Doses from Computed Tomography (CT) Examinations in the UK – 2003 Review

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ABSTRACT

A new UK computed tomography (CT) survey has provided a useful snapshot of patient doses for 2003. Scan details for nearly 850 standard protocols and 2,000 individual patients relating to 12 common CT examinations on adults and children were collected by questionnaires voluntarily submitted by a widely-distributed sample of 126 scanners. This represented more than a quarter of all UK scanners and included 37% with multislice capability. Scanner-specific normalised CT dose data published by ImPACT were used to estimate standard dose indices $CTDI_w$ and $CTDI_{vol}$ for each sequence and, with knowledge of scan lengths, DLP for each examination. Effective doses were subsequently estimated from the calculated values of DLP. Wide variations in practice were still apparent between CT centres, although the overall levels of exposure were in general lower by 10-40% than previous UK survey data for 1991. There was, however, an apparent trend for slightly increased doses from multislice (4+) (MSCT) relative to single slice (SSCT) scanners for adult patients. Values of $CTDI_{vol}$ were broadly similar to recent survey data for MSCT from Europe for 2001. Effective doses to very young patients (aged 0-1 years) were typically higher than corresponding values for adults. Doses to individual patients were on average similar to those for the standard protocols established for each scanner, although significant variations were also apparent.

The report includes summaries of the dose distributions observed and, on the basis of third quartile values, presents national reference doses for examinations on adults (separately for SSCT and MSCT) and children. The PREDICT (Patient Radiation Exposure and Dose in CT) database established by the survey represents a sustainable national resource for monitoring continuing developments in CT through the ongoing collation of further survey data.

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1 INTRODUCTION

Computed tomography (CT) was first established as being a relatively high-dose x-ray imaging technique by a national survey conducted in the UK around 1990 by the National Radiological Protection Board (Shrimpton et al, 1991). At that time, CT practice involved single slice scanners largely operating in a slice-by-slice, axial scanning mode (also known as incremental, sequential, serial or step-and-shoot scanning). Dose information from this early UK study provided the basis for reference doses subsequently published in 1999 as part of European guidelines on quality criteria for CT (European Commission, 1999), although it was recognised that helical (or spiral) scanning mode was by then commonplace for rapid volumetric data acquisition.

The significant benefits to healthcare afforded by CT have ensured continuing steady growth in both scanner technology and clinical application (Golding and Shrimpton, 2002; Lewis, 2001; Klingenbeck-Regn et al, 1999; UNSCEAR, 2000). In consequence, CT's contribution to the collective effective dose from medical x-rays in the UK has more than doubled over the last ten years to about 47% (Hart and Wall, 2004); a total of some 2.0 million CT examinations were reported for the National Health Service (NHS) in England for the year 2003-04, representing about 9% of all x-ray examinations (Department of Health, 2004).

CT practice continues to evolve with, in particular, the introduction of multislice CT (MSCT) that utilises multi-detector rows (hence the alternative term MDCT) to allow fast helical scanning and rapid imaging of large volumes of the patient (Kalender 2000; Prokop, 2003). Such technology is promoting the further development of new and complex diagnostic and interventional CT procedures, with clear potential for increased doses to individuals and populations (Sablayrolles, 2002). Conversely, there is increasing attention to optimisation of patient protection through improvements in CT technology and practice, with some possibilities for dose reduction (ICRP, 2000; Kalender, 2004; Kalra et al, 2004a).

In view of the significant changes in the application of CT since the earlier study (Shrimpton et al, 1991), a new national survey has been carried out in collaboration with the CT Users Group (http://www.ctug.org.uk/) and the CT evaluation facility ImPACT (Imaging Performance and Assessment of CT) of the Medicines and Healthcare products Regulatory Agency (MHRA) (http://www.impactscan.org/). This survey has sought to provide a snapshot of UK practice for 2003, with updated information relevant to helical and multislice CT on adults and children, and updated national reference doses. It also establishes a sustainable database, known as PREDICT (Patient Radiation Exposure and Dose in CT), for the ongoing collation of further data so as to facilitate the analysis of trends and periodic review of national reference doses. The project has been endorsed by the Department of Health and the professional bodies, the Institute of Physics and Engineering in Medicine (IPEM), the Royal

College of Radiologists (RCR) and the Society and College of Radiographers (SCOR).

2 SURVEY METHODS

2.1 Data collection and analysis

2.1.1 Design of questionnaire

The timely collection of representative dose data for a complex and wide-scale practice such as CT is always difficult and necessarily involves a balance between available resources and requirements for the survey results. The present survey has inevitably involved data collection for a sample of national practice, with voluntary data submission following a standard format representing the best practical option. This approach does, of course, have potential for bias if the self-selected sample is, for example, not sufficiently representative of typical practice, although this is unlikely to be a significant problem for the present purposes of promoting patient protection.

Key data on local CT practice were collected by means of a questionnaire that was completed for each CT scanner participating in the survey. The questionnaire was published in October 2002 on the CT Users Group website (http://www.ctug.org.uk/) for downloading, manual completion and postal return to NRPB; extracts to illustrate its scope are shown in Appendix A. The form was based on a questionnaire originally developed by a CT Working Group for a 2001 European Survey on CT (Geleijns, 2002) that was subsequently modified for the UK survey.

There were three aspects to data collection, covered by separate sections in the questionnaire. Firstly, information was sought in relation to the standard protocols established for some common CT examinations conducted on standard (average-sized) patients. In order to allow more robust analyses and meaningful comparisons of practice between CT centres, the survey has focussed on particular scans performed in relation to specific clinical indications, since these are likely to dictate necessary conditions of scanning. The selected procedures are listed in Table 1 and include six common examinations for typical adult patients and two examinations each performed for three ages of children (0-1 year old, 5 year old and 10 year old, as broadly characterising the range in paediatric technique). This initial choice of procedures was thought to include some of the most common CT procedures and hence represent the bulk of core practice. Such standard protocols should form the basis for typical practice and its variants at each CT centre. Protocols may consist of a number of separate scan sequences, each representing a single helical exposure or a series of similar axial exposures for common scan conditions.

Secondly, the survey sought information from CT centres on the actual scan sequences used for individual patients, since these may differ from the standard

protocols according to particular clinical needs. Data were requested ideally for a sample of at least 10 patients for each of the selected procedures in Table 1, and including adult patients who are close to average size (excluding those who are excessively small or large) or, for paediatric examinations, children of any recorded age. Such audit data allow useful comparisons against corresponding standard protocols. Finally, the questionnaire invited (as an option) the reporting without further detail of any measurements of dose performed locally as part of routine quality assurance for CT. These data provided a useful check against typical dose data published for each scanner model (ImPACT, 2004).

TABLE 1 Common CT examinations and their specific clinical indications selected for study in the present UK CT dose survey

Examination	Clinical indication
Adults	
Routine head	Acute stroke
Abdomen	Liver metastases
Abdomen and pelvis	Abscess
Chest, abdomen and pelvis	Lymphoma staging or follow up
Chest	Lung cancer (known, suspected or metastases)
Chest (Hi-resolution)	Diffuse lung disease
Children	
Paediatric chest	Detection of malignancy (0-1 year old)
Paediatric chest	Detection of malignancy (5 year old)
Paediatric chest	Detection of malignancy (10 year old)
Paediatric head	Trauma including non-accidental injury (0-1 year old)
Paediatric head	Trauma including non-accidental injury (5 year old)
Paediatric head	Trauma including non-accidental injury (10 year old)

The questionnaire was designed to be as simple as possible (with explanatory notes), whilst providing sufficient information on practice so as to characterise technique and allow the calculation of relevant dose quantities (Appendix A). All efforts were made to minimise ambiguity, although it was recognised that the forms were still complex. The principal data requested for each particular scan sequence included the location (as pictorial response) and the anatomical range (descriptive response); the acquisition mode (axial or helical scanning); the use of intravenous contrast; the machine settings (such as the nominal acquired slice width and number of such simultaneous slices, the applied potential, the tube current and the rotation time); the table increment per rotation or the pitch; the imaged slice thickness; and (for individual patients) the number of axial slices or the length of helical scanning. Values were also requested for any doses displayed on the scanner console. Finally, all sequences were characterised as being either *Routine* (and so performed for every patient) or *Ad-hoc* (and carried out only in response to findings in a previous sequence, or as an occasional alternative technique). Respondents also provided full details of their particular CT scanner model and location, although results of the present survey are, as for

all other NRPB surveys (Hart, Hillier and Wall, 2002), reported only in anonymous form.

2.1.2 Quality assurance

Quality assurance measures for both the input (raw) data and the analyses programs are an essential element of the study and underpin confidence in any reported results. The questionnaires were annotated with unique identifiers and, after processing, were archived sequentially, together with their record sheets that were used to log progress towards completion. Data from each questionnaire were entered manually into an Excel spreadsheet (Microsoft Office 97) and independently checked against the original forms, for subsequent import into a dBASE (relational) database (dataBased Intelligence, Inc. NY, USA). Manipulation of this information required the use of 10 supplementary data files, which were similarly carefully constructed and checked. These files included look–up tables with, for example, codes relating to examination types and scanner models, as well as the dose coefficients and other key data.

Data analyses were conducted using well-structured programs using the software package Visual dBASE V language (version 5.5) that supports high-level language constructs such as subroutines, functions, loops and 'if' blocks, as well as some database-specific operations. Program development followed best computing practices, including the use of comments and documentation, and intermediate check-steps and flags to monitor progress during computation, together with some manual checking of results (Hillier, 2004). The data and program files are stored on the NRPB PC network, with access restricted to a single user account (in addition to the network administrator) and with password protection for both initial access and the PC screen-saver. The network maintains comprehensive and up-to-date virus protection and is backed-up systematically on a daily basis.

Validation of the raw and calculated data was a laborious but necessary process, with a suite of analyses being carried out to check for consistency between the various data. This included studying the expected relationships between the different quantities reported for each individual sequence, as well as examining the ranges observed for particular subsets of the survey data so as to identify potentially erroneous values. The sequence data were also manipulated to derive all possible estimates of the quantities of interest following alternative approaches, as broad checks for the reported and calculated values. For example, values of total current-time product (mAs) that were often reported for helical sequences were used to derive estimates of scan length for comparison against reported figures. Any residual queries following such review and validation of the raw data were resolved by further discussions with the particular CT centres involved.

2.2 Dosimetry

2.2.1 Strategy

The framework for CT dosimetry is already well established (European Commission 1999; ICRP, 2000; McNitt-Gray, 2002; Wall, 2004a). Monitoring of performance in CT as part of routine quality assurance is based on the practical dose quantities: weighted CT dose index ($CTDI_w$), volume weighted CT dose index ($CTDI_{vol}$) (IEC, 2003) and dose-length product (DLP). These form the basis for reference doses (and diagnostic reference levels, DRLs) set for the purposes of promoting optimisation of patient protection (IPEM, 2004; Wall, 2004b). In addition, values of effective dose (E) (ICRP, 1991) for complete CT examinations are also useful for comparison with other types of radiological procedure.

Since 1999, the International Electrotechnical Commission has recommended the display on the CT console of values of CTDI corresponding to the particular scan settings selected (IEC, 1999). Initially, there was some confusion about the dose quantity to be displayed, although this was subsequently clarified in 2003 as being $CTDI_{vol}$ (IEC, 2003). Some manufacturers also display values of DLP. However, not all scanners in the present study had such display capabilities. Moreover, there have been some concerns about reliability of the dose values displayed. Accordingly, it was decided for uniformity of approach to calculate all dose values for the survey from the scan parameters provided for each sequence on the questionnaires, using the scanner-specific normalised CTDI data published by ImPACT (2004). It was also planned to compare, where possible, each set of calculated and displayed doses in order to explore the suitability of the latter data for direct use in future surveys.

In practice, a range of methods was necessarily employed to derive appropriate values of $CTDI_w$ and $CTDI_{vol}$ per sequence, and DLP and E per examination, depending on the particular data available on each questionnaire. The analysis for the survey was designed to provide characteristic data for the observed dose distributions, together with NRPB national reference doses as rounded third quartile values. This information will inform the subsequent setting of national DRLs by the Department of Health (IPEM, 2004).

The results of any standard measurements of CTDI conducted locally by CT centres were included in the survey only in order to allow broad verification of the scanner model by comparison of these reported doses against corresponding published generic data. Such local measurements were not subsequently used when assessing doses for the survey. The particular analyses carried out in relation to these reported measurements are discussed in Section 3.2.

2.2.2 CT dose indices

Values of $CTDI_w$ and $CTDI_{vol}$ per rotation were calculated for each axial or helical sequence on the basis of the representative $CTDI_w$ coefficients published by ImPACT (2004) as part of its CT patient dosimetry calculator. These relate to typical values of $CTDI_w$ measured in the standard adult head or body CT

dosimetry phantom for each particular scanner model (or class of similar models) operated with specific settings of applied potential and nominal beam collimation, NxT; here N is the number of tomographic sections, each of nominal thickness T (mm), from a single rotation. (For multi-slice CT scanners, where N > 1, NxT (mm) represents the total detector acquisition width, such as 4 x 5 mm). The $CTDI_w$ doses are normalised to a current-time setting of 100 mAs and tabulated for a standardised nominal beam collimation of around 10 mm (thus, $({}_nCTDI_w)_{scanner,phantom,kV,NxT}$). Relative factors are also provided for each scanner model, which express the dose coefficients for all other available collimation settings (F_{NxT}).

Accordingly, $CTDI_w$ was calculated for each axial or helical sequence from the reported current-time product per rotation, C (as tube current, mA, and rotation time, s, or as displayed if 'true mAs' and re-corrected if 'effective mAs' with pitch already included), using the specific ImPACT dose coefficients appropriate for the scanner model and operational settings:

$$CTDI_w = \left({}_nCTDI_w\right)_{scanner,phantom,kV,N\times T} \times \left(F_{N\times T}\right)_{scanner} \times C \qquad \text{(mGy)} \qquad (1)$$

Corresponding values of $CTDI_{vol}$ were calculated on the basis of the reported pitch (IEC, 2003):

$$CTDI_{vol} = \frac{CTDI_w}{CT\ pitch\ factor} \qquad \text{(mGy)} \qquad (2)$$

where

$$CT\ pitch\ factor = \frac{\Delta d}{N \times T} \qquad (3)$$

and Δd is the distance (mm) moved by the patient support in the z-direction between consecutive axial scans or per rotation in helical scanning.

For scan sequences on the adult head and for all paediatric procedures (Shrimpton and Wall, 2000), the calculated values of $CTDI_w$ and $CTDI_{vol}$ relate to the 16 cm diameter (head) CT dosimetry phantom, whereas those for examinations on the adult trunk relate to the 32 cm diameter (body) CT dosimetry phantom.

