An Investigation into CT Dosimetry using an Elliptical Phantom

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INTRODUCTION

The CT dose index (CTDI) and the cumulative dose (CD) used for CT dosimetry are measured in cylindrical phantoms. But a cylinder does not represent the shape of a typical patient. Therefore there are arguments in favour of adopting an elliptical phantom as a standard for CT dosimetry. CT dose distributions have been measured using Gafchromic film to assess differences between elliptical and cylindrical phantoms.

METHODS

Dose distributions have been measured with strips of Gafchromic XR-QA film, scanned in reflection mode using an Epson V700 flat-bed scanner. The optical density from the red channel was used for dose assessments and the film calibrated using a Gulmay superficial therapy unit (Martin et al 2011). Dose distributions were measured in a cylindrical CT dosimetry phantom 320 mm diameter and an elliptical phantom with major and minor axes of 330 and 220 mm, on a GE Lightspeed 16 scanner. Measurements were made of single rotation dose profiles (SRDPs) with the primary beam either at the midpoint of the phantom or 25 mm from one end *(figure 1)*. Measurements were performed at different exposure levels to obtain sufficient accuracy over a large dose range and results combined to derive complete beam profiles.

Values for the CTDI100 were calculated by summing doses recorded with the beam at the midpoint of the phantom. Dose profile data sets from positioning the primary beam at the longitudinal midpoint and near the edge of the phantom were combined to derive assessments of CDs and CTDIs in longer phantoms. Exponential fits to the tails of the SRDPs were used to extrapolate scatter levels to greater distances. Helical scans were simulated by combining SRDPs in order to build up CD distributions along the central axes of the phantoms. CDs for scans with lengths up to 450 mm were calculated by summing contributions to the dose in the middle 20 mm of a phantom.

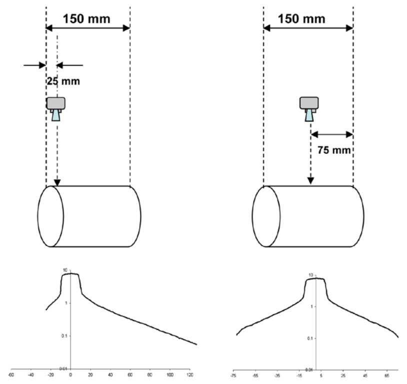

Fig 1

Diagrams show positions of primary beam used for recording of SRDPs; edge beam profile (a) and mid point beam profile (b)

RESULTS

SRDPs in the elliptical and cylindrical phantoms recorded with the same exposure factors are compared in *figure 2*. The dose levels within the main beam at the anterior periphery and centre of the ellipse are greater than those for the cylinder, while the doses for the lateral periphery are similar *(Table 1)*.

Table 1. CTDI values in mGy for same scanner settings

Phantom	Length	$CTDI_{100}$ 150 mm	$CTDI_{300}$ 300 mm	$CTDI_{100}$ / $CTDI_{\infty}$
Elliptical phantom	Centre	5.39	7.58	0.66
	AP	8.21	9.71	0.81
	Lateral	7.14	8.50	0.85
Cylindrical phantom	Centre	3.38	5.29	0.61
	AP	6.61	8.12	0.82
	Lateral	7.26	8.64	0.85

Dose distributions for helical scans along the central axis of the elliptical phantom are shown for scan lengths between 100 and 400 mm in *figure 3*. The CDs that would be measured by a 20 mm long chamber in the central and peripheral positions calculated by summation of SRDPs are plotted against scan length in *figure 4* and given in *Table 2*.

Table 2. Cumulative doses (mGy/100mAs)

Phantom	Scan length	150 mm	400 mm
Elliptical phantom	Centre	5.10	7.82
	AP	7.95	9.87
	Lateral	7.19	8.54
Cylindrical phantom	Centre	4.29	5.51
	AP	7.27	8.10
	Lateral	7.87	8.58

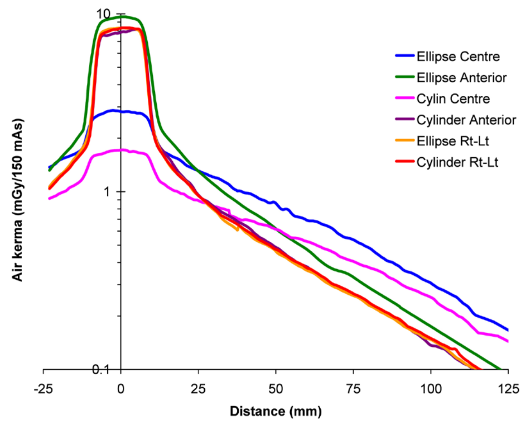

Fig 2

Comparisons of dose profiles in elliptical and cylindrical phantoms at the centre, anterior and lateral positions for a 20 mm beam wide.

