Dose measurements in cone beam CT – how appropriate is the 10 cm pencil chamber?

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Overview

- Absorbed dose in CT
- Absorbed dose measurement on CBCT
- Is it time to retire the CTDI?

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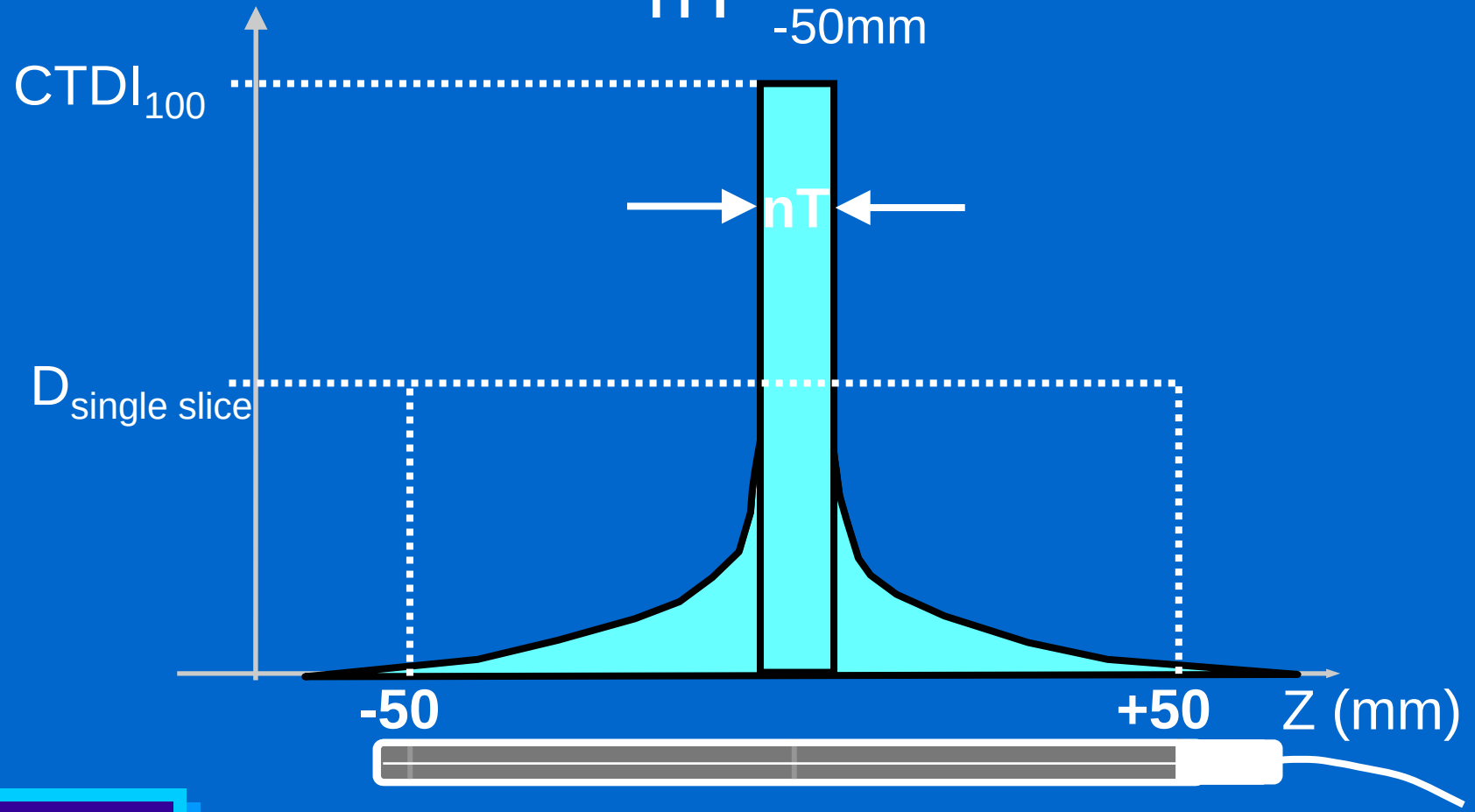
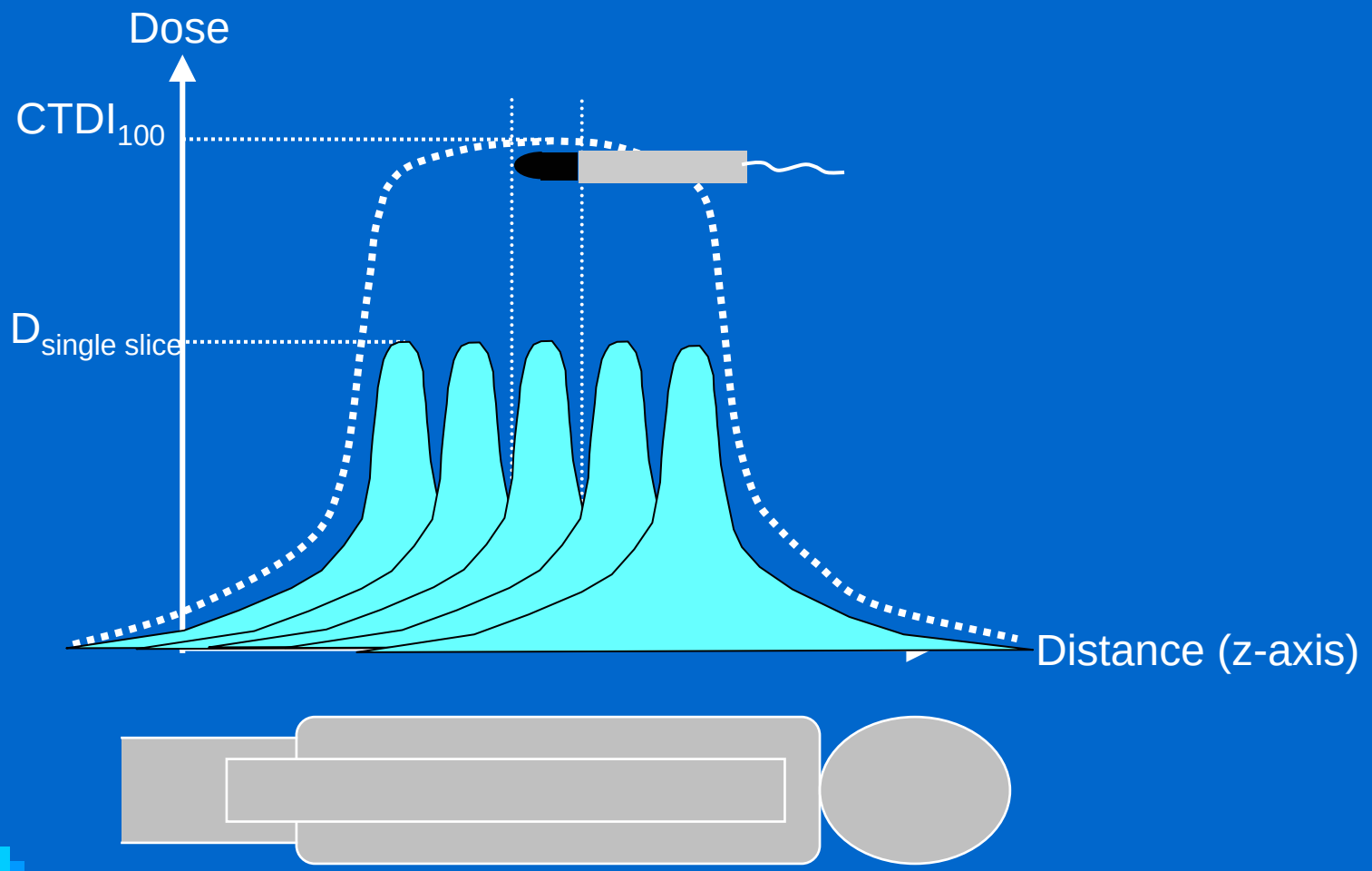
Absorbed dose measurement in CT