For scanners operated in auto dose reduction mode with automatic tube current modulation (Kalra et al, 2004b; Keat, 2005; Lewis, 2005), doses were calculated, where available, using reported values of (average) tube current or mAs that included the effects of modulation. Exceptionally, where insufficient information was supplied on the questionnaire for such calculations of dose, reported values of (generally) $CTDI_{vol}$ were used directly, with subsequent derivation of the corresponding levels of $CTDI_w$ (Equation 2). These doses were, however, compared with other data in the survey calculated for similar circumstances in order to check their likely validity.

As a broad check of the methods, calculated values of CTDI were compared against any corresponding displayed values of dose reported in the questionnaires (Section 3.4).

2.2.3 Dose-length product

Dose-length products were derived from the values of $CTDI_w$ or $CTDI_{vol}$ calculated for each scan sequence using the following general approaches, depending on the information available:

$$DLP = CTDI_W \times n \times T \quad \text{(mGy cm)} \quad (4)$$

where n is the total number of acquired slices, each of thickness T cm, during an axial scan sequence; or

$$DLP = CTDI_{vol} \times L \quad \text{(mGy cm)} \quad (5)$$

where L is the scan length (cm), limited by the outer margins of the exposed scan range, irrespective of pitch (which is, of course, already included in $CTDI_{vol}$) (McNitt-Gray, 2002). For a helical scan sequence, this is the total scan length that is exposed during (raw) data acquisition, including any additional rotation(s) at either end of the programmed scan length necessary for data interpolation (Nicholson and Fetherston, 2002). For axial scanning, L is the distance between the outer margins of the first and last slices in a sequence. Estimates of L were possible when displayed values of both $CTDI_{vol}$ and DLP were reported, and could be used (after review) in the absence of more specific information.

Exceptionally, as a practical alternative where the information provided was insufficient to use Equations 4 or 5, DLP was estimated from the total current-time product for the entire (axial or helical) sequence (C_{total}, mAs) that was sometimes available:

$$DLP = \left({}_n CTDI_w\right)_{scanner,phantom,kV,N\times T} \times \left(F_{N\times T}\right)_{scanner} \times \left(N \times T\right) \times C_{total} \quad \text{(mGy cm)} \quad (6)$$

where (NxT) is the nominal beam collimation (in cm), defined above. In the further absence of critical information, reported values of sequence DLP were used directly, after broad validation against other data in the survey calculated for similar circumstances.

In the case of the survey data for individual patients, specific details were generally recorded for each scan sequence for direct use in Equations 4, 5 or 6. However, such information (on number of acquired axial slices or scan length) was not usually available for sequences comprising the standard (prospective) protocols. Accordingly, standard scan lengths were then assumed for use in Equation 5 on the basis of the particular scan ranges indicated in each questionnaire, as specified by the lines marked on the anatomical diagrams and by the anatomical landmarks denoting the scan limits. These standard lengths were derived using a scheme developed for the survey that characterises the typical distances between common anatomical landmarks for four standard

patient ages (Dunn, 2003). Table 2 summarises the perpendicular distances between planes through landmarks in the head, relative to a plane through base of skull and superior orbital margin, and in the trunk, relative to a transverse plane through the lung bases.

TABLE 2 Assumed typical relative distances (mm) between anatomical landmarks for 4 standard patient ages

Landmark	Adult[a]	10 y old[b]	5 y old[b]	0-1 y old[b]
Head	*Perpendicular distance (mm) to plane through base of skull and superior orbital margins)*			
Base of skull	0	0	0	0
Superior orbital margin	0	0	0	0
Petrous ridge	22	21	20	17
Mastoids (superior)	29	28	26	22
Posterior fossa (superior)	40	38	36	30
Inner table vertex	115	109	104	87
Outer table vertex	122	116	110	93
Trunk	*Perpendicular distance (mm) to transverse plane through lung bases*			
Lung apices	250	205	158	133
Sternoclavicular joint	218	*	*	*
Carina	147	*	*	*
Hilar	126	*	*	*
Diaphragm (right dome)	42	34	26	22
Superior border of liver	42	34	26	22
Lung bases	0	0	0	0
Inferior border of liver	-119	-98	-75	-63
Iliac crests	-153	-125	-96	-81
Symphysis pubis (mid)	-333	*	*	*
Symphysis pubis (inferior)	-346	-284	-218	-183
Inferior pubic rami	-370	-303	-233	-196

Notes:

[a]Typical data for the adult are based on measurements performed on scan projection radiographs for a series of average-sized patients (Dunn, 2003).

[b]Paediatric data are derived from adult values using scaling factors based on anthropometric data published for the head and torso (Norris and Wilson, 1995; Peebles and Norris, 1998).

In addition to the particular data shown for the head, distances were also derived (and used when appropriate) relevant to other angulations of the CT gantry for two further scan baselines: true transverse; and a plane through base of skull and inner canthus. The typical data for the adult represent mean values from measurements performed on scan projection radiographs (14 of the head and 19 of the trunk) for a series of average-sized patients that included a mix of males (40%) and females (60%), and with a mean weight close to 70 kg. In view of the practical difficulties in similarly reviewing sufficient scan projection radiographs for children, typical data for three standard ages were derived from the adult values using broad linear scaling factors based on anthropometric data

published for the head and torso (Norris and Wilson, 1995; Peebles and Norris, 1998). These approaches were shown to be sufficiently robust by comparison of standard scan lengths against scan lengths reported for comparable scan ranges (Section 3.3).

Dose-length products for complete examinations were calculated by summation of the DLPs for all sequences reported for each individual patient and, by default, all the *Routine* sequences listed for each standard protocol. Separate assessments were also made of the total DLP for each standard protocol on the basis of all the sequences, including both *Routine* and *Ad-hoc* (Section 3.6). Exceptionally, reported values of examination DLP were used directly, after broad validation, when calculations of DLP were not possible for all component sequences.

Particular care was taken in interpreting the information supplied for axial scans with multislice scanners, in order to ensure that the reported number of slices was consistent with the imaged slice thickness. For helical scan sequences, it was also recognised that calculated values of DLP using scan lengths based on the planned start and stop positions of the patient couch might lead to underestimates of dose, in view of the additional rotations necessary for data interpolation at either end of the planned image volume. This additional dose can be particularly significant for short scan lengths and is relatively more important for multislice scanners since the total x-ray beam width is usually greater (Lewis, 2005). As a broad check of the survey methods described above, calculated values of DLP were compared against any corresponding displayed values of dose reported in the questionnaires (Section 3.4).

2.2.4 Effective dose

Sufficiently robust estimates of effective dose (E) were made for the survey from the values of DLP (European Commission, 1999; Shrimpton and Wall, 2000), as being a more practical approach than detailed calculations on the basis of organ doses (ImPACT, 2004; Jones and Shrimpton, 1993). Thus, for each sequence, E was broadly assessed from the calculated DLP using a region- and age-specific coefficient:

$$E = \left(E_{DLP}\right)_{region,age} \times DLP \qquad \text{(mSv)} \qquad (7)$$

where $(E_{DLP})_{region,\ age}$ (mSv (mGy cm)$^{-1}$) is the normalised value of effective dose per dose-length product over a specific body region for a particular standard patient age. A comprehensive set of such coefficients relating to six broad regions and five standard ages has been derived for general use (Shrimpton, 2004) from a series of Monte Carlo dose calculations for a family of mathematical phantoms (Khursheed et al, 2002). These data, which are largely independent of scanner model and operating conditions, are shown in Table 3. There is a systematic trend with age, such that the coefficients for the newborn (0 year old) are larger than those for the adult by factors of about 5 for the head region and about 3 for the trunk.

TABLE 3 Normalised values of effective dose per dose-length product (DLP) over various body regions and (standard) patient ages (Shrimpton, 2004)

Region of body	Effective dose per DLP (mSv (mGy cm)$^{-1}$) by age				
	0 y old[a]	1 y old[a]	5 y old[a]	10 y old[a]	Adult[b]
Head & neck	0.013	0.0085	0.0057	0.0042	0.0031
Head	0.011	0.0067	0.0040	0.0032	0.0021
Neck	0.017	0.012	0.011	0.0079	0.0059
Chest	0.039	0.026	0.018	0.013	0.014
Abdomen & pelvis	0.049	0.030	0.020	0.015	0.015
Trunk	0.044	0.028	0.019	0.014	0.015

Notes:

[a]All data normalised to $CTDI_w$ measured in the 16 cm diameter CT dosimetry phantom.

[b]Data for the head & neck regions normalised to $CTDI_w$ in the 16 cm diameter CT dosimetry phantom; data for other regions normalised to $CTDI_w$ in the 32 cm diameter CT dosimetry phantom.

Effective doses for complete examinations were approximated by summation of the effective doses for all sequences reported for each individual patient and, by default, all the *Routine* sequences listed for each standard protocol.

3 RESULTS

3.1 Survey sample

3.1.1 Scanner distribution

The survey was launched in October 2002 with publication of the questionnaire on the website of the CT Users Group (CTUG, 2002) and active promotion both amongst its members and the wider UK medical physics community (IPEM, 2002; Medical-Physics-Engineering, 2002). During the six-month period to March 2003, 153 questionnaires were returned to NRPB, as separate submissions of data from 126 scanners located at 118 hospitals in the UK. Participating sites are marked schematically on the map in Figure 1 and listed alphabetically in Appendix B.

The substantial sample includes reasonable geographical spread around the UK. Table 4 gives detailed analyses for the regional distribution of CT scanners both in the survey sample and the UK as a whole. Around three-fifths of the scanners in the survey sample were based in the NHS in England, with about a further fifth operating in the NHS in Scotland and about a tenth in the NHS in Northern Ireland; the remaining tenth was split between the NHS in Wales and scanners operating in the private sector. Overall, the sample included over a quarter of the estimated total of 471 CT scanners in clinical service in the UK during 2003. Sampling rates for England (with about 70% of all UK scanners) and Wales (about 4% of the UK total) were broadly appropriate, although Scotland and

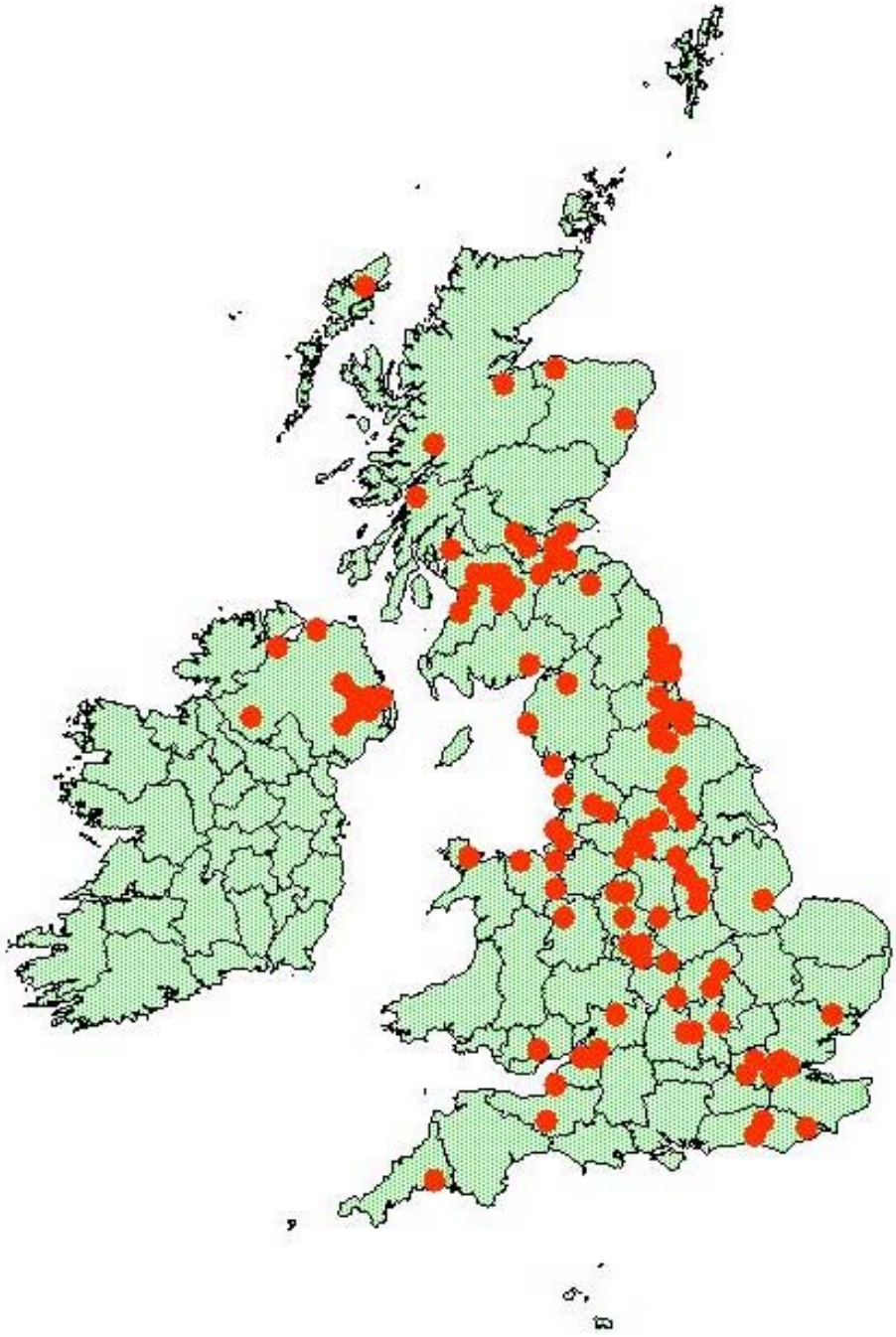

FIGURE 1 Geographical distribution of CT scanner sites in survey sample (not to scale)

Northern Ireland were somewhat over-represented in the sample, whereas scanners included in the 'Other' category were under-represented.

TABLE 4 Geographical distribution of CT scanners in the survey sample and in the UK

Domain	Region	Scanners in region		Scanners in sample		
		No.	% in UK	No.	% in sample	% in region
NHS England	London	64	13.6	10	7.9	15.6
	Midlands & East	85	18.0	15	11.9	17.6
	North	107	22.7	36	28.6	33.6
	South	72	15.3	16	12.7	22.2
	ALL (100%)	328[a]	69.6	77	61.1	23.5
NHS Northern Ireland	ALL	19[a]	4.0	12	9.5	63.2
NHS Scotland	ALL	40[b]	8.5	28	22.2	70.0
NHS Wales	ALL	19[a]	4.0	4	3.2	21.1
Other[c]	ALL	65[a]	13.8	5	4.0	7.7
UK	NHS & Other	471	100	126	100	26.8

Notes:

[a]Data on numbers of scanners (Stonell, 2004) refer to following time frames: England and Other category, January 2004; Northern Ireland, October 2003; Wales, December 2003.

