Some thoughts on CT Dosimetry Methods

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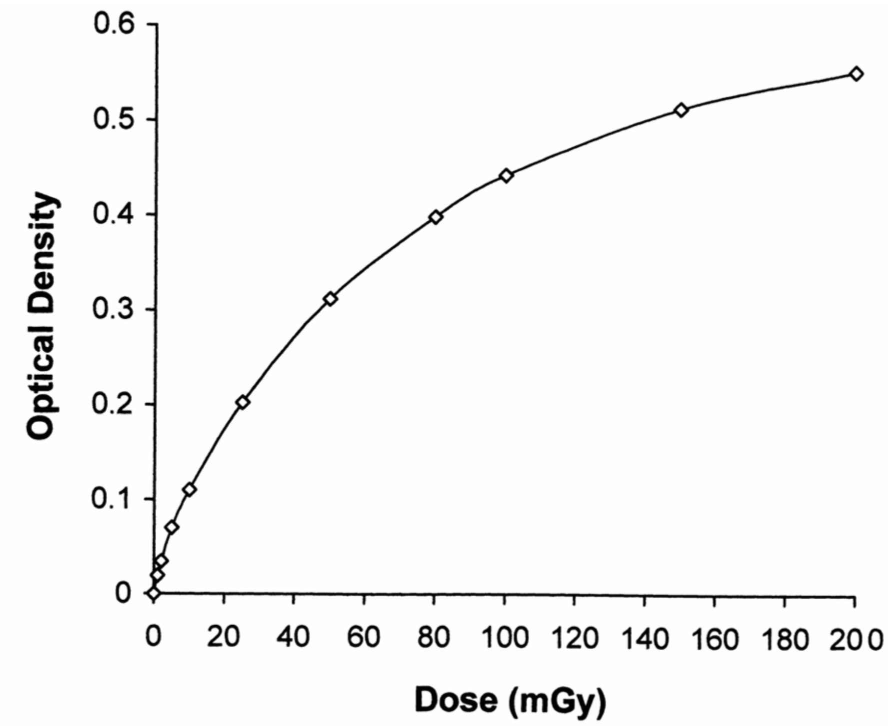
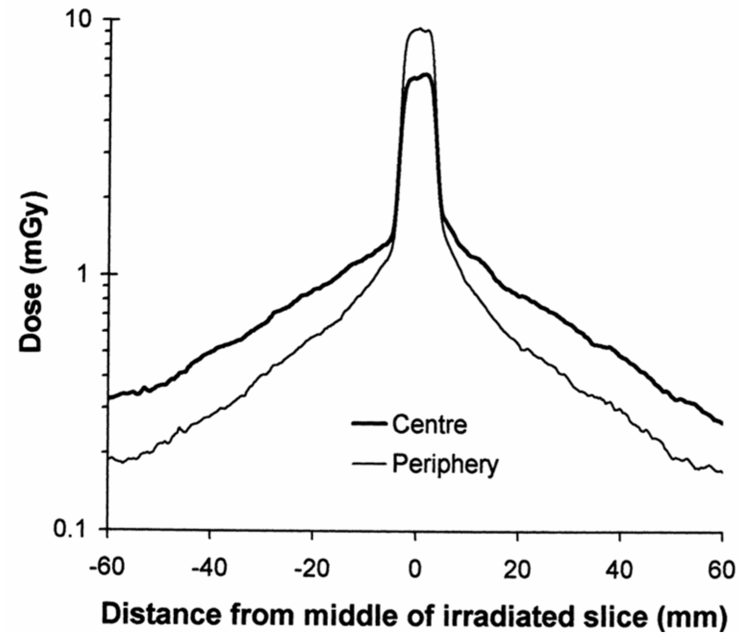
Calibration of Gafchromic film

Gulmay superficial therapy unit used for calibration exposures with 110 kV and 8 mm Aluminium HVL