$$CTDI_{100} = \frac{1}{nT} \int_{-50mm}^{+50mm} D(z)dz$$



Absorbed dose measurement in CT

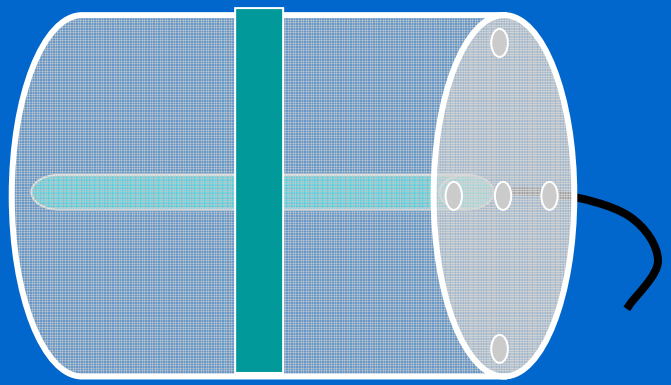
- $CTDI_{100}$ is the absorbed dose at the centre of 100 mm scan of length

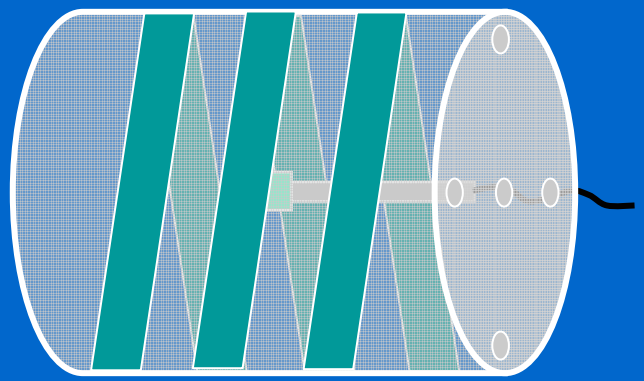


Absorbed dose measurement in CT

2 approaches to measuring dose in CT:

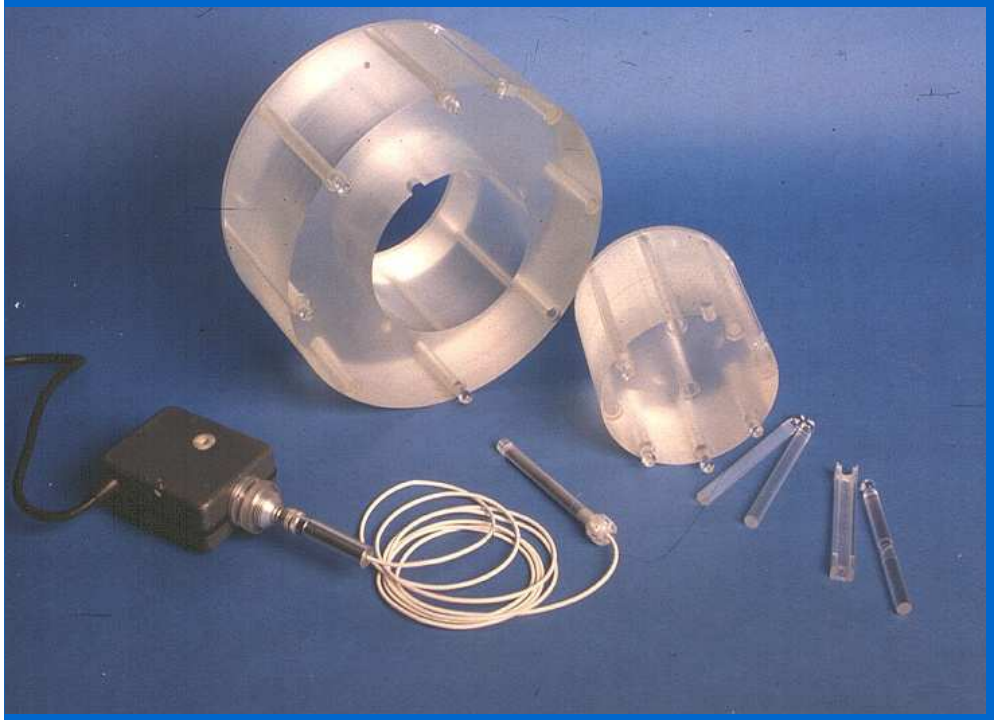
- Conventional approach
  - Pencil chamber
  - Single axial slice
  - Dose calculated from integral of single slice profile
- Alternative approach
  - Small volume chamber
  - Irradiate scan length
  - Dose measured directly