[b]Data for Scotland (Audit Scotland, 2004) refer to 2003.

[c]Other category includes scanners in the private sector, mobile scanners and others in the Defence sector; data refer (primarily) to England.

An analysis of the survey sample by scanner model is presented in Table 5, following the classification scheme developed by ImPACT (2004) for aggregating models with similar performance characteristics. The sample includes examples of 45 such different scanner groups. Overall, 29% of the 126 scanners in the survey were manufactured by GE, 27% by Philips, 30% by Siemens and 14% by Toshiba. On the basis of the broad scope of the sample, this distribution is likely to be similar to the profile for the UK.

In contrast to the technology prevalent during the previous UK survey (Shrimpton et al, 1991), all scanners in the present survey could be operated in helical scanning mode, with over one third of the sample also having multislice capability (Table 6). In view of the rapid pace of change in the provision for CT in recent years, this proportion is rather less than the overall pattern for the NHS in 2004, where multislice scanners comprise 57% of the total in England, 53% in Northern Ireland and 74% in Wales (Stonnell, 2004). In particular, there is some under-representation of quad and 16-slice scanners in the self-selected sample (Table 6). It was not possible to make any further comparisons of the sample against national patterns for specialised scanner application, such as neuro-radiology, radiotherapy or paediatrics, or for workload.

TABLE 5 Analysis of scanner models in survey sample

Manufacturer	Model	Slice class[a]	No. in survey	% Total
GE	HiSpeed Advantage	1	4	3.2
	HiSpeed CT/I (no SmartBeam)	1	3	2.4
	HiSpeed CT/I (with SmartBeam)	1	5	4.0
	Sytec Sri	1	1	0.8
	Prospeed SX, SX Power	1	3	2.4
	Prospeed SX Advantage	1	1	0.8
	HiSpeed LX/I	1	4	3.2
	LightSpeed QX/i, Advantage	4	1	0.8
	LightSpeed Plus, Plus Advantage	4	8	6.3
	LightSpeed Ultra, Ultra Advantage	8	6	4.8
	ALL	-	36	29
Philips	AV, AV-PS	1	10	7.9
	AV Performance, AV-P1	1	2	1.6
	Secura	1	4	3.2
	Aura	1	2	1.6
	CT Twin, Twin Flash, Twin RTS	2	3	2.4
	Mx8000	4	7	5.6
	MX8000 Infinite	16	1	0.8
	PQ S	1	1	0.8
	PQ 5000, PQ 5000V	1	2	1.6
	PQ 6000, PQ 6000V	1	1	0.8
	SR7000	1	1	0.8
	ALL	-	34	27
Siemens	AR Star	1	4	3.2
	AR.HP	1	1	0.8
	AR-T	1	1	0.8
	Plus 4, 4A, 4B, 4C	1	9	7.1
	Plus 4 Expert/ Xenon detectors)	1	2	1.6
	Plus 4 Expert/ Lightning detectors	1	2	1.6
	Plus 4 Power/ Lightning detectors	1	3	2.4
	Emotion	1	1	0.8
	Emotion Duo	2	2	1.6
	Volume Access	2	2	1.6
	Volume Zoom	4	6	4.8
	Sensation 4	4	1	0.8
	Sensation 16	16	1	0.8
	Hi Q S	1	1	0.8
	Plus-S	1	2	1.6
	ALL	-	38	30
Toshiba	Xvision, Xvision EX, Xvision GX	1	1	0.8
	Xpress GX (pre 1998)	1	2	1.6
	Asteion VF	1	2	1.6
	Asteion VI, Asteion VR	1	2	1.6
	Asteion VR Multi (older tube)	4	3	2.4
	Aquilion Multi/4	4	4	3.2
	Xpress HS	1	1	0.8
	Xspeed II	1	1	0.8
	Asteion VR Multi (C series tube)	4	2	1.6
	ALL	-	18	14
ALL	ALL	-	126	100

Note:

[a]Maximum number of tomographic sections acquired simultaneously.

TABLE 6 Analysis of single and multislice scanners in the survey sample and in the National Health Service (NHS)

Slice Class[a]	Survey (2003)		National Health Service[b]		
	No.	% Total	% England[c]	% Northern Ireland[c]	% Wales[d]
Single	79	63	43	47	26
Dual	7	5.6	3.3	-	-
Quad	32	25	36	-	-
Eight	6	4.8	2.4	-	-
Sixteen	2	1.6	13	-	-
ALL	126	100	100	100	100

Notes:

[a]Maximum number of tomographic sections acquired simultaneously.

[b]Data for the NHS from Stonell (2004).

[c]Data refer to 2004.

[d]Data refer to 2003.

Nevertheless, the survey does include a substantial sample (about 27%) of UK scanners, with a reasonable spread in terms of geography and technology. It provides a useful update on practice (from single through to 16-slice scanners) that is sufficiently representative for the purposes of setting national reference doses. Importantly, the survey also establishes the methodology for conducting further periodic reviews of CT practice.

3.1.2 Scan sequences

The survey has included detailed information for 4,753 separate scan sequences, relating to 832 standard protocols (Table 7) and 1,964 individual patients (Table 8). These tables show analyses by examination type for sample size, scan mode (axial or helical), type of sequence (*Routine* or *Ad-hoc*) and use of contrast media.

Head and high-resolution chest examinations were largely performed using axial scan sequences without the administration of contrast media, whereas helical scanning with contrast predominates for the other procedures on the trunk. The vast majority of sequences were described as being *Routine* and so performed as part of every standard protocol. Supplementary or alternative *Ad-hoc* sequences were relatively infrequent, even for the examinations on individual patients. Analyses of doses for standard protocols were therefore primarily conducted by including only the *Routine* sequences, although further analyses including all sequences (*Routine* and *Ad-hoc*) were also performed (Section 3.6).

Patterns for standard protocols (Table 7) and individual patients (Table 8) were broadly similar, with the apparent exception of contrast use for chest examinations on children; in this case, contrast use was indicated as being high for protocols and low for individual patients, although sample sizes here were rather small for reliable comparison (in particular, only 17 sequences from 4 centres in relation to the patient data).

TABLE 7 Sample size in relation to standard examination protocols

Examination: Indication	Age group	No. of protocols	No. of scan sequences (and % of total)							
			Total	Scan mode		Type of sequence		Use of contrast media		
				Axial	Helical	*Routine*	*Ad-hoc*	No	Yes	Unknown
Routine head: Acute stroke	Adult	118	281	263	18	238	43	198	48	35
			(100%)	(94%)	(6%)	(85%)	(15%)	(70%)	(17%)	(12%)
Abdomen: Liver metastases	Adult	81	124	1	123	117	7	18	106	0
			(100%)	(1%)	(99%)	(94%)	(6%)	(15%)	(85%)	-
Abdomen & pelvis: Abscess	Adult	97	125	16	109	115	10	24	99	2
			(100%)	(13%)	(87%)	(92%)	(8%)	(19%)	(79%)	(2%)
Chest, abdomen & pelvis: Lymphoma staging or follow up	Adult	98	180	3	177	179	1	26	125	29
			(100%)	(2%)	(98%)	(99%)	(1%)	(14%)	(69%)	(16%)
Chest: Lung cancer (known, suspected or metastases)	Adult	110	193	11	182	185	8	16	164	13
			(100%)	(6%)	(94%)	(96%)	(4%)	(8%)	(85%)	(7%)
Chest (Hi-resolution): Diffuse lung disease	Adult	108	139	133	6	127	12	118	0	21
			(100%)	(96%)	(4%)	(91%)	(9%)	(85%)	-	(15%)
Paediatric chest: Detection of malignancy	0-1y	20	23	0	23	21	2	5	17	1
			(100%)	-	(100%)	(91%)	(9%)	(22%)	(74%)	(4%)
Paediatric chest: Detection of malignancy	5y	19	21	0	21	19	2	5	15	1
			(100%)	-	(100%)	(90%)	(10%)	(24%)	(71%)	(5%)
Paediatric chest: Detection of malignancy	10y	21	24	0	24	21	3	5	18	1
			(100%)	-	(100%)	(88%)	(13%)	(21%)	(75%)	(4%)
Paediatric head: Trauma including non-accidental injury	0-1y	56	93	85	8	89	4	87	3	3
			(100%)	(91%)	(9%)	(96%)	(4%)	(94%)	(3%)	(3%)
Paediatric head: Trauma including non-accidental injury	5y	55	103	94	9	101	2	95	4	4
			(100%)	(91%)	(9%)	(98%)	(2%)	(92%)	(4%)	(4%)
Paediatric head: Trauma including non-accidental injury	10y	49	99	95	4	97	2	95	2	2
			(100%)	(96%)	(4%)	(98%)	(2%)	(96%)	(2%)	(2%)

TABLE 8 Sample size in relation to examinations on individual patients

Examination & indication	No. of patients (scanners)	No. of scan sequences (& % of total)								
		Total	Mode		Type of sequence			Use of contrast media		
			Axial	Helical	*Routine*	*Ad-hoc*	Unknown	No	Yes	Unknown
Adults										
Routine head: Acute stroke	476	988	909	79	892	15	81	682	28	278
	(57)	(100%)	(92%)	(8%)	(90%)	(2%)	(8%)	(69%)	(3%)	(28%)
Abdomen: Liver metastases	193	305	12	293	261	17	27	47	233	25
	(30)	(100%)	(4%)	(96%)	(86%)	(6%)	(9%)	(15%)	(76%)	(8%)
Abdomen & pelvis: Abscess	239	293	15	278	248	10	35	28	201	64
	(34)	(100%)	(5%)	(95%)	(85%)	(3%)	(12%)	(10%)	(69%)	(22%)
Chest, abdomen & pelvis: Lymphoma staging or follow up	256	480	0	480	475	5	0	88	304	88
	(40)	(100%)	-	(100%)	(99%)	(1%)	-	(18%)	(63%)	(18%)
Chest: Lung cancer (known, suspected or metastases)	407	695	10	685	656	6	33	21	545	129
	(53)	(100%)	(1%)	(99%)	(94%)	(1%)	(5%)	(3%)	(78%)	(19%)
Chest (Hi-resolution): Diffuse lung disease	321	414	412	2	366	32	16	271	2	141
	(45)	(100%)	(100%)	(0%)	(88%)	(8%)	(4%)	(65%)	(0%)	(34%)
Children										
Paediatric chest: Detection of malignancy	16	17	0	17	15	1	1	14	3	0
	(4)	(100%)	-	(100%)	(88%)	(6%)	(6%)	(82%)	(18%)	-
Paediatric head: Trauma including non-accidental injury	56	100	97	3	96	4	0	82	2	16
	(11)	(100%)	(97%)	(3%)	(96%)	(4%)	-	(82%)	(2%)	(16%)

Information was also recorded on the questionnaire concerning the use of automatic tube current modulation (Kalra et al, 2004b; Keat, 2005). Overall, 50% of the scanners in the survey included such dose-reduction technology, although this facility was employed in only 15% of all sequences.

3.2 Local $CTDI_w$ measurements

The collection of data on local CTDI measurements represented only a minor aspect of the survey and was included largely as a quality assurance measure to verify the reported scanner model. Submitted normalised values of CTDI (mGy per mAs) measured free-in-air ($CTDI_{air)}$ and/ or in the standard CT dosimetry phantoms ($CTDI_w$) were compared against the corresponding doses calculated under similar conditions following the methodology outlined in Section 2.2.2 and using scanner-specific representative coefficients published by ImPACT (2004). Table C1 (Appendix C) summarises the results of an analysis by scanner model of each ratio of local measurement to ImPACT dose in terms of the sample size, mean, coefficient of variation (%CV), minimum and maximum values. In general, agreement between the two sets of measurements is good, with the mean ratios for each manufacturer and for the whole survey being close to unity. However, wide differences are also apparent for a few particular pairs of data, with individual dose ratios ranging from 0.6 to 1.7, even after extensive review and often revision of outlying data. In some cases, this residual poor agreement could be due to subtle changes in design (such as filtration) between different examples of the same scanner model, leading to a mismatch when comparing exposure conditions. In other cases, the protocols used for local measurements might have differed from the standard methods systematically adopted by ImPACT in establishing typical CT dose data, in terms of the measurement equipment (including calibration) and technique employed. There will also be some differences owing to variations in x-ray tube output.

Measurements of CTDI should, of course, be carried out for each CT scanner as a routine part of acceptance and performance testing (IEC, 1994; ImPACT, 2001; IPEM 1997; IPEM 2003).

3.3 Examination technique and dose for standard protocols

An analysis over all scanners in the survey of applied potential setting by examination type is shown in Table C2 (Appendix C) in terms of the percentage distributions over the discrete settings available. Data are included both for standard protocols (on the basis of only the *Routine* sequences) and also individual patients, with separate analyses for common regions of scan, as well as all sequences together, for each type examination. Settings for examinations on adults range from 110 kV to 140 kV and for children from 80 kV to 140 kV, with a modal value of 120 kV for all scans except those through the posterior fossa region in the head, where a higher setting of 140 kV was most common.

Higher applied potentials were also often used for high-resolution scans of the chest.

Further information concerning general technique and dose for standard protocols (with the analysis based on *Routine* sequences only) is summarised for adult and paediatric patients over all scanners in Table C3 (Appendix C). Examination technique is characterised here by the number of sequences per protocol, the pitch and imaged slice thickness per sequence (analysed by particular scan region and all sequences together), and the scan length for both individual sequences and whole examinations; brief descriptions of these terms are given in the Survey Instructions in Appendix A. Dose information includes $CTDI_w$ and $CTDI_{vol}$ per sequence, and DLP and effective dose per whole examination. Distributions for each data set are summarised in terms of sample size and values of the mean, coefficient of variation (%CV) and quartiles (25^{th}, 50^{th} and 75^{th} percentiles).

Reasonable agreement was found between the standard scan lengths assumed for a given anatomical region (Section 2.2.3) and corresponding specific data reported for sequences when the latter were available, generally in the case of survey data for individual patients. The mean ratio of recorded length to standard length was 1.10 over all sequences.

The results demonstrate wide variations in practice between different CT centres for similar procedures. Distributions in dose ($CTDI_w$, $CTDI_{vol}$, DLP and effective dose) for standard protocols are shown in Appendix D: Figures D1 to D4 for adult patients and Figures D5 to D8 for paediatric patients.