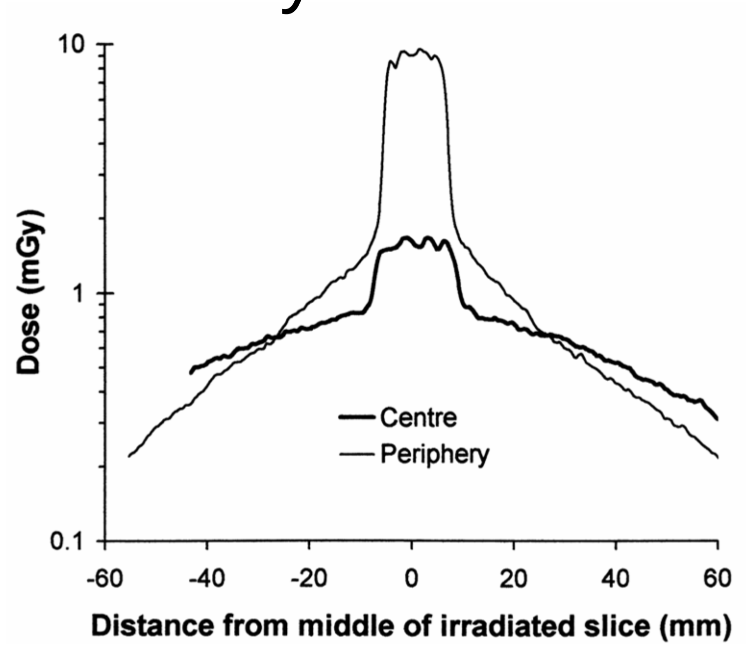


Dose distributions in phantoms

Head

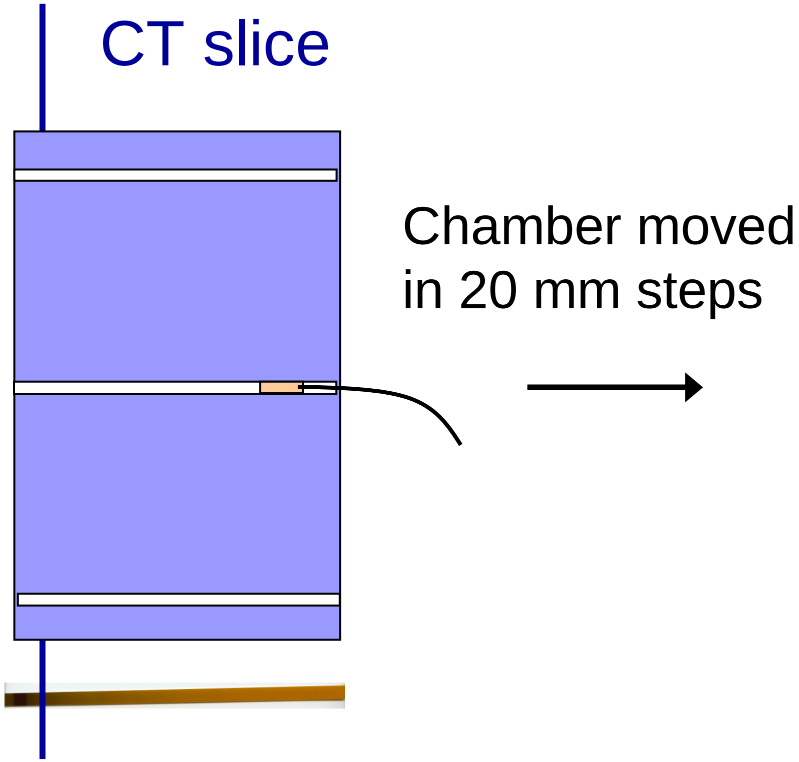


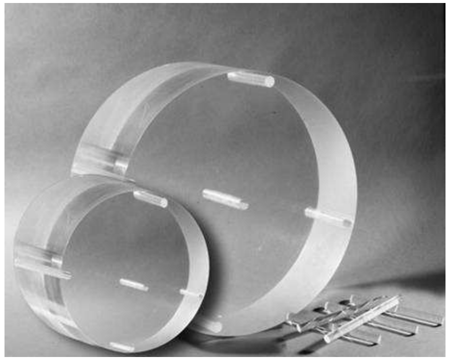
Body



Irradiated slice through middle of each phantom