Absorbed dose measurement in CT

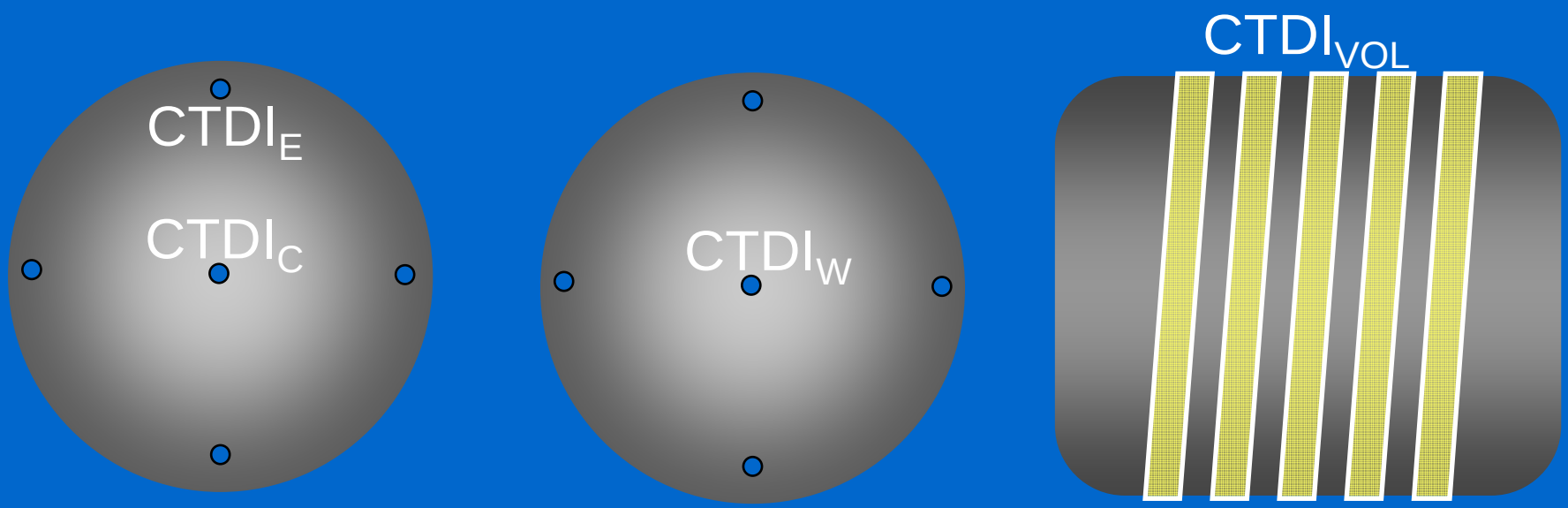
- $CTDI_{100}$



- 14 cm long Perspex cylinders
- Head 16 cm ø; Body 32 cm ø
- Dose at centre & edge
- Absorbed dose to air (mGy)

Absorbed dose measurement in CT

- CTDI definitions
  - $CTDI_C$ & $CTDI_E$
  - $CTDI_W = 1/3\ CTDI_C + 2/3\ CTDI_E$
  - $CTDI_{VOL} = \frac{CTDI_W}{Pitch}$



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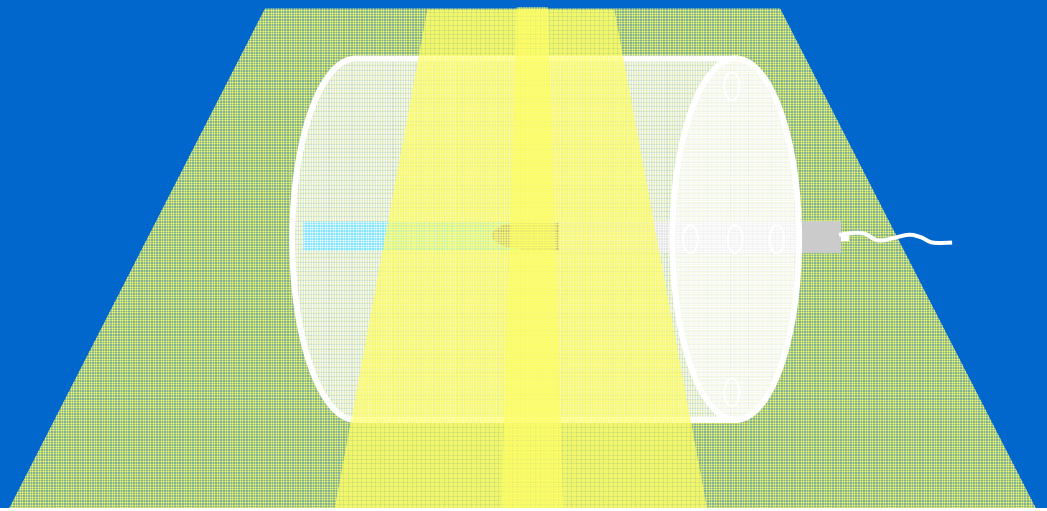
Cone Beam CT

- A number of different systems introduced over last few years
- Flat panel CBCT on
  - Angiography systems
  - Radiotherapy simulators
  - On board imagers on Radiotherapy Linacs
  - Dental systems
- MSCT : beam widths soon up to 12.5 cm

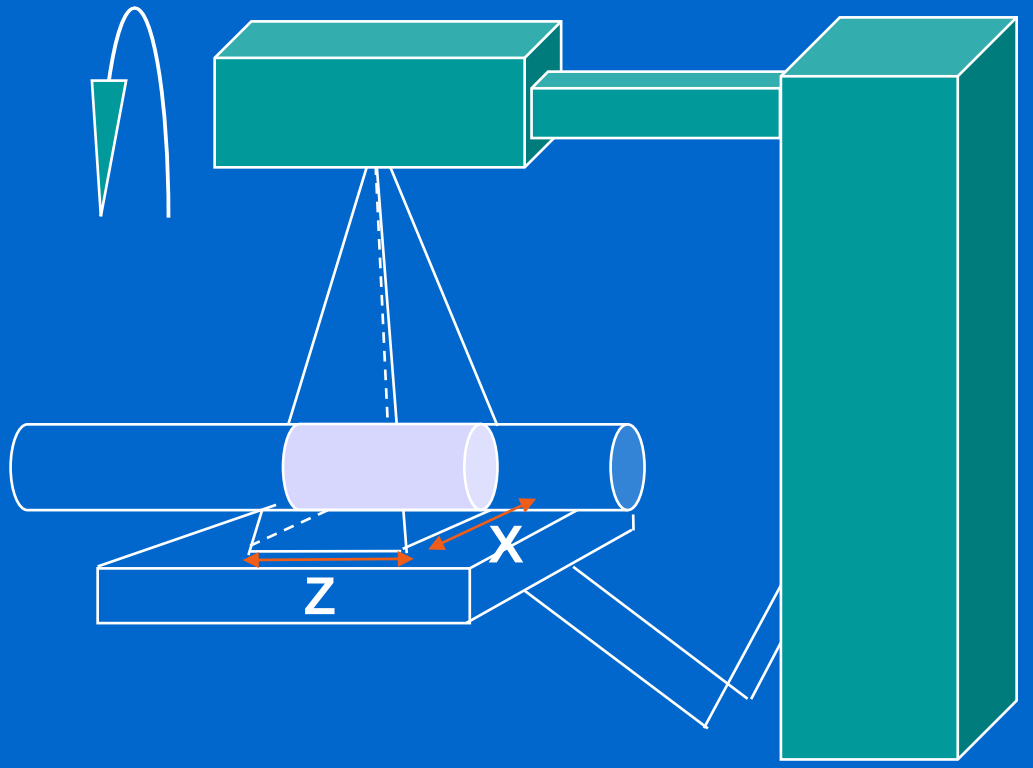
Absorbed dose measurement on CBCT

- CTDI approach developed for irradiation with multiple narrow beams
- CBCT: whole volume generally imaged in one rotation
- Direct measurements with small volume chamber more appropriate
- CTDI-type measurement on CBCT enables dose comparisons with conventional CT