3.4 Comparison between calculated and displayed doses

Values of $CTDI_{vol}$ and DLP calculated for each scanner following the methods in Section 2.2 were compared against any values reported from the scanner display. An analysis by examination type of each ratio of calculated to reported dose is summarised in Table C4 (Appendix C) in terms of the sample size, mean, coefficient of variation (%CV), minimum and maximum values. Results are shown separately for the quantities $CTDI_{vol}$ and DLP per sequence, and DLP per complete protocol, with analyses included for both standard examination protocols and individual patient data. In general, agreement between the two sets of data is reasonable, with the mean ratios for the whole survey being close to unity for each quantity: 0.98 for $CTDI_{vol}$; 0.90 for DLP per sequence and 0.95 for DLP per examination. However, wide differences are also apparent for a few particular pairs of data, with individual dose ratios ranging from 0.2 to 3.2, even after extensive review of outlying data.

The apparent disagreement for chest examinations on children is largely explained by differences in how values of $CTDI_w$ (and hence $CTDI_{vol}$ and DLP) are expressed for paediatric patients. Doses calculated for the survey have followed previous recommendations that, irrespective of patient age and scan location,

doses for all paediatric examinations should be expressed in terms of absorbed dose to the smaller (16 cm) standard CT dosimetry phantom (Shrimpton and Wall, 2000). However, manufacturers may not always have followed this convention in displaying dose values for scans on the paediatric trunk. Under similar conditions of exposure, $CTDI_w$ measured in the 16 cm diameter dosimetry phantom is about twice that for the 32 cm diameter phantom and so this would account for a factor of about 2 in the ratio of calculated to displayed dose (ImPACT, 2004; Siegel et al, 2004).

Notwithstanding this potential problem for paediatric examinations, poor agreement in other cases could be due to differences in the basis for deriving DLP, with values calculated for the survey sometimes assuming a standard scan length, whereas displayed values will utilise the scan length as set and also probably include any additional rotations in helical scanning (overscan). However, such differences in scan length are not in general large (Section 3.3). Other sources of uncertainty for the displayed doses include the use of generic and conservative data for each scanner model, inaccuracies in implementation for the selected scan conditions (particularly for older scanner models), simple mis-reporting of values in the questionnaire or mismatch of models in comparing doses (Section 3.2).

However, the analysis does suggest that dose displays are probably sufficiently accurate for direct use in dose audit, including future national surveys, provided some initial checks are carried out locally to validate the readings.

3.5 Comparison between single- and multislice scanners

In addition to overall results from the survey including all scanners together (Section 3.3 and Table C3, Appendix C), analyses have also been carried out to study potential differences in results between evolving CT technologies, as characterised by a slice class (1, 2, 4 or 8+) assigned to each scanner model; this refers to the maximum number of simultaneous tomographic sections acquired per rotation (i.e. the maximum number of detector channels available for simultaneous data acquisition).

Table C5 (Appendix C) shows a comparison by scanner slice class of techniques for standard examination protocols for adults and children (on the basis of only the *Routine* sequences). Results are included for number of sequences, pitch, imaged slice width and scan length, with analyses by particular scan region and whole examination. Distributions for each data set are summarised in terms of sample size and values of the mean, coefficient of variation (%CV) and quartiles (25^{th}, 50^{th} and 75^{th} percentiles). Table C6 (Appendix C) shows similar analyses for the dose quantities $CTDI_w$, $CTDI_{vol}$, DLP and effective dose.

Notwithstanding rather small sample sizes in some cases, particularly for the 2 and 8+ slice classes, number of sequences, pitch and scan length appear broadly similar between the classes for most examinations. There are, however, some

consistent differences in imaged slice width, which is largest for single slice scanners (Table C5). Doses appear lowest for the dual scanners and highest for the quad scanners and, although these particular trends are probably not statistically significant (Table C6), they are similar to those reported for surveys of CT in East Anglia (Yates, Pike and Goldstone, 2004) and Germany (Brix et al, 2003). The increased doses observed for quad scanners is consistent with x-ray beam penumbral effects, which lead to reduced z-axis geometric efficiency, being most pronounced for such scanners (Lewis, 2005; Nagel 2002).

A further comparison between single and multislice CT scanners is shown in Table C7 (Appendix C), which includes summaries (sample size, mean and %CV) by slice group for $CTDI_{vol}$ per sequence, and scan length, DLP and effective dose per standard examination protocol. For this analysis, scanners have been grouped into three categories: single slice (S), dual slice (D) and multislice (4+) (M) as representing quite distinct technologies in terms of likely dosimetric performance (Lewis, 2005). These tabulated data are also summarised for adult protocols in Figure 2 and for paediatric protocols in Figure 3, in terms of mean values of $CTDI_{vol}$ per sequence (averaged over all sequences) and DLP per protocol (based on only the *Routine* sequences).

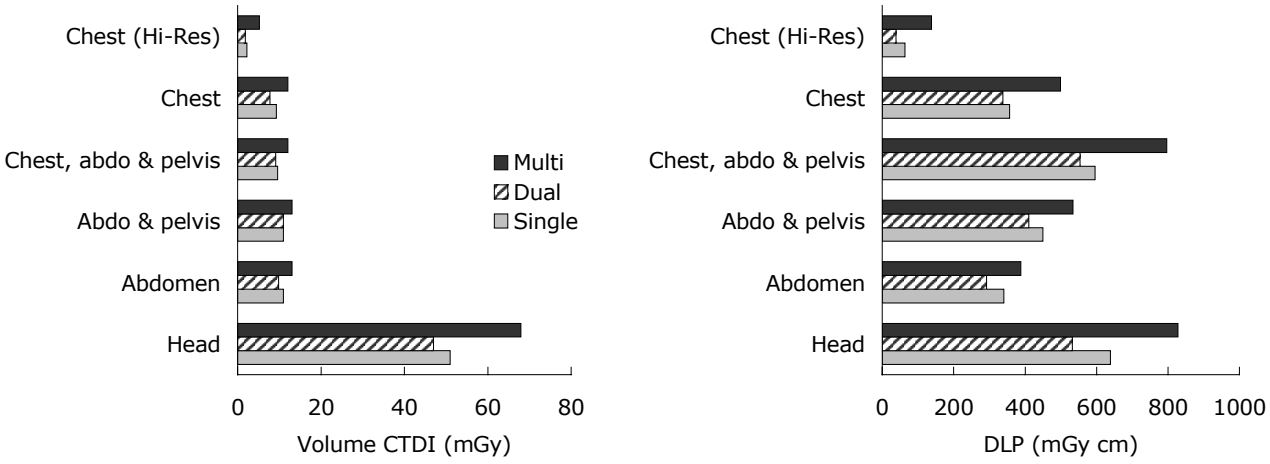

FIGURE 2 Mean doses by scanner group for standard examinations (*Routine* sequences only) on adult patients; *multi* refers to systems capable of acquiring 4 or more simultaneous slices.

As a broad trend, values of $CTDI_{vol}$ and DLP for adults appear on average to be lower from single and dual slice scanners than from multislice (4+) scanners, although these trends are probably not statistically significant. In particular, the distinction in dose between single and multislice scanners appears greatest for examinations using axial scanning mode and narrow beam collimations, such as

head and chest (high-resolution), owing to beam collimation effects and differences in z-axis geometric efficiency (Yates, Pike and Goldstone, 2004).

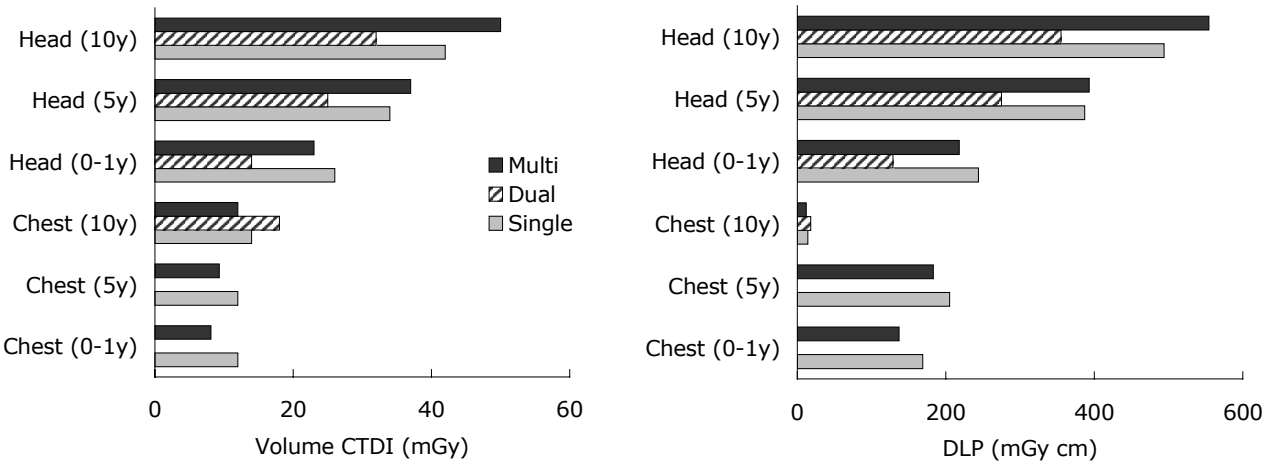

FIGURE 3 Mean doses by scanner group for standard examinations (*Routine* sequences only) on children; *multi* refers to systems capable of acquiring 4 or more simultaneous slices.

Similar trends for increased doses from multislice CT are apparent for head examinations on children aged 5 years and 10 years, although this trend is reversed for chest examinations and head examinations on children aged 0-1 years, where values of $CTDI_{vol}$ and DLP are lower for multislice than single slice scanners. One should be careful not to overinterpret such limited data, but reasons for this interesting observation could include the increased operational flexibility for newer (and often multislice) scanners and also the increasing awareness of the need for particular care when conducting CT examinations on young children. For both adults and children, the doses from dual scanners are generally less than those from single or multislice systems (Brix et al, 2003).

Further survey data are required in order to clarify trends in dose due to changing technology.

3.6 Comparison between corresponding dose data for standard protocols and individual patients

Every CT procedure should, of course, be tailored to meet the needs of the individual patient, with standard protocols providing the basic framework for examination selection. It is important, therefore, to compare whether the doses to individual patients differ significantly from those for each standard protocol. Table C8 (Appendix C) shows an analysis, by examination type, of the ratio of the mean dose for a group of adult patients relative to the dose for the

corresponding standard protocol at each individual CT scanner. Data are included in relation to DLP per examination, considering separately doses for only *Routine* sequences and for all potential sequences (*Routine* and *Ad-hoc*), and $CTDI_w$ and $CTDI_{vol}$ per sequence (over all sequences). The distributions for each ratio are summarised in terms of sample size and values of the mean, coefficient of variation (%CV), minimum, maximum and quartiles (25^{th}, 50^{th} and 75^{th} percentiles).

In general, agreement between sets of data is good, with mean ratios and quartile values being close to unity (and mostly within 10%), particularly for $CTDI_w$ and $CTDI_{vol}$. As an exception, the DLPs to patient groups undergoing scans of the abdomen in relation to liver metastases appear consistently larger than corresponding standard protocols, with a mean ratio of 1.48 when considering only *Routine* sequences for the latter. As might be expected, the mean ratios for DLP are reduced for all examinations when the analysis is extended to include all possible sequences for the standard protocols, although the ratio for abdomen scans remains significantly high at 1.45 and suggests the use of additional sequences for patients, as discussed further below.

Notwithstanding this pattern of general agreement, wide differences are also apparent for particular pairs of data, with individual dose ratios ranging from 0.50 to 1.7 for $CTDI_w$, 0.10 to 1.6 for $CTDI_{vol}$ and 0.15 to 5.3 for DLP, even after extensive review to identify misreported data. Any differences in DLP due to the assumption of standard scan lengths for protocols and reported lengths for patients will in general be small for similar sequences (Section 3.3). On the basis of the extreme dose ratios observed, standard protocols at some centres (as presented on the survey questionnaires) do not appear to reflect their general practice.

Absolute values of DLP for standard protocols and patients are summarised by examination type in Table C9 (Appendix C). Data are included in relation to standard protocols (with separate analyses for *Routine* sequences and all potential sequences), mean values for the patient groups at each scanner and all patients together. These DLP distributions are summarised in terms of sample size and values of the mean, coefficient of variation (%CV) and quartiles (25^{th}, 50^{th} and 75^{th} percentiles). In general for examinations on adults, mean DLPs for patient groups are larger than those for most standard protocols based on *Routine* sequences, although the significance of this observation is limited by the wide coefficients of variation for the data sets. Mean DLPs for all standard protocols are increased when all sequences (*Routine* and *Ad-hoc*) are included in the analysis, although these doses remain less than mean DLPs for patient groups undergoing examinations of the ‘abdomen’ (for liver metastases), ‘chest, abdomen and pelvis’ (lymphoma), and ‘chest’ (lung cancer). In the case of the first two of these examinations, mean numbers of sequences appear larger for patients than for the standard protocols (Table C10, Appendix C) and this suggests, perhaps, the use in practice of additional sequences for further phases of contrast. Unfortunately, similar analyses for examinations on children were not possible owing to the limited sample sizes.

3.7 NRPB national reference doses

3.7.1 Adult CT

A key aim of the survey is to provide updated national reference doses for CT for the purposes of promoting continuing review and improvement in local practice in the pursuit of optimisation of patient protection (Wall, 2004a). Historically, such guidance levels have been set pragmatically on the basis of third quartile values of the dose distributions from wide-scale surveys. Data from an earlier UK CT survey (Shrimpton et al, 1991) were subsequently used when establishing reference doses as part of European guidelines on quality criteria for CT (European Commission, 1999). Third quartile doses for examinations on adult patients from the present survey are summarised in Table 9 separately for single slice (SSCT) and multislice CT (MSCT) scanners, together with similar data for SSCT from the 1991 UK survey and a more recent survey of multislice CT in Europe conducted in 2001 (MSCT, 2004). Values are shown in relation to DLP per whole examination (on the basis of *Routine* sequences only) and $CTDI_w$ and $CTDI_{vol}$ per sequence, with separate values for common regions of scan, as well as all sequences together, for each type of examination. With due rounding, these data provide the foundation for the updated national reference doses for CT on adult patients in the UK shown in Table 10. In view of the differences in dose presently observed between SSCT and MSCT scanners, separate values are presented for these technologies. Although dual slice scanners were excluded from this analysis, the national reference doses shown for SSCT can in practice also be applied to these scanners. For comparison, corresponding recommendations on dose from the European CT Quality Criteria are also included for $CTDI_{vol}$ per sequence (MSCT, 2004) and for DLP per examination (European Commission, 1999).

