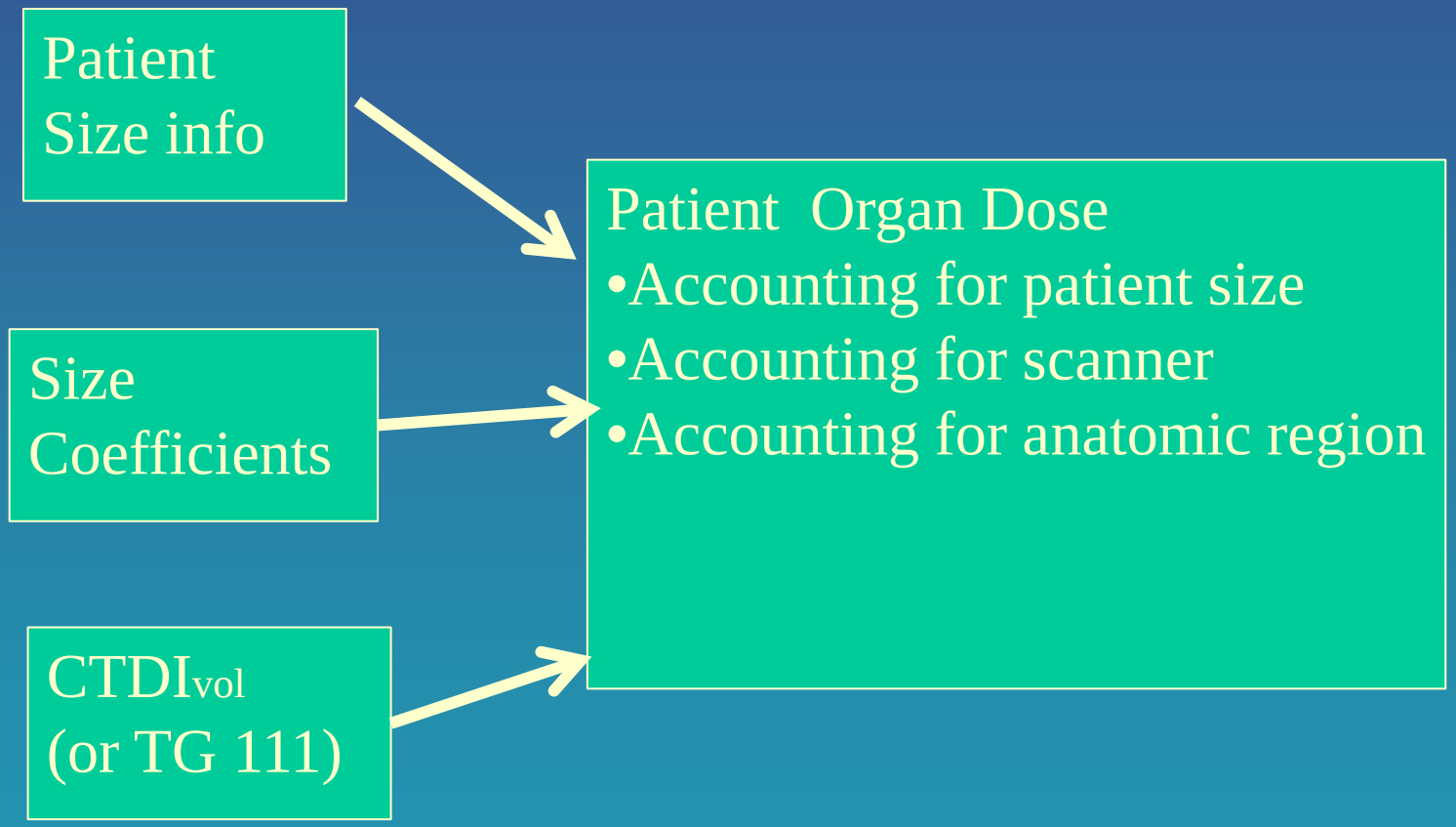


# Normalized Organ Dose as function of Pt. Size (Abdomen Scans for each Patient)




Turner et al RSNA 2009

# Future of Dosimetry?



# Summary

- CTDI is scanner output
- It is NOT patient dose
- CTDI can be used to help estimate dose to a “standard patient”
- There may be methods to use CTDI to help estimate patient dose which account for scanner and patient differences