Unfors prototype 20 mm CT ionisation chamber

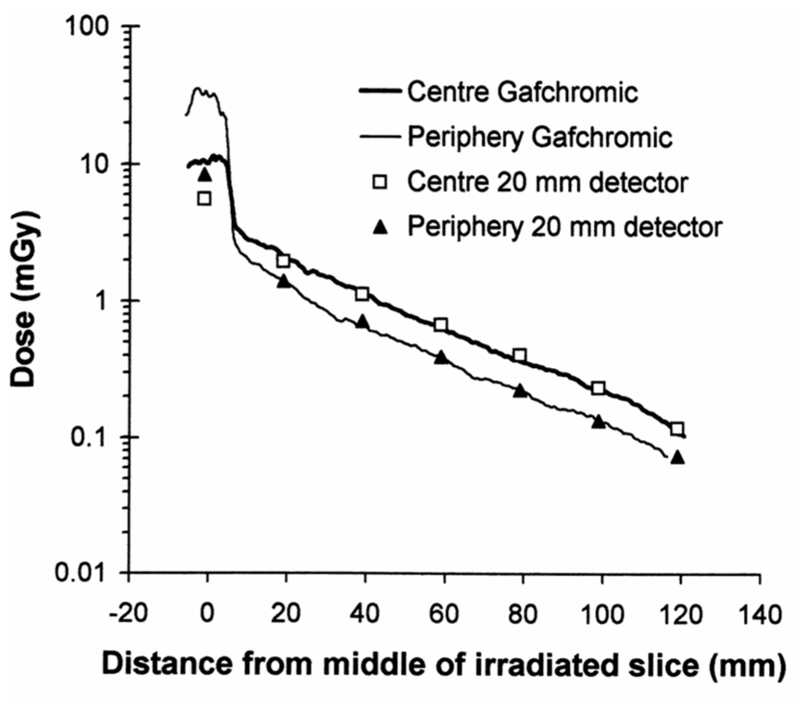




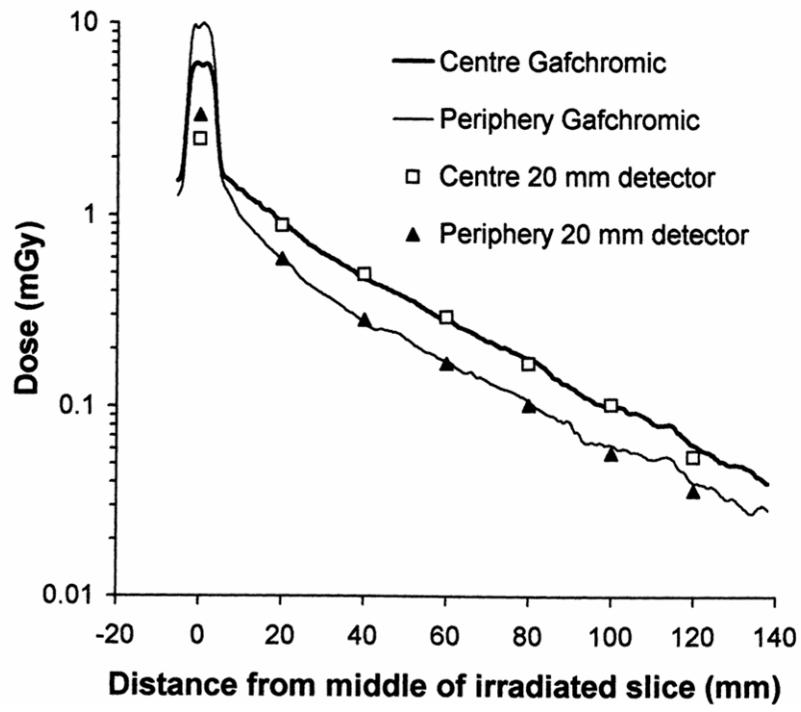
- Comparison of results in CT phantoms
- Gafchromic film
- 20 mm long prototype detector from Unfors