3.7.2 Paediatric CT

Third quartile doses for examinations on paediatric patients from the present survey are summarised in Table 11, together with similar data from European surveys conducted in 1998 (Shrimpton and Wall, 2000) and 2001 (MSCT, 2004). Notwithstanding the apparent differences between doses to children from SSCT and MSCT scanners discussed previously in Section 3.5 (Tables C6 and C7, Appendix C), which were based on limited data analyses involving quite small numbers of scanners, results are presented here as single values covering all scanners in the survey. Values are shown in relation to DLP per whole examination (on the basis of *Routine* sequences only) and $CTDI_w$ and $CTDI_{vol}$ per sequence, with separate values for common regions of scan, as well as all sequences together, for each type of examination and standard patient age. With due rounding, these data provide the foundation for the general national reference doses for CT on paediatric patients in the UK that are shown in Table 12, together with comparative data from Europe (Shrimpton and Wall, 2000).

TABLE 9 Comparison of doses to adults from 2003 review of CT with results from previous surveys

Examination (clinical indication)	Scan region	Third quartile values for dose distributions observed in survey												
		$CTDI_w$ (mGy)[a]				$CTDI_{vol}$ (mGy)[a]				DLP (mGy cm)[a]				
		UK 2003[b]			Europe 1999[c]	UK 2003[b]			Europe 2004[d]	UK 2003[b]			Europe 1999[c]	Europe 2004[d]
		SSCT	MSCT	All CT	SSCT	SSCT	MSCT	All CT	MSCT	SSCT	MSCT	All CT	SSCT	MSCT
Routine head (acute stroke)	Post Fossa	71	107	82	-	64	103	80	-	-	-	-	-	-
	Cerebrum	56	63	57	-	56	63	57	-	-	-	-	-	-
	All sequences	63	79	66	58	59	80	64	77	-	-	-	-	-
	Whole exam	-	-	-	-	-	-	-	-	760	931	787	1045	989
Abdomen (liver metastases)	All sequences	20	20	20	34	13	14	14	15	-	-	-	-	-
	Whole exam	-		-	-	-	-	-	-	455	472	472	894	989
Abdomen & pelvis (abscess)	All sequences	18	20	19	33	13	14	13	16	-	-	-	-	-
	Whole exam	-	-	-	-	-	-	-	-	508	559	534	774	726
Chest, abdomen & pelvis (lymphoma staging or follow up)	Lung	12	16	15	27	10	12	11	-	-	-	-	-	-
	Abdo/ Pelvis	17	20	18	33	12	14	13	-	-	-	-	-	-
	All sequences	17	18	17	-	12	13	12	-	-	-	-	-	-
	Whole exam	-	-	-	-	-	-	-	-	762	937	786	-	-
Chest (lung cancer: known, suspected or metastases)	Lung	13	18	15	27	10	13	11	-	-	-	-	-	-
	Liver	17	19	18	34	11	14	13	-	-	-	-	-	-
	All sequences	16	18	17	-	11	13	12	12	-	-	-	-	-
	Whole exam	-	-	-	-	-	-	-	-	427	575	488	649	430
Chest: Hi-resolution (diffuse lung disease)	All sequences	22	48	33	35	3	7	4	9	-	-	-	-	-
	Whole exam	-	-	-	-	-	-	-	-	77	174	104	278[e]	334

Notes:

[a]For examinations of the adult head, calculated values of $CTDI_w$, $CTDI_{vol}$ and DLP relate to the 16 cm diameter CT dosimetry phantom; for examinations of the adult trunk, calculated values of $CTDI_w$, $CTDI_{vol}$ and DLP relate to the 32 cm diameter CT dosimetry phantom.

[b]Results for standard examination protocols, including only *Routine* sequences, for single slice (SSCT), multislice (MSCT) (4+) and all scanners.

[c]European Commission (1999); all values based on UK survey data (Shrimpton et al, 1991) for SSCT, with the exception of those for Abdomen (liver metastases) and Chest (Hi-Resolution), which relate to a European survey for 1998.

[d]MSCT (2004); data for multislice CT from a European survey for 2001.

TABLE 10 National reference doses for CT on adult patients (2003 review) and comparison with previous recommendations

Examination (clinical indication)	Region	National reference doses for single slice (SSCT) and multislice (MSCT) scanners								
		$CTDI_w$ (mGy)[a,b]			$CTDI_{vol}$ (mGy)[a]			DLP (mGy cm)[a]		
		UK 2003[c]		Europe 1999[d]	**UK 2003**[c]		Europe 2004[e]	**UK 2003**[c]		Europe 1999[d]
		SSCT	*MSCT*	SSCT	**SSCT**	**MSCT**	MSCT	**SSCT**	**MSCT**	SSCT
Routine head (acute stroke)	Post Fossa	*70*	*110*	-	**65**	**100**	-	**-**	**-**	-
	Cerebrum	*55*	*65*	-	**55**	**65**	-	**-**	**-**	-
	Whole exam	-	-	60	**-**	**-**	60	**760**	**930**	1050
Abdomen (liver metastases)	Whole exam	*20*	*20*	35	**13**	**14**	25	**460**	**470**	900
Abdomen & pelvis (abscess)	Whole exam	*18*	*20*	35	**13**	**14**	15	**510**	**560**	780
Chest, abdomen & pelvis (lymphoma staging or follow up)	Lung	*12*	*16*	30	**10**	**12**	-	**-**	**-**	-
	Abdo/ Pelvis	*17*	*20*	35	**12**	**14**	-	**-**	**-**	-
	Whole exam	-	-	-	**-**	**-**	-	**760**	**940**	-
Chest (lung cancer: known, suspected or metastases)	Lung	*13*	*18*	30	**10**	**13**	-	**-**	**-**	-
	Liver	*17*	*19*	35	**11**	**14**	-	**-**	**-**	-
	Whole exam	-	-	-	**-**	**-**	10	**430**	**580**	650
Chest: Hi-resolution (diffuse lung disease)	Whole exam	*22*	*50*	35	**3**	**7**	10	**80**	**170**	280

Notes:

[a]For examinations of the adult head, calculated values of $CTDI_w$, $CTDI_{vol}$ and DLP relate to the 16 cm diameter CT dosimetry phantom; for examinations of the adult trunk, calculated values of $CTDI_w$, $CTDI_{vol}$ and DLP relate to the 32 cm diameter CT dosimetry phantom.

[b]Values of $CTDI_w$ are included here primarily for comparison with historical data, since this dose descriptor has in practice been superseded as a (primary) reference dose quantity by $CTDI_{vol}$.

[c]Based on rounded third quartile values observed in the present survey for standard examination protocols, including only *Routine* sequences, for single slice (SSCT) and multislice (MSCT) (4+) scanners. Dual slice scanners should utilise the national reference dose values shown for SSCT.

[d]Comparable data for SSCT published by the European Commission (1999).

[e]Guideline values for MSCT from the 2004 CT Quality Criteria (MSCT, 2004), based on dose data from a European survey for 2001.

TABLE 11 Comparison of doses to paediatric patients from 2003 review of CT with results from previous surveys

Examination (clinical indication)	Region	Third quartile values for dose distributions observed in survey						
		$CTDI_w$ (mGy)[a]		$CTDI_{vol}$ (mGy)[a]		DLP (mGy cm)[a]		
		UK 2003[b]	Europe 2000[c]	UK 2003[b]	Europe 2004[d]	UK 2003[b]	Europe 2000[c]	Europe 2004[d]
Chest (detection of malignancy): 0-1 y old	All sequences	23	16	12	12[e]	-	-	-
	Whole exam	-	-	-	-	204	221	156[e]
Chest (detection of malignancy): 5 y old	All sequences	20	27	13	12[e]	-	-	-
	Whole exam	-	-	-	-	228	394	152[e]
Chest (detection of malignancy): 10 y old	All sequences	26	28	17	-	-	-	-
	Whole exam	-	-	-	-	368	613	-
Head (trauma including non-accidental injury): 0–1 y old	Post Fossa	34	-	34	-	-	-	-
	Cerebrum	28	-	28	-	-	-	-
	All sequences	28	42	28	31	-	-	-
	Whole exam	-	-	-	-	270	299[f]	333
Head (trauma including non-accidental injury): 5 y old	Post Fossa	50	-	49	-	-	-	-
	Cerebrum	42	-	42	-	-	-	-
	All sequences	43	58	43	47	-	-	-
	Whole exam	-	-	-	-	465	610[f]	374
Head (trauma including non-accidental injury): 10 y old	Post Fossa	68	-	65	-	-	-	-
	Cerebrum	46	-	46	-	-	-	-
	All sequences	52	69	51	-	-	-	-
	Whole exam	-	-	-	-	619	737[f]	-

Notes:

[a]Calculated values of $CTDI_w$, $CTDI_{vol}$ and DLP for CT on children relate to the 16 cm diameter CT dosimetry phantom.

[b]Results for standard examination protocols, including only *Routine* sequences.

[c]Unpublished data from a European survey described in Shrimpton and Wall (2000).

[d]MSCT (2004); data from a European survey for 2001.

[e]Dose data from *Europe 2004* for chest examinations originally referred to the 32 cm diameter CT dosimetry phantom (and have presently been corrected by multiplication by a factor of about two in order to allow comparison with corresponding data referring to the 16 cm diameter CT dosimetry phantom).

[f]DLP values from *Europe 2000* for head examinations refer to single phase procedures (with or without contrast).

TABLE 12 National reference doses for CT on paediatric patients (2003 review) and comparison with previous recommendations

Examination (clinical indication)	Region	National reference doses				
		$CTDI_w$ (mGy)[a, b]		$CTDI_{vol}$ (mGy)[a]	DLP (mGy cm)[a]	
		UK 2003[c]	Europe 2000[d]	**UK 2003**[c]	**UK 2003**[c]	Europe 2000[d]
Chest (detection of malignancy): 0-1 y old	Whole exam	*23*	20	**12**	**200**	200
Chest (detection of malignancy): 5 y old	Whole exam	*20*	30	**13**	**230**	400
Chest (detection of malignancy): 10 y old	Whole exam	*26*	30	**20**	**370**	600
Head (trauma including non-accidental injury): 0–1 y old	Post Fossa	*35*	-	**35**	**-**	-
	Cerebrum	*30*	-	**30**	**-**	-
	Whole exam	-	40	**-**	**270**	300[e]
Head (trauma including non-accidental injury): 5y old	Post Fossa	*50*	-	**50**	**-**	-
	Cerebrum	*45*	-	**45**	**-**	-
	Whole exam	-	60	**-**	**470**	600[e]
Head (trauma including non-accidental injury): 10 y old	Post Fossa	*65*	-	**65**	**-**	-
	Cerebrum	*50*	-	**50**	**-**	-
	Whole exam	-	70	**-**	**620**	750[e]

Notes:

[a]Calculated values of $CTDI_w$, $CTDI_{vol}$ and DLP for CT on children relate to the 16 cm diameter CT dosimetry phantom.

[b]Values of $CTDI_w$ are included here primarily for comparison with historical data, since this dose descriptor has in practice been superseded as a (primary) reference dose quantity by $CTDI_{vol}$.

[c]Based on rounded third quartile values observed in the present survey for standard examination protocols, including only *Routine* sequences, for all scanners.

[d]Shrimpton and Wall (2000).

[e]DLP values from *Europe 2000* for head examinations refer to single phase procedures (with or without contrast).

4 DISCUSSION

The present survey provides a snapshot of national CT practice that continues to evolve owing to further developments in the technology and clinical application of multislice CT scanners. The study has sought to provide more specific data in order to increase their utility, by including particular clinical indications for the common examinations studied and information for common scan sequences covering specific regions of anatomy. Results from the 2003 review confirm that there are still wide variations in technique and dose between CT centres for similar examinations, although the overall levels of exposure (based on all types of scanner) are in general lower by 10-40% than those for the UK in 1991 (European Commission, 1999).

It is useful to compare results in terms of third quartile values of the observed dose distributions, as a simple way of characterising survey data that is also of relevance to national reference doses. For adult patients, third quartile values of $CTDI_w$ over all types of CT scanner are similar to those relating to the 1991 UK survey (SSCT) (European Commission, 1999) for (axial) examinations of the 'head' and 'chest (high-resolution)', although specific values for SSCT and MSCT are relatively lower and higher, respectively (Table 9). Present values for other (helical) examinations on the trunk are about 40% lower than the previous UK survey. Doses are higher for scans through the 'posterior fossa' relative to the 'cerebrum', and for the 'abdomen/ pelvis' relative to the 'lungs'.

Corresponding values of $CTDI_{vol}$ reflect a typical pitch of about 1.4 for helical scans on the trunk, and about 1 and 10 for axial scans of the 'head' and 'chest (high-resolution)', respectively (Table 9). Third quartile values of $CTDI_{vol}$ for all scanners are broadly similar to corresponding survey data for MSCT from Europe for 2001 (MSCT, 2004), with the exception of axial scanning of the 'head' and 'chest (high-resolution)', where present data are over 15% and 55% lower, respectively (although the specific values for MSCT are more similar to the 2001 European levels (MSCT, 2004)).

Third quartile values of DLP for SSCT are lower than those for MSCT, particularly in the case of examinations of the 'chest (high-resolution)' (Table 9). The present values for SSCT are 30-70% lower than levels for the UK in 1991 (European Commission, 1999), whereas values for MSCT are only 10-50% lower. These latter values are similarly lower than those for MSCT in Europe in 2001 (MSCT, 2004), with the exception of chest scans in relation to lung cancer, for which the present survey value is 30% higher.

Fewer data were available for paediatric CT (Table 11), although the third quartile values of $CTDI_w$ and DLP are in general 10-40% lower than those from a survey in Europe published in 2000 (Shrimpton and Wall, 2000); the third quartile values of $CTDI_{vol}$, however, are similar to more recent European data for 2001 (MSCT, 2004).