Cone Beam CT

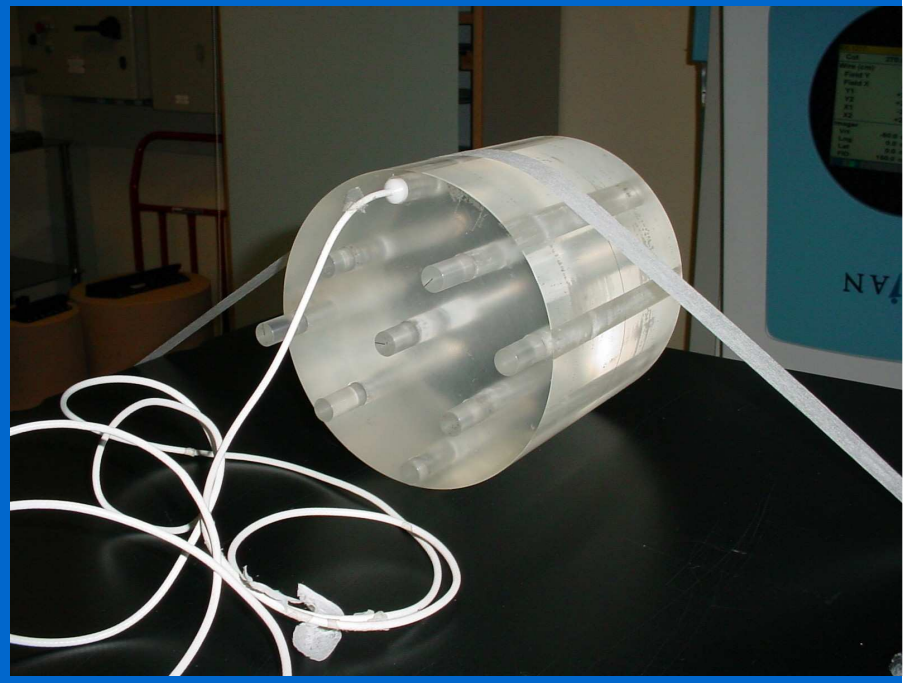
Varian Acuity CBCT



- Variable imaged length: 1 – 17 cm

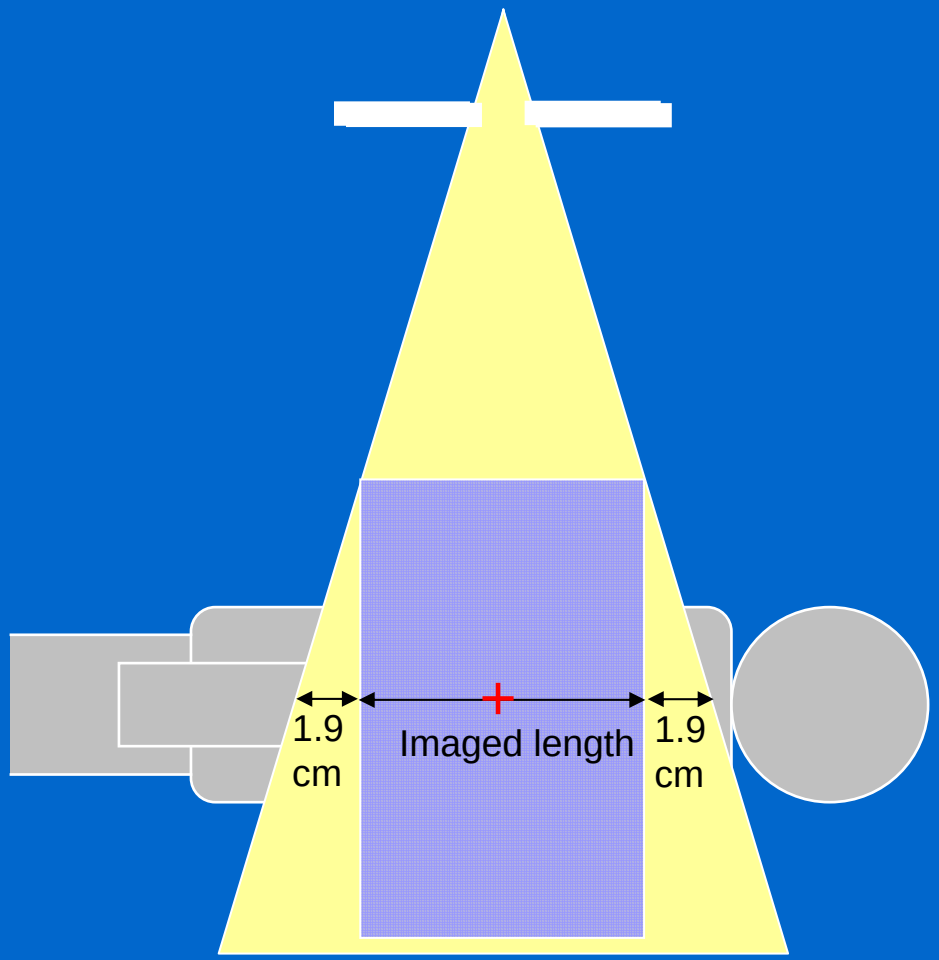
Pencil v Farmer chamber on Acuity CBCT

- CTDI Head & CTDI Body
- Measured with Farmer & CT pencil chambers for full range of scan lengths
- Adaptor made for Farmer chamber
- Additional scatter material added to ends of phantoms