Ionisation chamber and Gafchromic film results

Decline in dose with distance from irradiated slice at edge of phantom

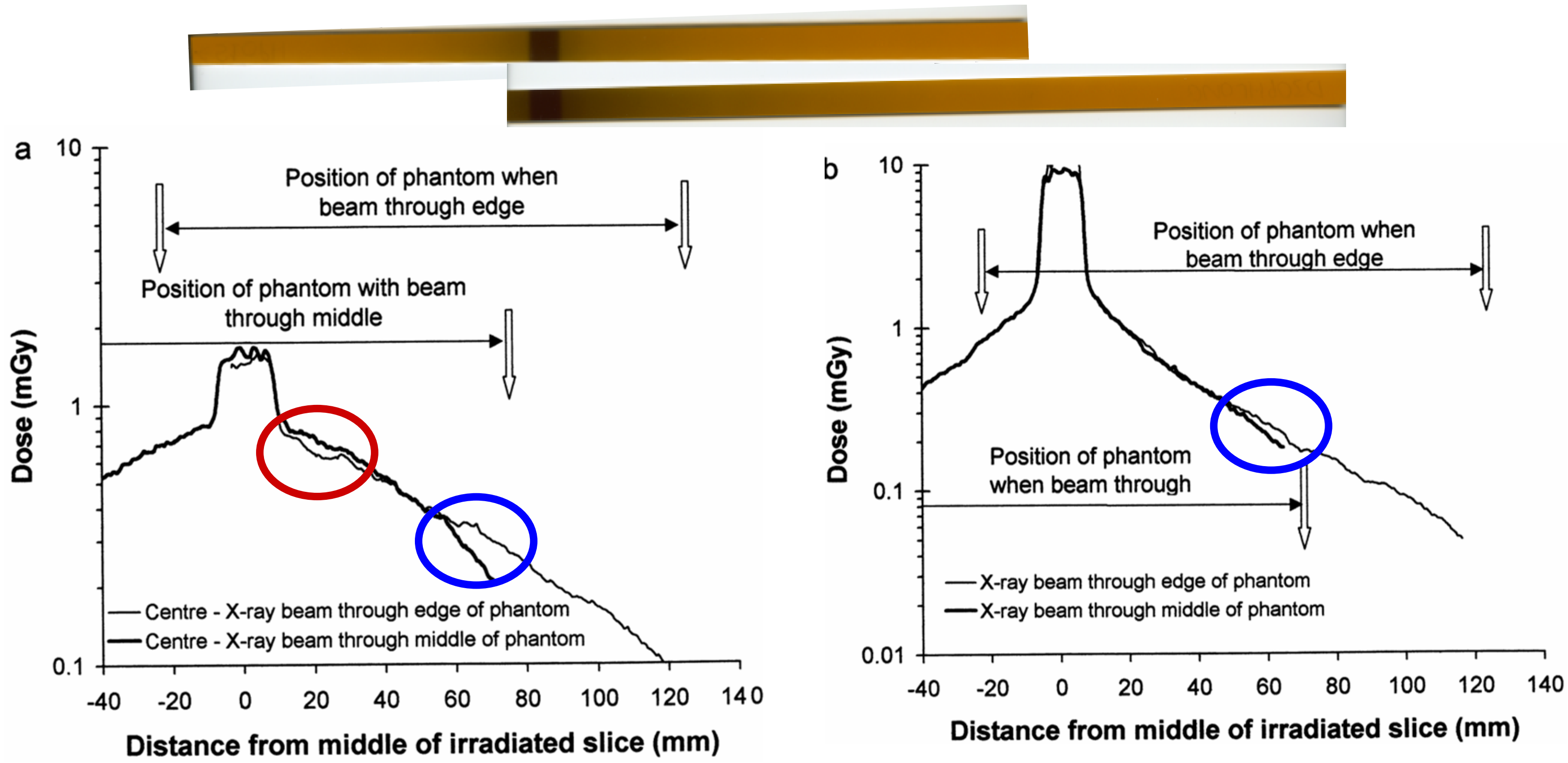


Toshiba Aquilion 64, 12 mm beam, 100 mAs



GE Brightspeed 16, 5 mm beam, 100 mAs

Comparison of measurements with X-ray beam through middle and edge of body phantom



Centre

Periphery

Edge – Dose lower near primary beam, as less scatter from far side of beam

Middle – Dose lower towards edge of phantom as lower back scatter contribution

Use of 20 mm chamber to derive values of CTDI for different chamber lengths

$$D_{20,x} = \int_{x-10}^{x+10} D(z)dz = D_{ax} \times 20$$

Absorbed dose D_{ax} in phantom at distance x from middle of beam

$D_{100,c} = D_{20,c,0} + 2\,(D_{20,c,20} + D_{20,c,40})$

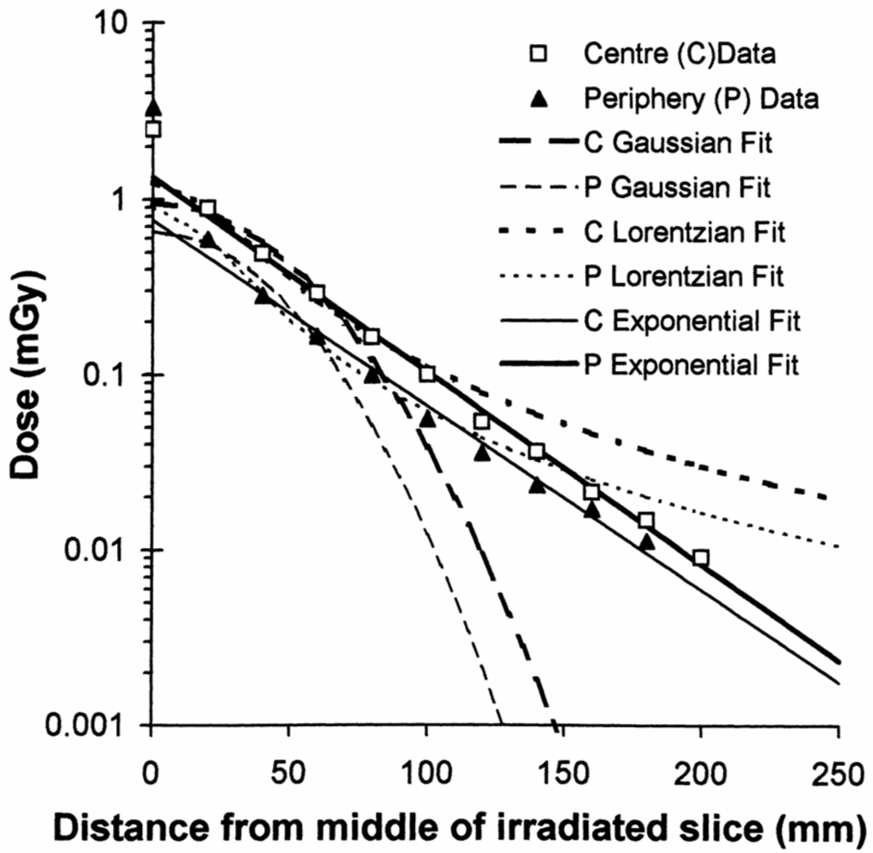
$D_{300,c} = D_{20,c,0} + 2\,\Sigma_{x\,=\,20,\,40,\,60,\,80,\,100,\,120,\,140}\, D_{20,c,x}$

Dose at different positions within phantom summed to simulate dose from chambers of differing length

Exponential decline with distance from irradiated slice

Decline in dose follows an exponential form

An exponential was used to extrapolate dose data



$CTDI_{\infty}/CTDI_{100}$ for a single head phantom

	CTDIc	CTDIp	CTDIw
GE Brightspeed 16	1.28 ± 0.01	1.17 ± 0.01	1.21 ± 0.01
Toshiba Aquilion 64	1.26 ± 0.01	1.14 ± 0.03	1.18 ± 0.03