Updated national reference doses for CT (2003 review) have been derived with due rounding (generally to two significant figures) from the third quartile values for the dose distributions observed for standard examination protocols (but including only *Routine* sequences). Separate values are presented for SSCT and MSCT examinations on adult patients, as representing an equitable approach in view of the differences in dose presently observed between these technologies. In contrast, single (general) values are presented as the best practical option for examinations on children on the basis of the limited survey data available. Accordingly, national reference values for $CTDI_{vol}$ and DLP are shown in Table 10 for examinations on adults and Table 12 for children; similar data have also been included for $CTDI_w$, largely for comparison with historical data, since this dose descriptor has in practice been superseded as a (primary) reference dose quantity by $CTDI_{vol}$. For adults, reference doses for SSCT are less than those for MSCT, particularly in relation to examinations of the 'chest (high-resolution)' and $CTDI_{vol}$ for examinations of the 'head'. Reference doses for children increase with increasing patient age (size). Direct comparisons between corresponding values of $CTDI_{vol}$ and DLP for adults and children need to take into account the fact that doses for examinations of the paediatric trunk are expressed in terms of measurements in the 16 cm diameter standard CT dosimetry phantom, whereas those for adults relate to the 32 cm diameter phantom; however, doses for examinations of the 'head' universally relate to the 16 cm diameter phantom.

European reference doses have already been published as part of the development of quality criteria for CT. These originally included reference values for $CTDI_w$ and DLP for adult patients (European Commission, 1999), although the revised criteria for multislice CT have included only levels of $CTDI_{vol}$ for quite general regions of scan (MSCT, 2004). Comparisons of the UK reference doses for adults against these European data (Table 10) lead to broadly similar patterns to those described above in relation to the third quartile doses. In terms of $CTDI_{vol}$ and recommendations for MSCT, there is agreement for scans of the 'cerebrum', and the 'abdomen and pelvis (abscess)', although UK reference doses are higher for scans of the 'posterior fossa' (by 70%) and the 'chest (lung cancer)' by 30-40%; conversely, UK figures are lower for scans of the 'abdomen (liver metastases)' by 40% and the 'chest (high-resolution)' by 30%. UK reference values of $CTDI_{vol}$ for SSCT are similar to those for *Europe 2004* (MSCT, 2004) in the case of scans of the 'posterior fossa' and 'chest (lung cancer)', although lower by 70% for 'chest (high-resolution)'. In terms of DLP, UK national reference dose values for adults are lower than the 1999 European guidelines (European Commission, 1999) by 30-70% for SSCT and by 10-50% for MSCT. Notwithstanding the more limited survey data available for children, UK national reference doses for DLP (Table 12) are up to 40% less than previous European recommendations for paediatric CT (Shrimpton and Wall, 2000).

The national reference doses from this review refer to the mix in practice pertaining in 2003 and, notwithstanding continuing evolution in CT, are suitable for general application in patient protection over the next few years (during which SSCT scanners will decline in number). CT centres should, as a routine part of clinical audit, compare the levels of dose for their locally established

standard protocols for common examinations against the relevant national reference dose (IPEM 2004; Wall, 2004b). These national reference doses are likely to underpin any national DRLs subsequently set by the Department of Health (IRMER, 2000). Doses consistently in excess of these latter guidelines should be investigated and either justified as being necessary to fulfil the clinical purpose of the examination or reduced accordingly. It is also important to audit examinations carried out on groups of patients in order to ensure that doses do not deviate significantly from the local norms. There is a clear need for further monitoring of practice through the continuing collation of routine survey data into the PREDICT database for periodic review to provide updated national reference doses. All CT centres are strongly encouraged to participate actively in this important process by the regular submission of new data.

Typical doses from CT in the UK are summarised in Table 13, as mean values over the whole survey (and all scanner models) for $CTDI_w$, $CTDI_{vol}$, DLP and effective dose for standard examination protocols (on the basis of *Routine* sequences only). Typical effective doses for adult patients are less than those previously assumed for the UK in the 1990s (i.e. 2 mSv, 8 mSv and 10 mSv for examinations of the 'head', 'chest' and 'abdomen', respectively (Wall and Hart, 1997; Hart and Wall, 2002)), although there are still wide variations in practice. In particular, doses to adults from SSCT scanners are slightly lower than these general values, whereas those from MSCT scanners are slightly higher (Table C7, Appendix, C).

For examinations on children, typical values of the dose descriptors $CTDI_w$, $CTDI_{vol}$ and DLP decrease with decreasing age (and size), whereas the corresponding effective dose increases. Indeed, effective doses to children aged 0-1 years from examinations of the 'head' and the 'chest' were typically higher than those for adults. Since children are potentially more susceptible to radiation effects, special efforts should be made in clinical practice to reduce their doses by the use of size-specific scan protocols for optimised CT imaging (Khursheed et al, 2002).

TABLE 13 Typical doses[a] from CT in the UK (2003 review)

Examination (indication)	$CTDI_w$ (mGy)[b, c]	$CTDI_{vol}$ (mGy)[b, c]	DLP (mGy cm)[b]	E (mSv)
Adults				
Routine head (acute stroke)	57	56	690	1.5
Abdomen (liver metastases)	16	12	350	5.3
Abdomen & pelvis (abscess)	16	11	470	7.1
Chest, abdomen & pelvis (lymphoma staging or follow up)	14	10	670	9.9
Chest (lung cancer: known, suspected or metastases)	14	10	400	5.8
Chest: Hi-resolution (diffuse lung disease)	25	3.2	88	1.2
Children				
Chest (detection of malignancy): 0-1 y old	15	11	160	6.3
Chest (detection of malignancy): 5 y old	16	11	200	3.6
Chest (detection of malignancy): 10 y old	19	14	300	3.9
Head (trauma including non-accidental injury): 0–1 y old	24	25	230	2.5
Head (trauma including non-accidental injury): 5 y old	35	34	380	1.5
Head (trauma including non-accidental injury): 10 y old	44	44	510	1.6

Notes:

[a]Doses represent overall mean values observed in the present survey for standard examination protocols, including only *Routine* sequences, for all scanners.

[b]For examinations of the adult head and children, calculated values of $CTDI_w$, $CTDI_{vol}$ and DLP relate to the 16 cm diameter CT dosimetry phantom; for examinations of the adult trunk, calculated values of $CTDI_w$, $CTDI_{vol}$ and DLP relate to the 32 cm diameter CT dosimetry phantom.

[c]Data for $CTDI_w$ and $CTDI_{vol}$ per rotation represent mean values over all sequences included in each examination.

5 CONCLUSIONS

The present review includes data from over a quarter of all CT scanners in the UK and provides a substantial snapshot of CT practice for 2003 relating to 12 common types of examination on adults and children. Robust methods have been used systematically to calculate established dose indicators ($CTDI_w$, $CTDI_{vol}$, DLP and effective dose) for nearly 850 standard protocols and 2,000 individual patients. There are still wide variations in practice between CT centres for similar procedures, although levels of exposure are in general lower by a few tens of percent than corresponding data for adults in the UK from 1991 (European Commission, 1999). However, doses to adults from multislice (4+) (MSCT) scanners tend consistently to be slightly higher than from single slice (SSCT) scanners; in particular, doses appear lowest for dual scanners and highest for quad scanners. Values of $CTDI_{vol}$ are broadly similar to recent survey data for multislice CT from Europe for 2001 (MSCT, 2004). Effective doses to very young patients (aged 0-1 years) were typically higher than corresponding values for adults. Doses to individual patients were on average similar to those for the standard protocols established for each scanner, although significant variations were also apparent, particularly in relation to increased doses from examinations of the abdomen for liver metastases.

The review provides essential data to facilitate further initiatives in the optimisation of patient protection in CT. In particular, the report includes national reference dose values (derived as rounded third quartiles for $CTDI_{vol}$ per sequence and DLP per examination) as simple yardsticks to help identify centres where levels of dose are unusually high. Separate values are presented for SSCT and MSCT examinations on adult patients, owing to observed differences in dose, although general values are presented for examinations on children. Results from the survey will also inform the subsequent setting of national diagnostic reference levels (DRLs) by the Department of Health in accordance with IRMER (2000). The PREDICT database established by the study represents a useful and sustainable national resource for monitoring continuing developments in CT practice through the ongoing collation of further survey data. Periodic review of these data will allow timely analyses of trends and the updating of national reference doses for CT.

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APPENDIX A

EXTRACTS FROM QUESTIONNAIRE USED FOR DATA COLLECTION

The questionnaire for the present survey was published in October 2002 on the CT Users Group website (http://www.ctug.org.uk/) for downloading and manual completion. Extracts are included here to illustrate its scope.

FIGURE A1 Cover page of questionnaire used for data collection.

FIGURE A2 Contents page of survey questionnaire.

FIGURE A3 Introduction page of survey questionnaire.

FIGURE A4 Instructions for completing survey questionnaire.

FIGURE A5 Instructions for completing survey questionnaire (continued).

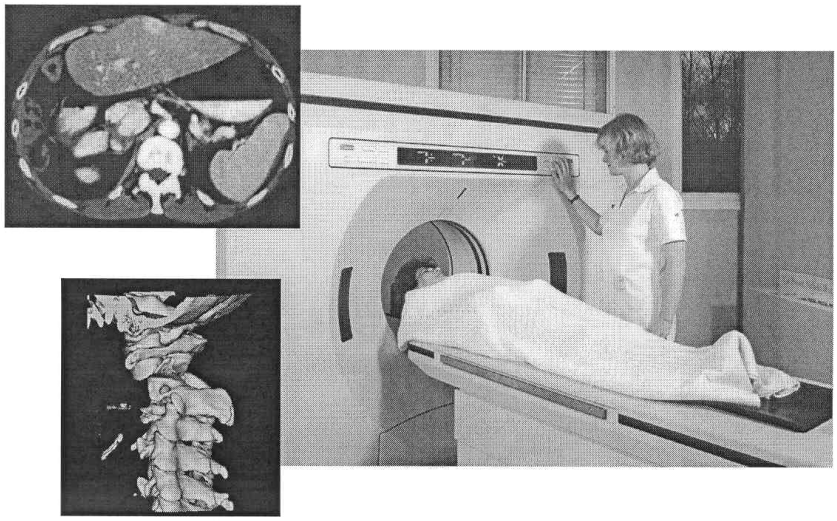
FIGURE A6 Instructions for completing survey questionnaire (continued).

FIGURE A7 Instructions for completing survey questionnaire (continued).

FIGURE A8 Example of form for collecting standard protocol data.

FIGURE A9 Example of form for collecting individual patient data.

UK CT DOSE SURVEY
2002



Instructions and Questionnaire

nrpb

CT Users Group

ImPACT

FIGURE A1 Cover page of questionnaire used for data collection.

UK CT DOSE SURVEY

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FIGURE A2 Contents page of survey questionnaire.

UK CT Dose Survey

Introduction

Computed tomography examinations already account for about 40% of the population dose resulting from medical x-ray examinations in the UK, and it is likely that this contribution is increasing. There are presently no UK-wide data on current CT patient doses and examination protocols. This lack of information makes it difficult to assess trends in the application of CT and, importantly in the context of IR(ME)R 2000, impossible to set reliable national Diagnostic Reference Levels (DRLs). The present survey will establish at NRPB initial data for a long-term national patient dose database on CT, which will be reviewed periodically in order to provide both the basis for national DRLs and also data relevant to the optimisation of CT exposures.

The survey aims to cover the whole of the UK, all scanner models including single and multi-slice systems, all healthcare sectors and both adult and paediatric CT. Data are requested for standard protocols and also individual patient studies using the attached forms. Please complete these following the instructions below for each of those examinations listed which are undertaken using your particular CT scanner. If you have several standard protocols for an examination/ indication, please provide details for the one most commonly use.

Please return all completed form **AS SOON AS POSSIBLE** to:

Dr Paul C Shrimpton
Medical Dosimetry Group
National Radiological Protection Board
Chilton
Didcot
Oxon
OX11 0RQ.

Data forms should be returned by the end of November 2002 please; if data for individual patients are less readily available, these forms can be returned separately, when sufficient studies have been completed. Please enclose a data return form with **each** submission as provided in section 4

Your help in kindly participating in this national survey is very much appreciated, as contributing highly valuable data to an important national resource on patient doses from CT. All information will be treated in confidence and data from the survey will be published only in anonymous form, although participants will be gratefully acknowledged.

We are grateful to the EU CT Working Group for permission to base this questionnaire on that developed for the 2001 European Survey on CT.

FIGURE A3 Introduction page of survey questionnaire.

Survey Instructions

Overview

There are three aspects to data collection for the UK CT dose survey, with specific forms in separate sections of this questionnaire:

Section One – Survey of routine protocols

The protocol survey is being conducted to obtain information on the routine protocols used on each scanner for some common indications and a standard patient. You need only provide data for those examination/ indication categories shown on the forms.

Section Two – Survey of individual patients

The patient survey aims to gather information on the actual scan sequences used for an individual patient, since these may differ from the standard protocol according to particular clinical needs. For **each** of the particular combinations of examination and clinical indication shown, forms should be completed for ideally at least 10 patients. We require recent data from your archive for adult patients who are close to average size (excluding those who are excessively small or large) and for children (please indicate age in years). Please use the 'Form No.' field, if you wish, to help when collecting your data for 10 patients. We appreciate that collation and submission of these data might necessarily follow on behind sending us your information on standard protocols. It is hoped that such data collection for individual patients will become an ongoing exercise.

Section Three – CTDI measurements for your particular scanner

Any local measurements that you can provide for your scanner will be useful as a check when assessing your doses. However, submission of CTDI data is optional and may be done separately from your protocol and individual patient questionnaires.

Explanation of fields on forms

The following paragraphs are provided as a guide to completion of the forms.

1. Examination/ indication

There are separate forms for each of 12 scanning procedures on different anatomical regions and patient groups. It is important that you only provide information on each form in relation to the specific examination and indication shown, in order to allow subsequent comparison with similar data from different centres.

2. Manufacturer, model and hospital.

Include as much detail on the model as possible since this may affect the scanner dosimetry. A list of most scanner models installed in the UK is provided in Appendix 1. Please use these descriptions in full when completing the forms. If your scanner is not included in the list, please provide the full model name.

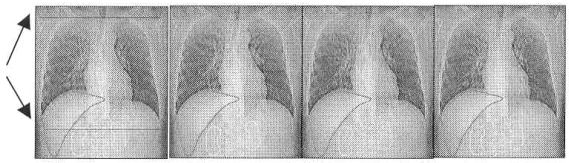
FIGURE A4 Instructions for completing survey questionnaire.

3. Sequences (1-4)

Data should be completed for each scanning sequence in the particular examination. If more than 4 sequences are used for an entire examination, then additional forms should be used (any continuation sheets should be clearly marked and linked to the initial sheet).

4. Anatomical range diagrams

Indicate clearly, using straight lines on the images, the start and stop positions for each sequence of images.



5. Anatomical range

Describe the range of the scan sequence (e.g. lung base to apices).