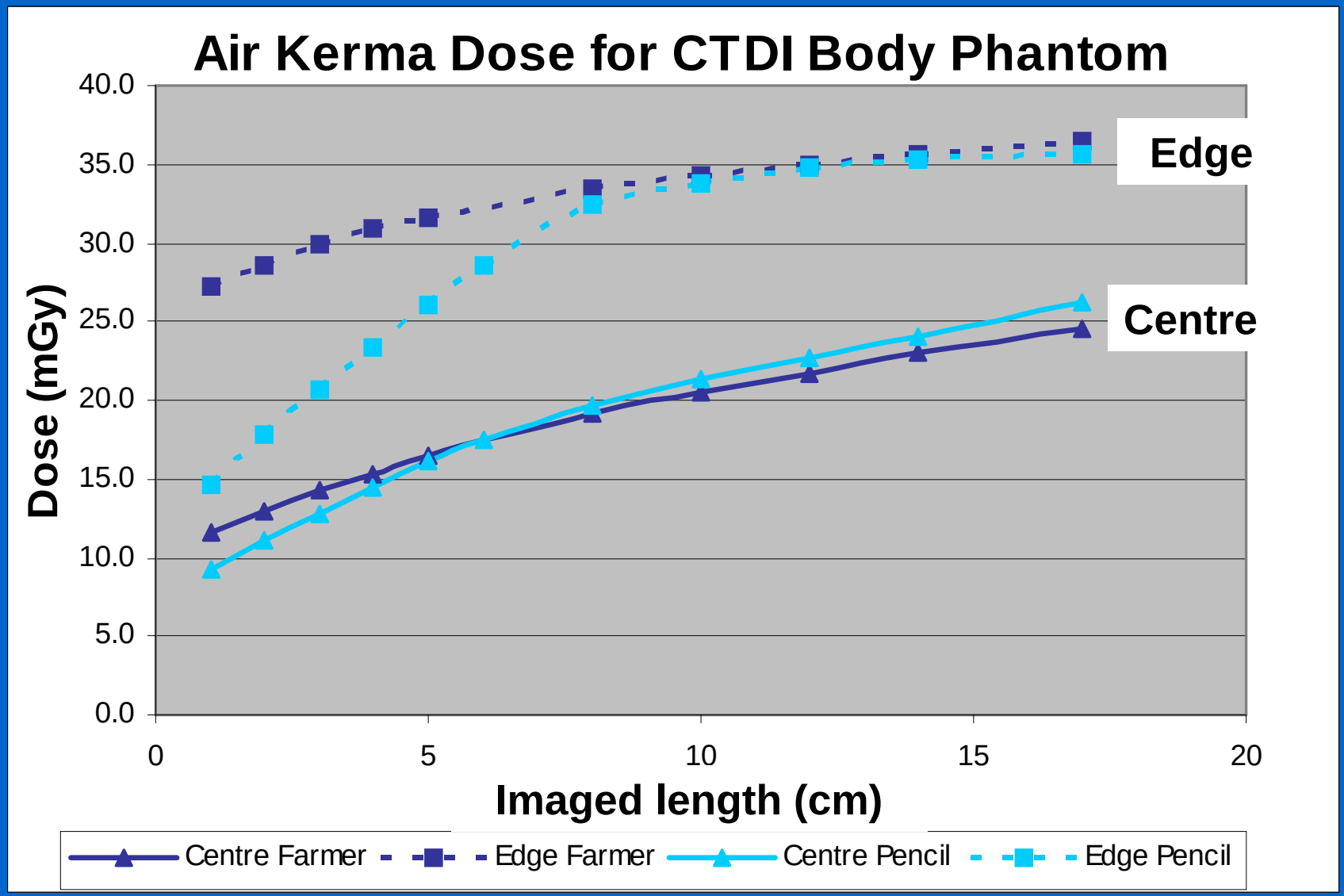


Varian Acuity CBCT

- Imaged length: 1 - 17 cm
- Irradiated length: Imaged length + 3.8 cm

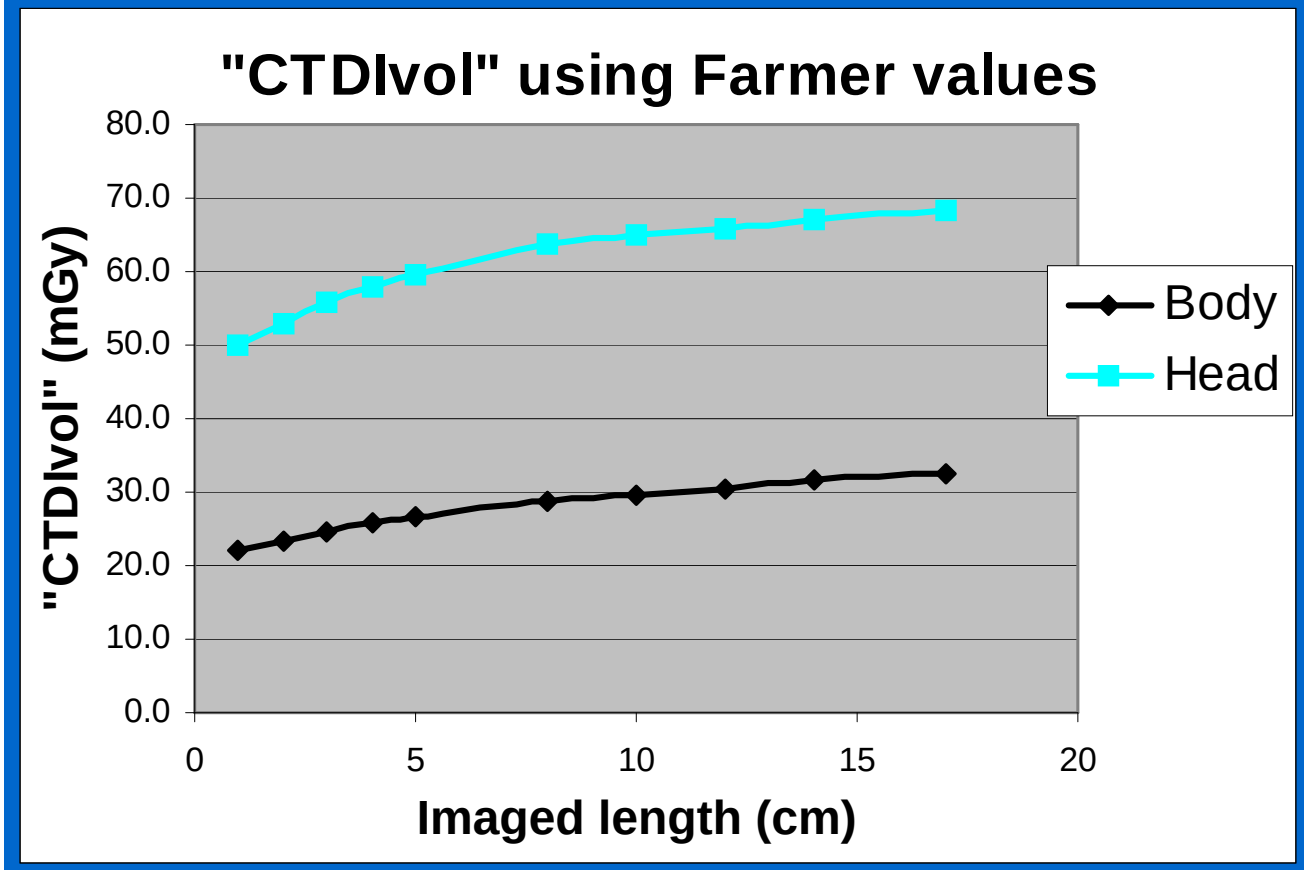


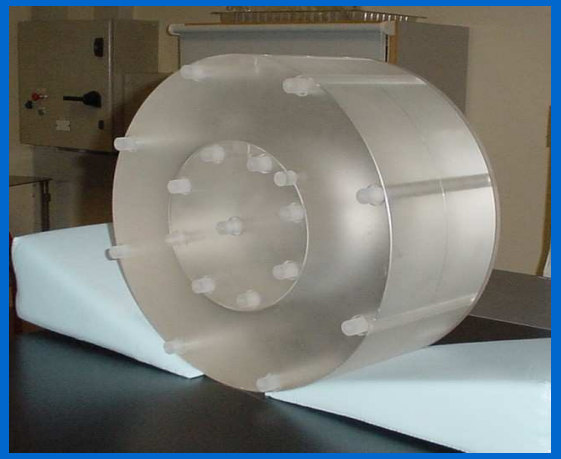
‘CTDI’ Body measurements



‘CTDI’ on CBCT

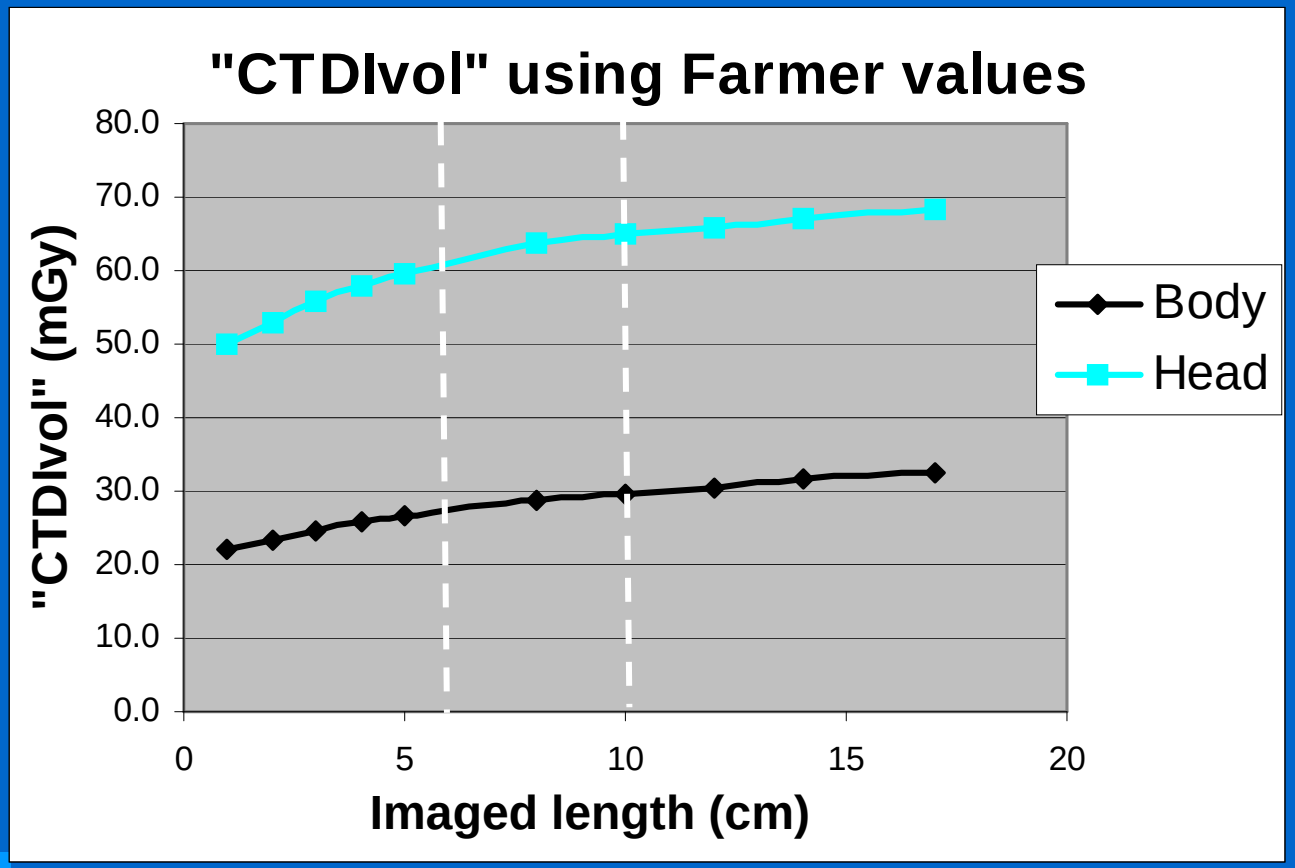
‘$CTDI_{vol}$’ = 1/3 $Dose_c$ + 2/3 $Dose_e$





Absorbed dose measurement on CBCT

- Which scan length should we use to for ‘CTDI’ ?
- 10 cm imaged length?
- Or 10 cm irradiated length?



Recommendations

To allow comparisons of CBCT doses with conventional CT scanners:

- Use a small volume ion chamber in standard CTDI phantoms
- Make direct dose measurements for a 10 cm imaged/irradiated length and report as dose to air

- This provides $CTDI_{vol}$ - equivalent values for CBCT
- DRLs can be calculated on CBCT for comparison with standard CT

Overview

- Absorbed dose measurement in CT
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- Is it time to retire the CTDI?