$CTDI_{\infty}$ derived to give indication of measurement with a long detector

Ratio $CTDI_{\infty}/CTDI_{100}$ calculated to give indication of radiation not detected

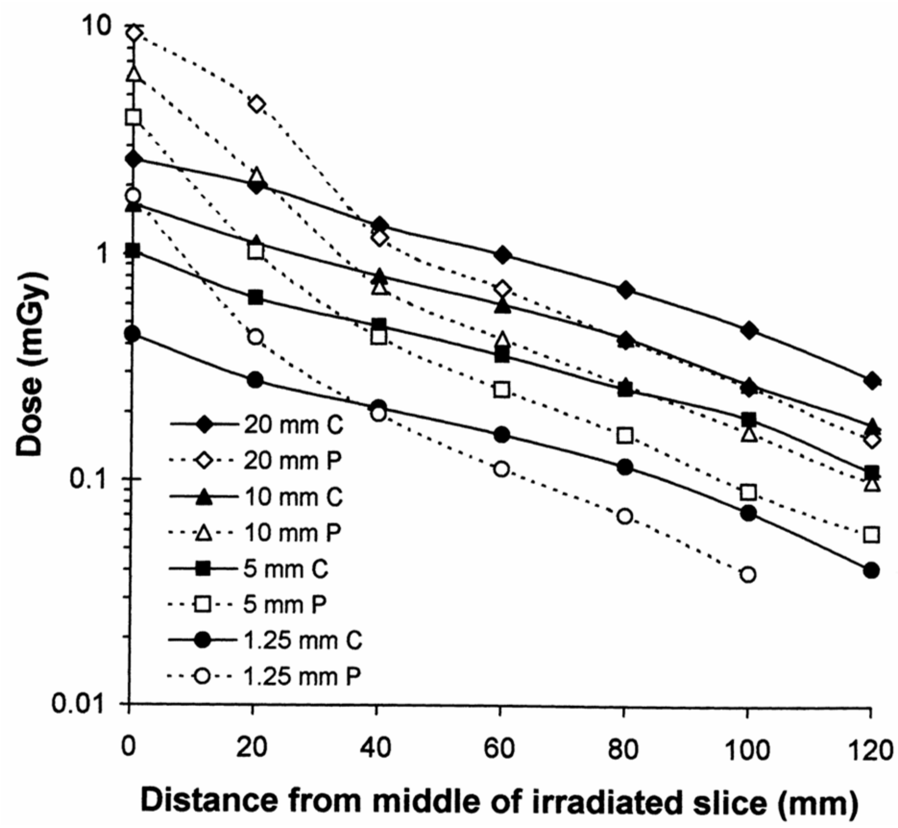
Ratios $CTDI_{\infty}$ / $CTDI_{100}$ derived for head phantoms with 10 mm slice widths

	Method	Centre	Periphery
Perisinakis et al 2007	Monte Carlo simulation Siemens Sensation 64	1.23	1.15
Boone 2007	Monte Carlo simulation GE Lightspeed 16	1.22	1.11
Zhou and Boone 2008	Monte Carlo simulation GE Lightspeed 16	1.21	
Present study	Toshiba Aquilion 64 s	1.26	1.14
Present study	GE Lightspeed16 (Two phantoms end to end)	1.28	1.17

Variation in dose with distance from middle of beam for different beam widths

Body phantom

Results from 20 mm detector



Ratio $CTDI_{\infty}/CTDI_{100}$ for different beam widths
with body phantom for GE Brightspeed 16 Scanner

	20 mm	10 mm	5 mm
$CTDI_c$	1.67 ± 0.03	1.69 ± 0.03	1.73 ± 0.03
$CTDI_p$	1.17 ± 0.02	1.18 ± 0.02	1.19 ± 0.02
$CTDI_w$	1.26 ± 0.02	1.28 ± 0.01	1.29 ± 0.02