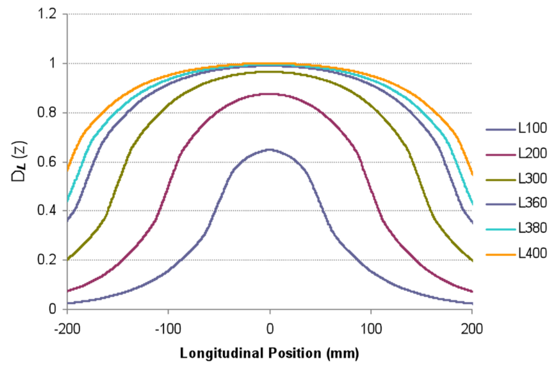

Fig. 3

Modelled cumulative dose distribution along central axis in the elliptical phantom of scanning lengths (L) of 100, 2000, 3000, 360, 380 and 400 mm.

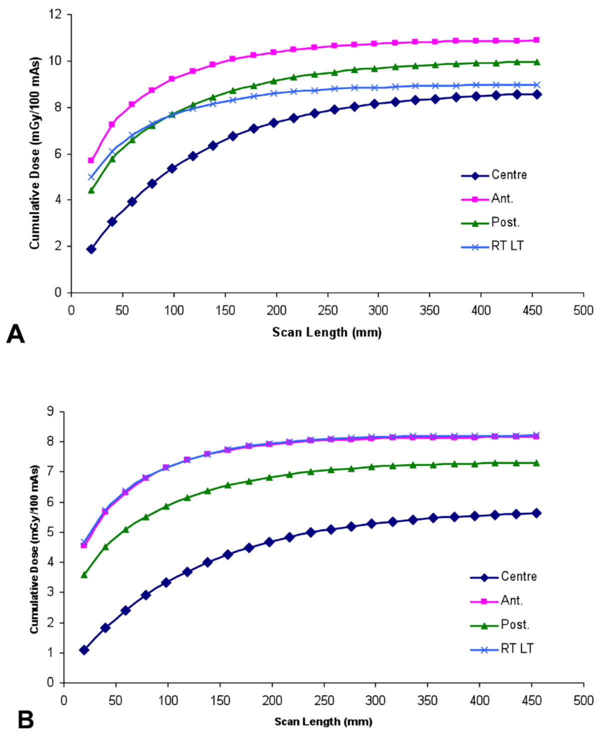

Fig 4

Calculations of cumulative dose at the centre and peripheral positions as a function of scan length derived for 20 mm beam widths for a) the elliptical phantom and b) a cylindrical phantom.

DISCUSSION

The doses at the anterior periphery and centre of the elliptical phantom are higher than those for the cylindrical one *(figure 2)*. This is partly because the transmitted X-ray dose is greater, but also the anterior surface in the elliptical phantom is nearer to the isocentre so that X-ray beams incident obliquely on the periphery pass through a section closer to the middle of the bow-tie filter. The CDs gradually increase with scan length *(figure 3)*, but vary in different ways within the two phantoms *(figure 4)*. The dose at the sides of the elliptical phantom is only marginally greater than the central dose as the scan length is increased, because the scatter dose falls more rapidly with distance from the primary beam.

CONCLUSIONS

An elliptical phantom gives a better representation of the dose to a human trunk and takes more account of differences in bow tie filters which are relevant to clinical practice. Since a typical patient is elliptical in cross section, the current cylindrical phantom may underestimate doses in some regions of the body. Another advantage of an elliptical phantom is that account can be taken of the effect of automatic tube current modulation in the x-y plane on dose levels to provide more complete performance testing of CT scanner facilities.

REFERENCES

Martin C, Gentle D, Sookpeng S and Loveland J 2011 Application of Gafchromic film in the study of dosimetry methods in CT phantoms. Journal of Radiological Protection 31 389-409