Is it time to retire the CTDI?

- Current methodology historical – slow equipment and small heat capacity of early CT x-ray tubes
- Developed to calculate absorbed dose from scan series using single slice measurement

Is it time to retire the CTDI?

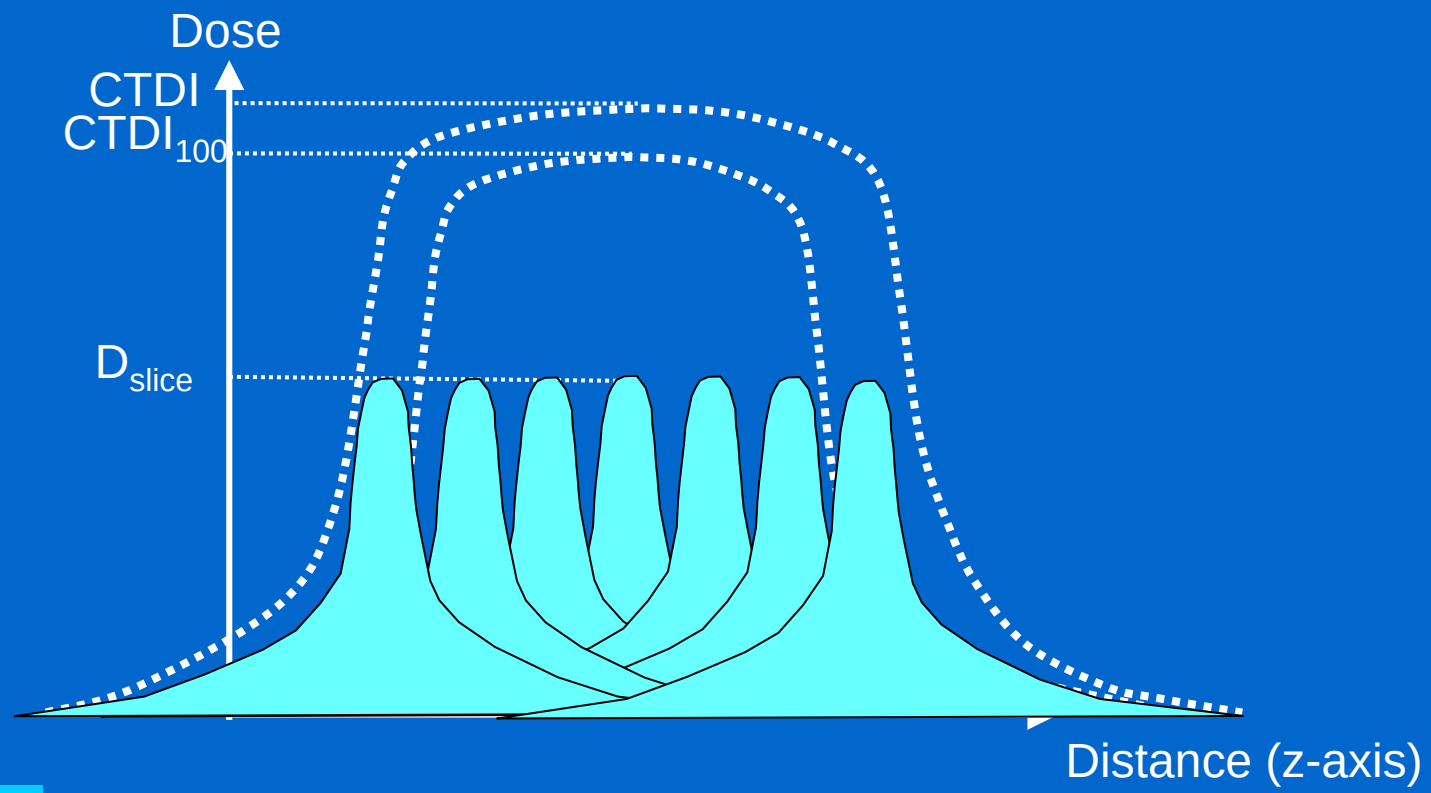
- A new look at CT dose measurement: Beyond CTDI
  Dixon RL, Med. Phys. 30 (6), 2003
- Novel methods of measuring single scan dose profiles and cumulative dose in CT
  Nakonechny KD et al, Med. Phys. 32 (1), 2005
- Enlarged longitudinal dose profiles in cone-beam CT and the need for modified dosimetry
  Mori S, Endo M et al, Med. Phys. 32 (4), 2005
- Is it time to retire the computed tomography dose index (CTDI) for CT quality assurance and dose optimization?
  Brenner DJ, McCullough CH et al Med. Phys. 33 (5), 2006
- “Death to the pencil chamber – long live the real CTDI”
  Dixon RL, Personal communication, 2006