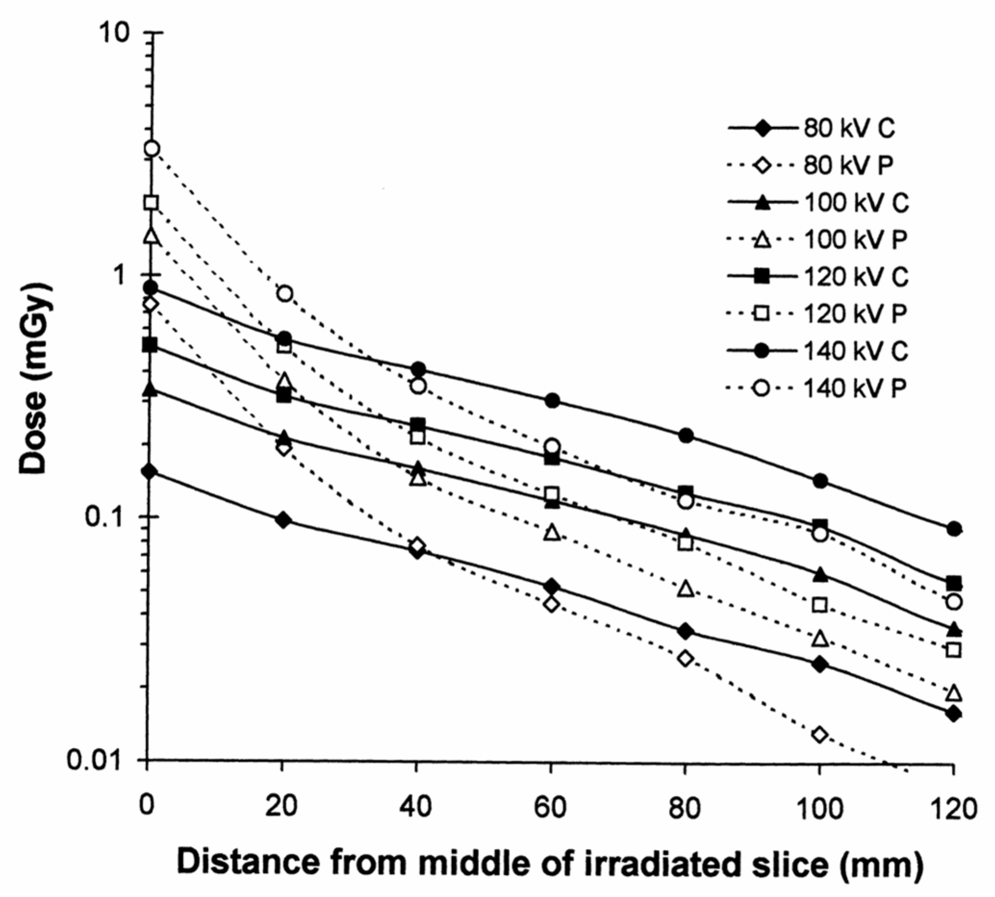
Ratio $CTDI_{\infty}/CTDI_{100}$ calculated to give indication of radiation not detected for body phantom

Does not vary significantly with slice width

Variation in dose with distance from middle of beam for different tube potentials

Body phantom

Results from 20 mm detector



Ratios $CTDI_{\infty}/CTDI_{100}$ for different tube potentials

with the body phantom for the GE Brightspeed 16 Scanner

	80 kV	100 kV	120 kV	140 kV
$CTDI_c$	1.66 ± 0.02	1.72 ± 0.02	1.73 ± 0.02	1.71 ± 0.02
$CTDI_p$	1.16 ± 0.02	1.18 ± 0.02	1.19 ± 0.02	1.19 ± 0.02
$CTDI_w$	1.24 ± 0.02	1.28 ± 0.02	1.29 ± 0.02	1.29 ± 0.01

Result for 80 kV lower because of higher attenuation in phantom

Ratios $CTDI_{\infty}$ / $CTDI_{100}$ derived for body phantoms with 10 mm slice widths

	Method	Centre	Periphery
Dixon et al 2007	Detector comparison 400 mm phantom GE Lightspeed 16	1.75	1.22
Boone 2007	Monte Carlo simulation GE Lightspeed 16	1.59	1.14
Zhou and Boone 2008	Monte Carlo simulation GE Lightspeed 16	1.39	
Present study	GE Lightspeed16	1.69	1.18

Alternative approach to dosimetry

- Measure equilibrium dose in middle of phantom for helical scan (Dixon 2003, 2006)
- Need to consider periodic variation in absorbed dose along phantom

Pitches for helical scans 1

p´ = (*S*-*R*)/*S* [Dixon 2003]

where *S* and *R* are the distances between the source and isocentre, and detector and isocentre respectively.

The pitch p´ defined here relates to the actual beam width including the penumbra, so the actual pitch chosen should be:

p = (*S*-*R*) (*fwhm*)/(*S.W*)

where fwhm = full width at half maximum of the X-ray beam and W = nominal beam width.

Pitches for helical scans 2

An alternative approach for the dosimetry method using a small detector would be to choose a scanning option such that the pitch p = L / N W