6. Standard protocol sequence or *ad-hoc* sequence

Indicate whether the sequence is routinely performed for every patient or only in response to findings in a previous sequence. When completing the routine protocol section of the survey, include any common (i.e. performed for at least a quarter of patients) additional sequences (e.g. following a routine head scan, an additional *ad-hoc* sequence may be performed using a contrast agent, if a tumour is suspected from the previous images).

7. IV contrast

Indicate if an IV contrast agent is used for the sequence. Indicate which phase of contrast enhancement is being imaged (e.g. arterial or venous phase).

8. Nominal beam collimation

Indicate the x-ray beam collimation as selected on the console. For single slice scanners, this will usually be the same as the imaged slice width. For multi-slice scanners, indicate the number of slices per rotation, as well as the acquired slice width (e.g. 4 ×1mm).
N.B Ignore any known variation between the displayed value and the actual value used (e.g. post-patient collimation).

9. Scanned field of view

Indicate the scanned or acquisition field of view (e.g. 50 cm or "Body").

FIGURE A5 Instructions for completing survey questionnaire (continued).

N.B This is not the same parameter as the reconstructed field of view, which can be smaller.

10. Tube voltage

Indicate the tube voltage used for each sequence scanned.

11. Tube rotation time

Indicate the rotation time selected on the scanner console (include partial rotation times).

12. Tube current

Indicate the tube current (set mA) used for the sequence. For the protocol survey, indicate the set mA for a standard patient. Ignore any dose saving (mA modulation) options that the scanner may use.

13. mAs

Indicate the displayed mAs used for the sequence. Since different scanners indicate mAs in different ways, please tick one box to show which value your scanner displays: mAs, mAs/slice or effective mAs. For the protocol survey, indicate the mAs displayed for a standard patient.

14. Auto dose reduction (mA modulation)

If your scanner has mA modulation, indicate the system used and also the average mA as given by the scanner, if available. On some models, other information (e.g. maximum mA used) may be given. Please indicate the basis for the value you provide.

15. Axial or helical scanning

Axial (or "step and shoot") mode is available on all scanner types. Helical or spiral mode is available on all multi-slice scanners and most single slice units. Indicate the scanning mode used for each sequence.

16. No. Axial slices/ scan length (individual patient survey only)

For axial mode, indicate the number of slices scanned for each sequence. For helical scanning, indicate the range scanned (mm) as indicated by the start and stop positions.

17. Table increment/ pitch

For axial scanning, indicate the table increment (in mm) between slices. For helical scanning, indicate the pitch if known. On some multi-slice models, the pitch may be assigned a name (e.g. HQ or HS mode).

FIGURE A6 Instructions for completing survey questionnaire (continued).

18. Overscan or partial scan (axial scanning only)

State degrees of scan angle if known, otherwise indicate if either mode has been used.

19. Table speed/ travel (helical scanning only)

This value will be used by the survey team, in conjunction with the collimated beam width, to calculated pitch if the latter is not provided.

20. Reconstruction interval (helical scanning only)

Indicate the spacing of the reconstructed slices.

21. Imaged slice thickness.

Indicate the thickness of the slices reconstructed from the data. For some scanners, the images may be reconstructed and then fused. The fused thickness should be recorded.

22. $CTDI_w$, $CTDI_{vol}$, DLP (DLP for individual patient survey only)

Where $CTDI_w$, $CTDI_{vol}$ or DLP are displayed on the console, the values should be included on the form. If these quantities are not displayed on the console, this part of the form may be left blank and the survey team will derive the data.

23. Comments

Please add, at the bottom of each form, any relevant comments in support of the data provided.

Advice on completing the survey

This form should be completed in collaboration with your Medical Physics Expert.

For any further advice, please contact:

Paul Shrimpton	(NRPB)	(01235 822646) paul.shrimpton@nrpb.org
Maria Lewis	(ImPACT)	(020 87253366) maria@impactscan.org
Matthew Dunn	(CTUG)	(0115 9249924) matthew.dunn@nottingham.ac.uk

The survey document and other information is available to download at:

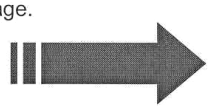
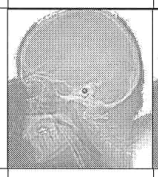
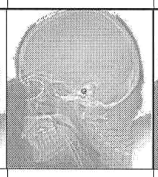
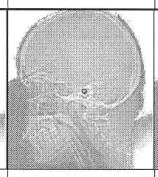
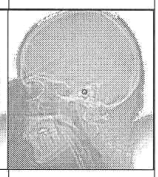
www.ctug.org.uk/ctsurvey.htm

MANY THANKS!

FIGURE A7 Instructions for completing survey questionnaire (continued).

Examination: **Routine head [Adult]**
Indication: **Acute stroke**

Manufacturer:	**Model:**	**Hospital:**

Routine Protocol Survey		Provide data for each axial or helical scan sequence of the examination.			
		Sequence 1	**Sequence 2**	**Sequence 3**	**Sequence 4**
Indicate the usual start and end positions with lines on each image. 					
Describe anatomical range scanned					
Standard sequence (*routine*) or additional in response to initial findings (*ad-hoc*)		❑ Routine ❑ Ad-hoc	❑ Routine ❑ Ad-hoc	❑ Routine ❑ Ad-hoc	❑ Routine ❑ Ad-hoc
IV contrast used? If YES, indicate name of phase		❑ Y ❑ N	❑ Y ❑ N	❑ Y ❑ N	❑ Y ❑ N
Nominal beam collimation (mm) (combination for multi-slice, e.g. 4 × 1mm)					
Scan field of view (mm or e.g. Head/ Body)					
Tube voltage (kV)					
Tube rotation time (s)					
Tube current (mA)					
Displayed mAs (mAs ❑ mAs/slice ❑ effective mAs ❑)					
Auto dose reduction used? Y/N Give name of system					
Axial Scanning	**Helical Scanning**	❑ Axial ❑ Helical	❑ Axial ❑ Helical	❑ Axial ❑ Helical	❑ Axial ❑ Helical
Table incr. (mm)	Pitch				
Overscan or partial scan angle (+° or -°)	Table speed/travel (mm per rotation)				
	Reconstr. int. (mm)				
Imaged slice thickness (mm)					
$CTDI_w$ (as indicated on console) mGy					

Comments:

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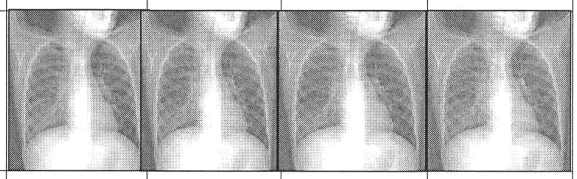
FIGURE A8 Example of form for collecting standard protocol data.

Examination: Paediatric Chest [Age .....] [Form No. ....]
Indication: Detection of malignancy

Manufacturer:	Model:	Hospital:

Individual Patient Survey		Provide data for each axial or helical scan sequence of the examination.			
		Sequence 1	**Sequence 2**	**Sequence 3**	**Sequence 4**
Indicate the actual start and end positions with lines on each image. 					
Describe anatomical range scanned					
Standard sequence (*routine*) or additional in response to initial findings (*ad-hoc*)		❑ Routine ❑ Ad-hoc	❑ Routine ❑ Ad-hoc	❑ Routine ❑ Ad-hoc	❑ Routine ❑ Ad-hoc
IV contrast used? If YES, indicate name of phase		❑ Y ❑ N	❑ Y ❑ N	❑ Y ❑ N	❑ Y ❑ N
Nominal beam collimation (mm) (combination for multi-slice, e.g. 4 × 1mm)					
Scan field of view (mm or e.g. Head/ Body)					
Tube voltage (kV)					
Tube rotation time (s)					
Tube current (mA)					
Displayed mAs (mAs ❑ mAs/slice ❑ effective mAs ❑)					
Auto dose reduction used? Y/N Give name of system If yes what was the displayed mA used?					
Axial Scanning	**Helical Scanning**	❑ Axial ❑ Helical	❑ Axial ❑ Helical	❑ Axial ❑ Helical	❑ Axial ❑ Helical
No. of axial slices	Scan length (mm)				
Table incr. (mm)	Pitch				
Overscan or partial scan angle (+° or -°)	Table speed/travel (mm per rotation)				
	Reconstr. int. (mm)				
Imaged slice thickness (mm)					
$CTDI_w$ (as indicated on console) mGy					
DLP for sequence (indicated) mGy cm					
DLP for total examination (indicated) mGy cm					

Comments:

FIGURE A9 Example of form for collecting individual patient data.

APPENDIX B

PARTICIPATING HOSPITALS

ENGLAND

Bishop Auckland General Hospital
Blackburn Royal Infirmary
BMI Park Hospital, Nottingham
BMI Priory Hospital, Birmingham
BUPA Glen Hospital, Bristol
Calderdale Royal Hospital, Halifax
Chelsea & Westminster Hospital, London
Cheltenham General Hospital
Churchill Hospital, Oxford
Claremont Hospital, Sheffield
Clatterbridge Centre for Oncology, Bebington
Colchester General Hospital
Conquest Hospital, Hastings
Cookridge Hospital, Leeds
Cumberland Infirmary, Carlisle
Darent Valley Hospital, Dartford
Darlington Memorial Hospital
Derriford Hospital, Plymouth
Freeman Hospital, Newcastle-Upon-Tyne
Frenchay Hospital, Bristol
Friarage Hospital, Northallerton
Furness General Hospital, Barrow-in-Furness
Guy's Hospital, London
Hammersmith Hospital, London
Harrogate District Hospital
Horton General Hospital, Banbury
Hurstwood Park Neurological Centre, Haywards Heath
John Radcliffe Hospital, Oxford
Kettering General Hospital
King's College Hospital, London
King's Mill Hospital, Sutton-in-Ashfield
Kingston Hospital, Kingston-on-Thames
Leeds General Infirmary
London Chest Hospital
Mayday Hospital, Croydon
Middlesbrough General Hospital
Newcastle General Hospital
North Staffordshire Royal Infirmary, Stoke
North Tyneside District Hospital, North Shields
Northampton General Hospital
Nottingham City Hospital
Ormskirk District General Hospital
Pilgrim Hospital, Boston
Pinderfields Hospital, Wakefield
Queen Elizabeth Hospital, Woolwich
Queens Hospital, Burton-on-Trent
Queen's Medical Centre, Nottingham
Radcliffe Infirmary, Oxford
Rochdale Infirmary
Royal Manchester Children's Hospital
Royal Preston Hospital

Royal Shrewsbury Hospital
Royal Sussex County Hospital, Brighton
Royal Victoria Infirmary, Newcastle-Upon-Tyne
Russells Hall Hospital, Dudley
Sandwell General Hospital, West Bromwich
South Tyneside District Hospital, South Shields
Southmead Hospital, Bristol
Southport & Formby District General Hospital
St. Bartholomews Hospital, London
St. George's Hospital, London
Stafford General Hospital
Stoke City General Hospital
Stoke Mandeville Hospital, Aylesbury
Sunderland Royal Hospital
Tameside General Hospital, Ashton-Under-Lyne
Taunton & Somerset Hospital
Trafford General Hospital, Manchester
University Hospital Hartlepool
University Hospital North Durham
University Hospital of North Tees, Stockton-on-Tees
Victoria Hospital, Blackpool
Walsgrave Hospital, Coventry
Wansbeck General, Ashington
West Cumberland Hospital, Whitehaven
Weston General Hospital, Weston-super-Mare

NORTHERN IRELAND

Altnagelvin Hospital, Londonderry
Antrim Area Hospital
Belfast City Hospital
Belvoir Park Hospital, Belfast
Causeway Hospital, Coleraine
Craigavon Area Hospital
Erne Hospital, Enniskillen
Lagan Valley Hospital, Lisburn
Mater Infirmorum, Belfast
Royal Victoria Hospital, Belfast
Ulster Hospital, Dundonald

SCOTLAND

Aberdeen Royal Infirmary
Ayr Hospital
Belford Hospital, Fort William
Borders General Hospital, Melrose
Crosshouse Hospital, Kilmarnock
Dr Grays Hospital, Elgin
Dumfries & Galloway Royal Infirmary
Falkirk & District Royal Infirmary
Gartnavel General Hospital, Glasgow
Golden Jubilee National Hospital, Clydebank
Hairmyres Hospital, Glasgow
Inverclyde Royal Hospital, Greenock
Lorn & Islands District General Hospital, Oban
Monklands Hospital, Airdrie
Queen Margarets Hospital, Dunfermline
Raigmore Hospital, Inverness
Royal Hospital for Sick Children, Edinburgh
Royal Hospital for Sick Children, Glasgow
Southern General Hospital, Glasgow

St. John's Hospital at Howden, Livingston
Stirling Royal Infirmary
Victoria Hospital, Kirkcaldy
Victoria Infirmary Glasgow
Western General Hospital, Edinburgh
Western Infirmary, Glasgow
Western Isles Hospital, Isle of Lewis
Wishaw General Hospital

WALES

Glan Clwyd Hospital, Rhyl
Velindre Hospital, Cardiff
Wrexham Maelor Hospital
Ysbyty Gwynedd, Bangor

APPENDIX C

TABLES OF DETAILED RESULTS FROM THE SURVEY

TABLE C1 Analysis by scanner model and dose quantity of the ratios of measured doses reported for individual scanners to corresponding values published by ImPACT (2004).

TABLE C2 Analysis of applied potential settings by examination type (all scanners).

TABLE C3 Analysis over all scanners of data on technique and dose for standard protocols (*Routine* sequences only).

TABLE C4 Comparison of calculated and reported (displayed) doses values for individual scanners.

TABLE C5 Comparison by scanner slice class of techniques for standard examination protocols.

TABLE C6 Comparison by scanner slice class of doses for standard examination protocols.

TABLE C7 Comparison between single- and multi-slice scanners of doses for standard examination protocols.

TABLE C8 Analysis by examination type of the ratio of the mean dose for a group of adult patients relative to the dose for the corresponding standard protocol at each individual CT scanner.

TABLE C9 Comparison by examination type between DLPs for standard protocols and DLPs observed for groups of individual patients (all scanners).

TABLE C10 Comparison by examination type between numbers of sequences for standard protocols and for individual patients (all scanners).