Disadvantages of current technique

- Causes confusion
  - Dose from multiple rotations calculated from a single rotation
  - Dose measured in Perspex and quoted as dose to air
  - Many different definitions of CTDI: $CTDI_{\infty}$, $CTDI_{14T}$, $CTDI_{100}$, $CTDI_{W}$, $CTDI_{VOL}$, $CTDI_{air}$,

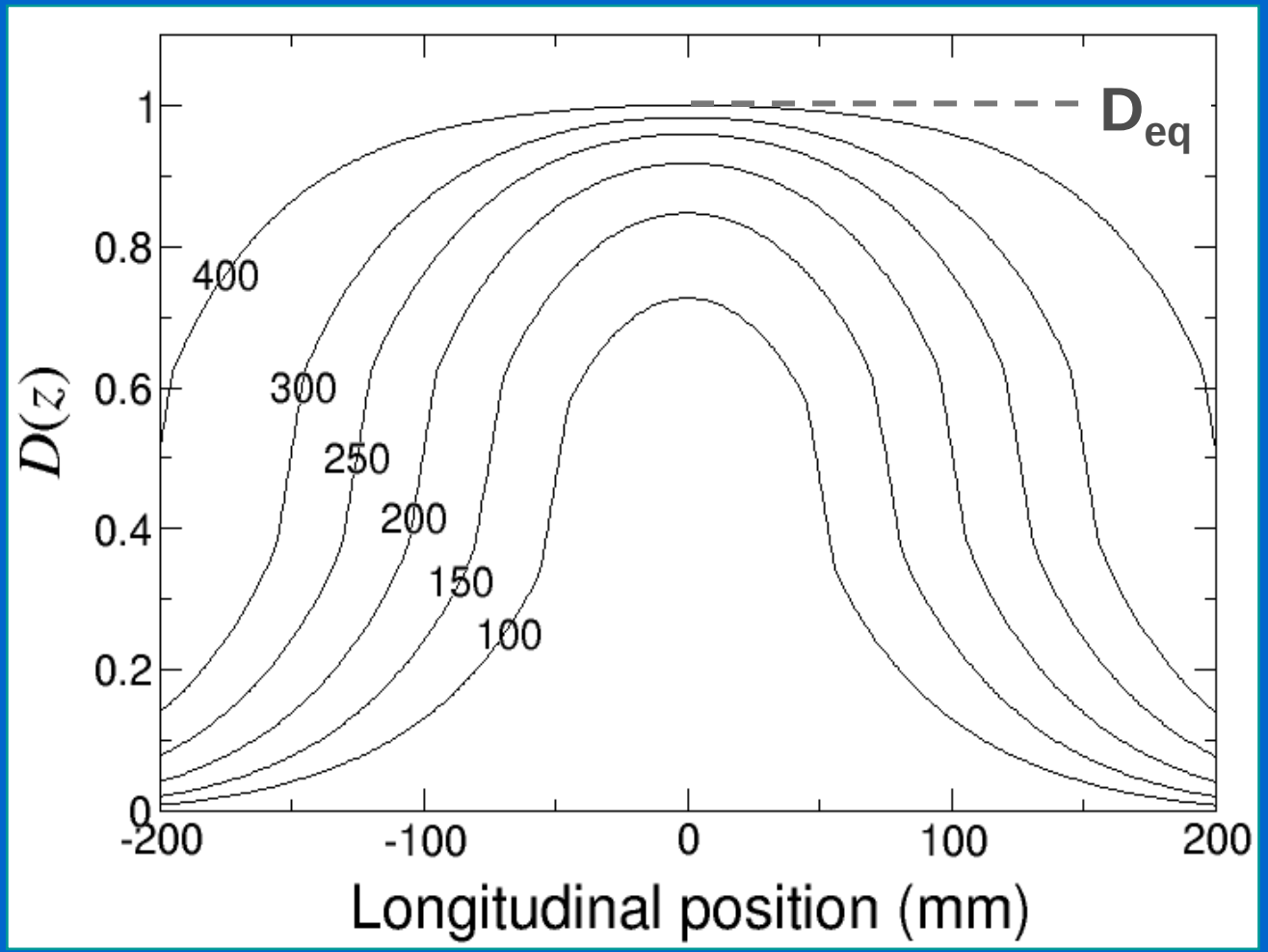
Disadvantages of current technique

- The 100 mm long pencil chamber correctly predicts the dose at $z = 0$ for only one particular scan length, L = 100 mm



Disadvantages of current technique

- $CTDI_{100}$ can significantly underestimate dose for longer scan lengths



Nakonechny KD et al, Med. Phys. 32 (1), 2005

Disadvantages of current technique

- At what scan length is equilibrium dose reached?
- For 20 cm beam width, centre CTDI phantoms:

- CTDI Body
- D_{eq} at L ≅ 300mm

$$\frac{D_{100}(0)}{D_{eq}} \approx 80\%$$

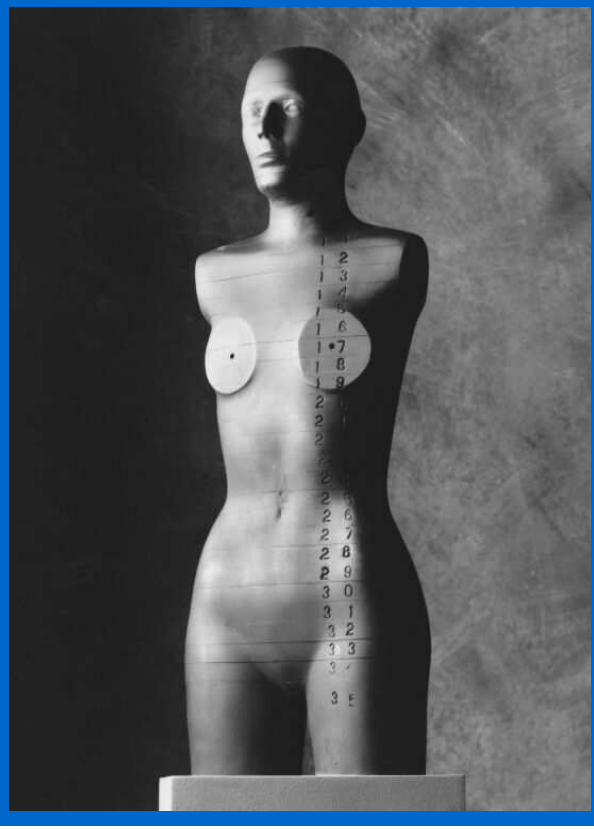
- CTDI Head
- D_{eq} at L ≅ 160 mm

$$\frac{D_{100}(0)}{D_{eq}} \approx 90\%$$

Dixon RL, Med. Phys. 30 (6), 2003

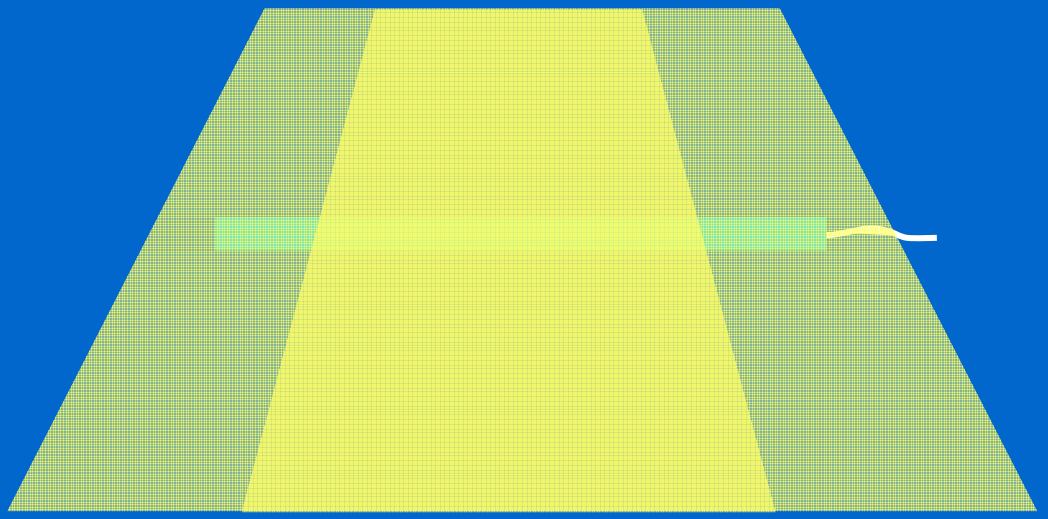
Disadvantages of current technique

- Body phantom not long enough to provide dose equilibrium
- Current phantoms are not representative of standard patient in size, composition or shape

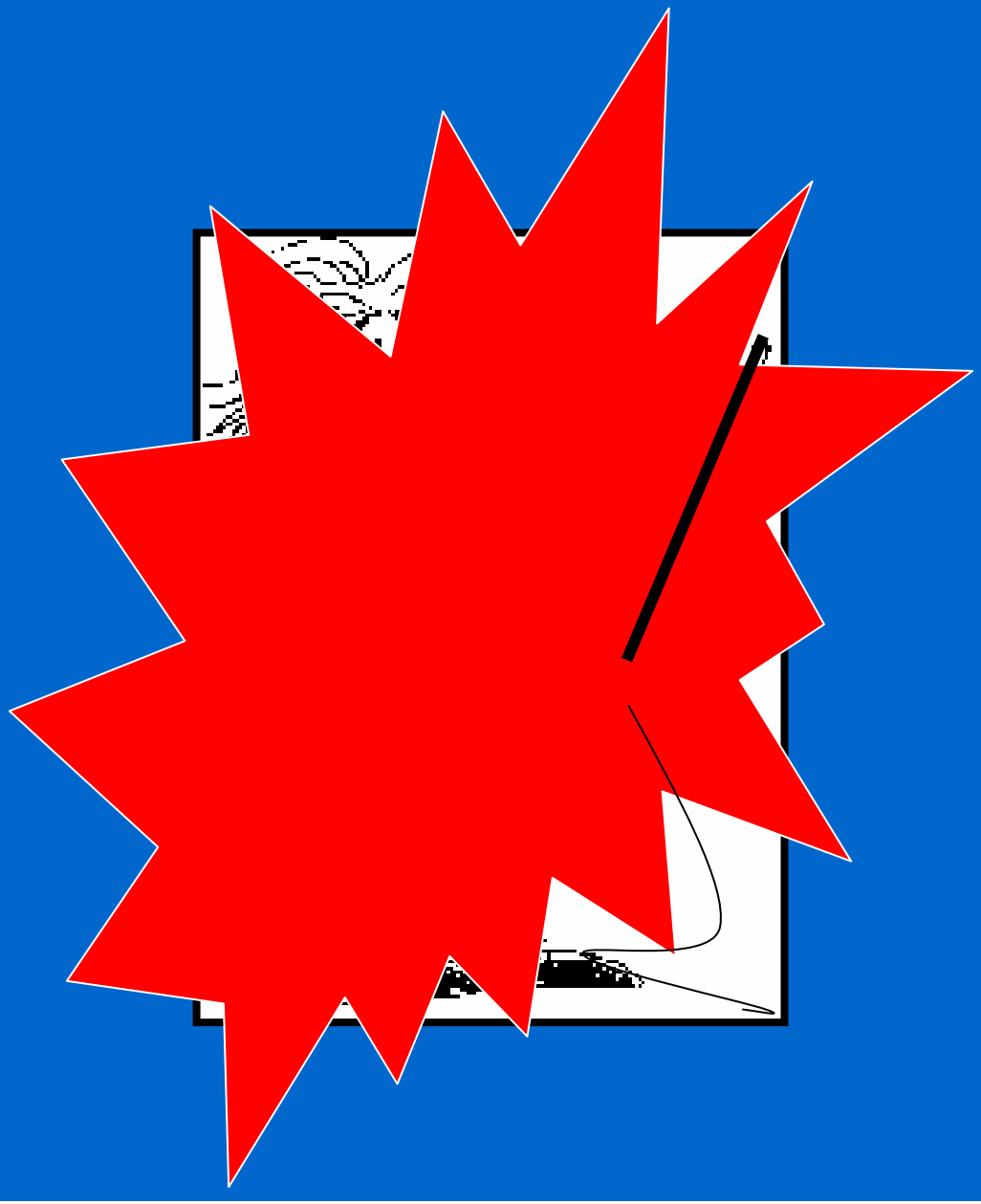


Disadvantages of current technique

- Method intended for narrow beam widths
- Not appropriate for beam widths approaching length of chamber and greater



Is it time to retire the CTDI?



Advantages of current technique

- Well established
  - Equipment available
  - Users familiar with values expected
  - DRLs established in terms of $CTDI_{vol}$ and DLP
- Quick & reproducible
- Dose at phantom periphery can be measured easily with pencil chamber
- Relatively cheap & simple phantoms

Is it time to retire the CTDI?

- Must be viewed as tool for QC and dose optimisation NOT as a measure of patient dose
- Other methods available for quantifying organ and effective doses
- Small volume chamber should be used for CBCT and can also be used on conventional scanners

Acknowledgements

- Alison Vinall, Radiotherapy Department, Norfolk and Norwich Hospital, for Varian Acuity data
- Robert Dixon for clip art ideas