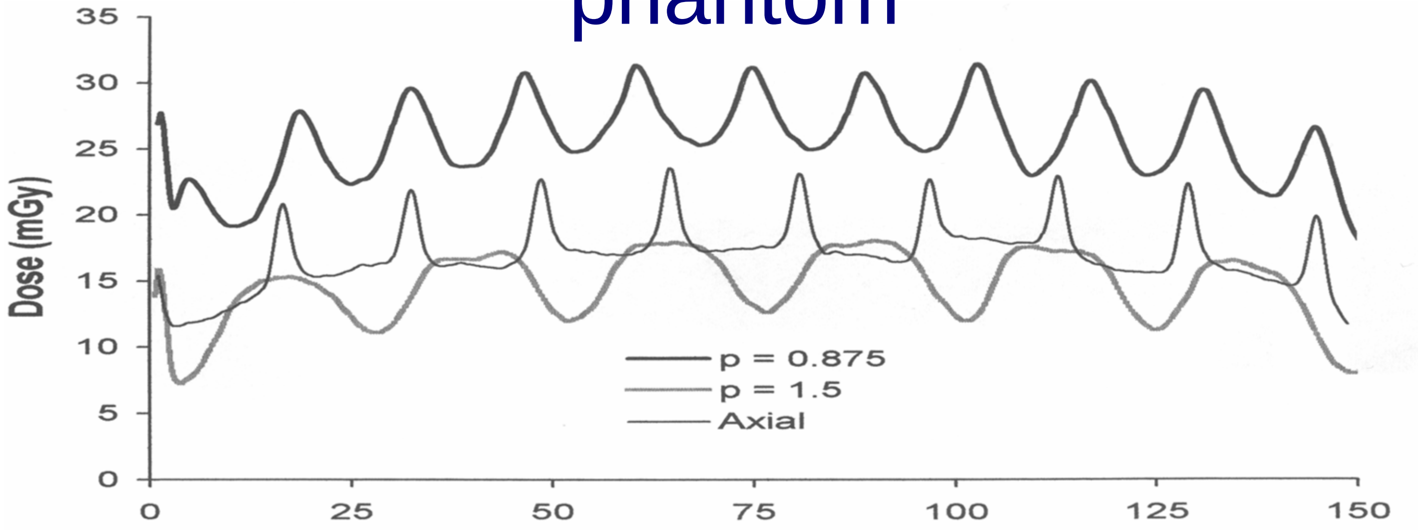
where L = dosimeter length

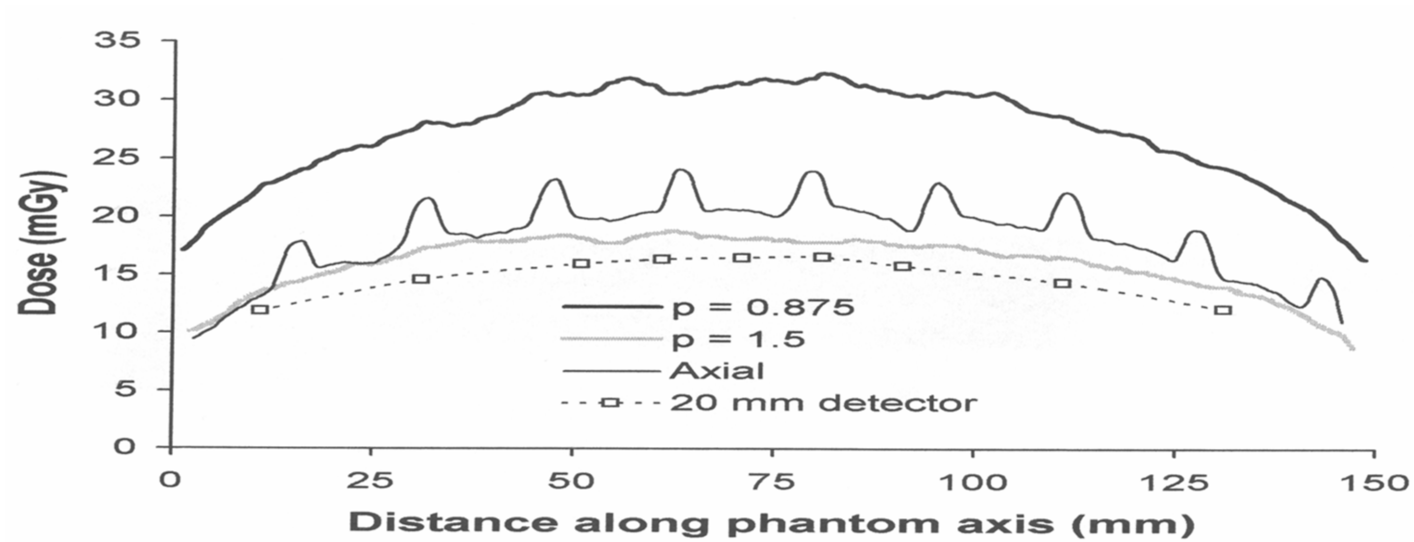
T = beam width

N is an integer [Zhang et al 2009],

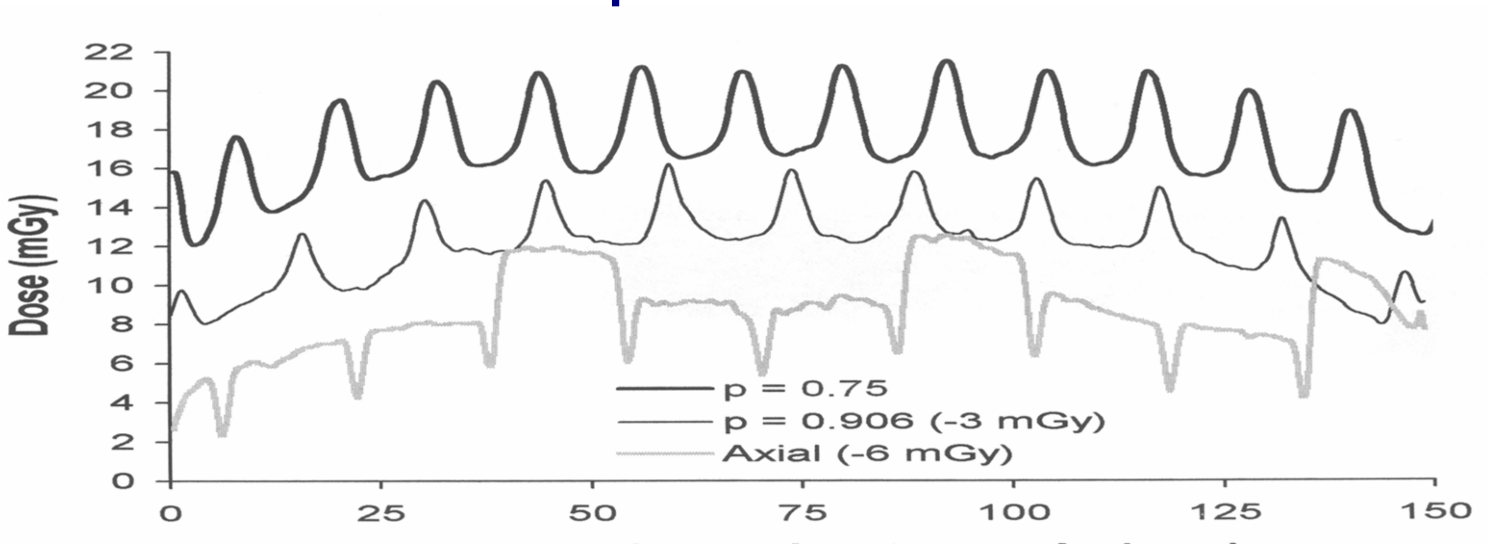
The periodicity of the variation in dose is equal to the length of the detector.

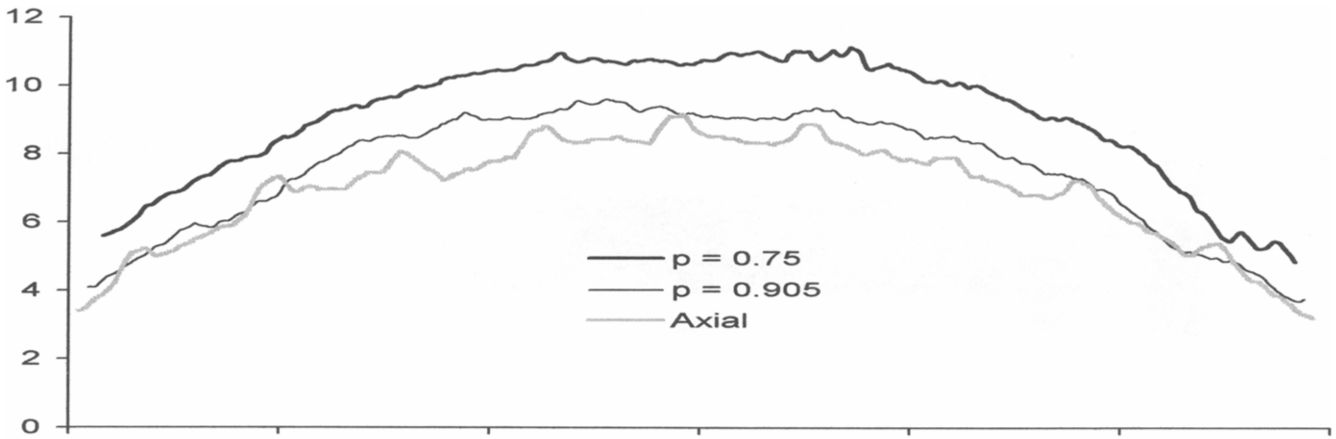
Dose distributions from helical scans in head phantom





Dose distributions from helical scans in body phantom





Possible Dosimetry Options

- Continue to use the existing 100 mm detector and apply standard correction factors,
- Use a short ionisation chamber and carry out helical scans with existing but longer phantom (Dixon 2006, 2007). Need to choose pitches and slice widths to minimise variations at the periphery.
- Develop methods of dosimetry based on anthropomorphic phantoms to assess effective dose (Brenner 2005, 2007).
- Develop alternative methods using a different design of phantom and depths of measurement point possibly using a smaller detector.
- Is it now time to move to an elliptical phantom for dosimetry?
  If so, what dimensions would be best?

Phantom Design

Ellipse – What dimensions should be used?

- 36 cm x 24 cm
- 35 cm x 25 cm
- Alternatives?

Is 1 cm depth appropriate for the peripheral measurements?

- Would a depth closer to that of more sensitive organs be appropriate?
  (lung, colon, stomach, bone marrow)
- 2 cm would have less periodic variation for helical scans