TABLE C1 Analysis by scanner model and dose quantity of the ratios of measured doses reported for individual scanners to corresponding values published by ImPACT (2004)

Manufacturer	Scanner model	Dose quantity	Analysis of dose ratios (Measured/ ImPACT) for individual CT scanners					
			No. of scanners	No. of measurements	Mean	%CV[a]	Min	Max
GE	9800 HiSpeed Advantage	$CTDI_{air}$	2	2	1.07	4.0	1.04	1.10
		$CTDI_{w}$	2	3	1.12	1.9	1.10	1.14
	HiSpeed CT/I (no SmartBeam)	$CTDI_{air}$	3	9	1.03	3.6	0.98	1.10
		$CTDI_{w}$	3	8	1.10	3.9	1.03	1.15
	HiSpeed CT/I (with SmartBeam)	$CTDI_{air}$	3	11	0.98	6.1	0.85	1.10
		$CTDI_{w}$	3	12	1.09	5.3	0.96	1.16
	Sytec Sri	$CTDI_{air}$	1	3	0.86	0.6	0.85	0.86
		$CTDI_{w}$	1	4	0.91	3.3	0.86	0.93
	Prospeed SX, SX Power	$CTDI_{air}$	2	4	1.07	5.7	1.00	1.15
		$CTDI_{w}$	1	2	1.03	2.5	1.01	1.04
	Prospeed SX Advantage	$CTDI_{air}$	1	1	0.94	-	0.94	0.94
		$CTDI_{w}$	0	-	-	-	-	-
	HiSpeed LX/I	$CTDI_{air}$	4	6	0.79	23	0.65	1.04
		$CTDI_{w}$	4	8	0.91	16	0.73	1.08
	LightSpeed QX/i, Advantage	$CTDI_{air}$	1	2	1.01	1.1	1.00	1.02
		$CTDI_{w}$	1	2	1.05	3.5	1.03	1.08
	LightSpeed Plus, Plus Advantage	$CTDI_{air}$	8	26	0.94	13	0.69	1.22
		$CTDI_{w}$	7	14	0.97	7.8	0.85	1.17
	LightSpeed Ultra, Ultra Advantage	$CTDI_{air}$	4	10	1.01	11	0.93	1.33
		$CTDI_{w}$	2	4	0.93	3.5	0.90	0.97
	ALL	$CTDI_{air}$	29	74	0.96	13	0.65	1.33
		$CTDI_{w}$	24	57	1.01	11	0.73	1.17

TABLE C1 (continued)

Manufacturer	Scanner model	Dose quantity	Analysis of dose ratios (Measured/ ImPACT) for individual CT scanners					
			No. of scanners	No. of measurements	Mean	%CV[a]	Min	Max
Philips	AV, AV-PS	$CTDI_{air}$	5	10	1.00	8.7	0.87	1.13
		$CTDI_{w}$	5	9	0.98	12	0.86	1.21
	AV Performance, AV-P1	$CTDI_{air}$	2	2	1.03	6.8	0.98	1.08
		$CTDI_{w}$	2	4	0.90	17	0.69	1.04
	Secura	$CTDI_{air}$	3	4	1.02	1.4	1.00	1.03
		$CTDI_{w}$	3	6	0.97	5.4	0.90	1.02
	Aura	$CTDI_{air}$	2	5	1.00	13	0.81	1.17
		$CTDI_{w}$	2	5	1.00	5.0	0.95	1.07
	CT Twin, Twin Flash, Twin RTS	$CTDI_{air}$	3	4	1.00	5.1	0.93	1.06
		$CTDI_{w}$	3	6	0.95	4.6	0.90	1.00
	Mx8000	$CTDI_{air}$	6	11	0.99	9.9	0.85	1.16
		$CTDI_{w}$	6	14	1.01	19	0.86	1.64
	PQ S	$CTDI_{air}$	1	1	1.10	-	1.10	1.10
		$CTDI_{w}$	1	2	1.06	0.4	1.06	1.07
	PQ 5000, PQ 5000V	$CTDI_{air}$	1	2	1.03	0.1	1.03	1.03
		$CTDI_{w}$	2	5	1.08	19	0.95	1.43
	SR7000	$CTDI_{air}$	1	1	1.13	-	1.13	1.13
		$CTDI_{w}$	1	2	1.10	4.3	1.06	1.13
	ALL	$CTDI_{air}$	24	40	1.01	8.4	0.81	1.17
		$CTDI_{w}$	25	53	1.00	14	0.69	1.64

TABLE C1 (continued)

Manufacturer	Scanner model	Dose quantity	Analysis of dose ratios (Measured/ ImPACT) for individual CT scanners					
			No. of scanners	No. of measurements	Mean	%CV[a]	Min	Max
Siemens	AR Star	$CTDI_{air}$	4	4	1.04	6.7	0.95	1.12
		$CTDI_{w}$	4	7	0.99	4.5	0.93	1.06
	AR.HP	$CTDI_{air}$	1	3	1.08	2.1	1.05	1.09
		$CTDI_{w}$	1	4	1.03	3.8	0.99	1.07
	Plus 4, 4A, 4B, 4C	$CTDI_{air}$	5	10	0.91	17	0.61	1.03
		$CTDI_{w}$	4	9	0.95	11	0.74	1.05
	Plus 4 Expert/ Xenon detectors)	$CTDI_{air}$	2	5	0.91	2.9	0.88	0.94
		$CTDI_{w}$	2	6	0.92	3.4	0.87	0.95
	Plus 4 Expert/ Lightning detectors	$CTDI_{air}$	2	6	0.92	11	0.77	0.99
		$CTDI_{w}$	2	8	0.92	14	0.64	1.05
	Plus 4 Power/ Lightning detectors	$CTDI_{air}$	3	9	0.95	4.9	0.90	1.03
		$CTDI_{w}$	3	11	0.99	9.6	0.87	1.17
	Emotion	$CTDI_{air}$	1	1	0.97	-	0.97	0.97
		$CTDI_{w}$	1	2	1.08	11	0.99	1.16
	Emotion Duo	$CTDI_{air}$	2	2	1.00	1.9	0.98	1.01
		$CTDI_{w}$	2	4	0.99	3.2	0.96	1.03
	Volume Access	$CTDI_{air}$	1	6	0.99	1.2	0.96	1.00
		$CTDI_{w}$	1	2	0.98	3.0	0.96	1.00
	Volume Zoom	$CTDI_{air}$	6	28	1.02	4.7	0.96	1.16
		$CTDI_{w}$	5	10	1.03	6.6	0.95	1.16
	Sensation 4	$CTDI_{air}$	0	-	-	-	-	-
		$CTDI_{w}$	1	2	0.97	0.1	0.97	0.97
	ALL	$CTDI_{air}$	27	74	0.98	8.9	0.61	1.16
		$CTDI_{w}$	26	65	0.98	9.0	0.64	1.17

TABLE C1 (continued)

Manufacturer	Scanner model	Dose quantity	Analysis of dose ratios (Measured/ ImPACT) for individual CT scanners					
			No. of scanners	No. of measurements	Mean	%CV[a]	Min	Max
Toshiba	Xvision, Xvision EX, Xvision GX	$CTDI_{air}$	1	2	1.08	11	1.00	1.16
		$CTDI_{w}$	1	2	1.26	8.2	1.19	1.33
	Xpress GX (pre 1998)	$CTDI_{air}$	1	1	1.63	-	1.63	1.63
		$CTDI_{w}$	1	3	1.11	8.2	1.05	1.21
	Asteion VF	$CTDI_{air}$	2	3	1.07	9.6	1.01	1.19
		$CTDI_{w}$	2	4	1.04	3.0	1.01	1.06
	Asteion VI, Asteion VR	$CTDI_{air}$	2	7	1.17	4.8	1.12	1.28
		$CTDI_{w}$	1	2	1.18	1.6	1.16	1.19
	Asteion VR Multi (older tube)	$CTDI_{air}$	3	5	0.98	3.3	0.94	1.01
		$CTDI_{w}$	2	4	1.10	39	0.80	1.73
	Aquilion Multi/4	$CTDI_{air}$	4	14	1.00	4.0	0.93	1.08
		$CTDI_{w}$	4	9	0.93	11	0.75	1.06
	Asteion VR Multi (C series tube)	$CTDI_{air}$	2	6	0.95	2.2	0.93	0.99
		$CTDI_{w}$	2	5	0.97	9.7	0.88	1.10
	ALL	$CTDI_{air}$	15	38	1.05	12	0.93	1.63
		$CTDI_{w}$	13	29	1.03	18	0.75	1.73
ALL	ALL	$CTDI_{air}$	95	226	0.99	11	0.61	1.63
		$CTDI_{w}$	88	204	1.00	13	0.64	1.73

Note:

[a]Coefficient of variation.

TABLE C2 Analysis of applied potential settings by examination type (all scanners)

Examination (indication)	Scan region	No. of sequences	% Distribution by applied potential setting									
			80 kV	90 kV	100 kV	110 kV	120 kV	130 kV	133 kV	135 kV	137 kV	140 kV
Standard examination protocols (Routine sequences only) – adults												
Routine head (acute stroke)	Post fossa	92	-	-	-	-	37	9.8	-	5.4	-	48
	Cerebrum	120	-	-	-	-	75	11	-	0.8	-	13
	All sequences	238	-	-	-	-	60	9.7	0.4	3.4	-	26
Abdomen (liver metastases)	Abdo/ pelvis	44	-	-	-	-	93	4.6	-	-	-	2.3
	Liver	73	-	-	-	-	82	15	-	-	-	2.7
	All sequences	117	-	-	-	-	86	11	-	-	-	2.6
Abdomen & pelvis (abscess)	All sequences	115	-	-	-	-	88	9.6	0.9	-	-	1.7
Chest, abdomen & pelvis (lymphoma staging or follow up)	Lung	68	-	-	-	-	90	7.4	-	-	-	2.9
	Abdo/ Pelvis	79	-	-	-	-	86	11	-	-	-	2.5
	All sequences	179	-	-	-	-	88	8.9	-	-	-	2.8
Chest (lung cancer: known, suspected or metastases)	Lung	88	-	-	-	-	86	8.0	1.1	-	1.1	3.4
	Liver	56	-	-	-	-	93	7.1	-	-	-	-
	All sequences	185	-	-	-	0.5	87	8.1	0.5	-	0.5	3.2
Chest: Hi-resolution (diffuse lung disease)	All sequences	127	-	-	-	-	54	13	0.8	1.6	1.6	29
Standard examination protocols (Routine sequences only) – children												
Chest (detection of malignancy): 0-1 y old	All sequences	21	9.5	-	4.8	4.8	67	14	-	-	-	-
Chest (detection of malignancy): 5 y old	All sequences	19	5.3	-	5.3	5.3	79	5.3	-	-	-	-
Chest (detection of malignancy): 10 y old	All sequences	21	4.8	-	4.8	4.8	81	4.8	-	-	-	-
Head (trauma including non-accidental injury): 0-1 y old	Post fossa	28	-	-	3.6	3.6	86	-	-	-	-	7.1
	Cerebrum	32	-	-	3.1	6.3	91	-	-	-	-	-
	All sequences	89	-	2.3	5.6	4.5	82	1.1	-	-	-	4.5
Head (trauma including non-accidental injury): 5 y old	Post fossa	34	-	-	-	2.9	71	8.8	-	-	-	18
	Cerebrum	46	-	-	2.2	-	80	11	-	-	-	6.5
	All sequences	101	-	1.0	3.0	1.0	77	7.9	-	-	-	9.9

TABLE C2 (continued)

Examination (indication)	Scan region	No. of sequences	% Distribution by applied potential setting									
			80 kV	90 kV	100 kV	110 kV	120 kV	130 kV	133 kV	135 kV	137 kV	140 kV
Head (trauma including non-accidental injury): 10 y old	Post fossa	35	-	-	-	-	54	5.7	-	-	-	40
	Cerebrum	49	-	-	-	-	84	8.2	-	-	-	8.2
	All sequences	97	-	-	-	-	74	6.2	-	-	-	20
Individual patients (adults)												
Routine head (acute stroke)	Post fossa	382	-	-	-	-	32	12	2.6	-	-	53
	Cerebrum	522	-	-	-	-	71	8.8	1.9	-	-	19
	All sequences	988	-	-	-	-	56	9.4	2.0	0.9	-	32
Abdomen (liver metastases)	Abdo/ pelvis	116	-	-	-	6.0	80	13	-	-	-	0.9
	Liver	185	-	-	-	-	89	6.0	4.9	-	-	-
	All sequences	305	-	-	-	2.3	86	8.5	3.0	-	-	0.3
Abdomen & pelvis (abscess)	All sequences	293	-	-	-	-	85	12	-	-	-	3.1
Chest, abdomen & pelvis (lymphoma staging or follow up)	Lung	160	-	-	-	-	83	16	-	-	-	1.3
	Abdo/ Pelvis	225	-	-	-	0.9	81	15	-	-	-	3.1
	All sequences	480	-	-	-	0.4	85	13	-	-	-	1.9
Chest (lung cancer: known, suspected or metastases)	Lung	351	-	-	-	0.3	90	5.7	1.4	-	1.1	1.4
	Liver	219	-	-	-	-	95	4.6	-	-	-	0.5
	All sequences	695	-	-	-	0.1	91	4.5	0.7	-	0.6	2.7
Chest: Hi-resolution (diffuse lung disease)	All sequences	414	-	-	-	-	65	8.5	1.7	-	-	25
Individual patients (children)												
Chest (detection of malignancy)	All sequences	17	-	-	-	59	41	-	-	-	-	-
Head (trauma including non-accidental injury)	Post fossa	31	-	-	-	3.2	32	26	-	-	-	39
	Cerebrum	41	-	-	-	12	59	9.8	-	-	-	20
	All sequences	100	-	-	-	6.0	60	14	-	-	-	20

TABLE C3 Analysis over all scanners of data on technique and dose for standard protocols (*Routine* sequences only)

Examination (indication)	Parameter	Scan region	Characteristic data[a] for the distribution of each parameter (all scanners)					
			No.	Mean	%CV	25th	50th	75th
Adult patients								
Routine head (acute stroke)	No. of sequences	Whole exam	118	2.0	36	2.0	2.0	2.0
	Pitch	Post fossa	92	1.1	21	1.0	1.0	1.0
		Cerebrum	120	1.0	2.7	1.0	1.0	1.0
		All sequences	238	1.0	16	1.0	1.0	1.0
	Imaged slice thickness (mm)	Post fossa	91	4.2	28	3.0	5.0	5.0
		Cerebrum	120	8.7	21	7.9	10	10
		All sequences	237	6.8	39	5.0	7.0	10
	Scan length (mm)	Post fossa	92	32	28	24	35	40
		Cerebrum	120	74	42	57	82	96
		All sequences	238	63	58	32	50	93
		Whole exam	118	127	23	122	122	126
	$CTDI_w$ (mGy)[b]	Post fossa	92	69	37	50	63	82
		Cerebrum	120	49	28	40	49	57
		All sequences	238	57	38	45	53	66
	$CTDI_{vol}$ (mGy)[b]	Post fossa	92	65	40	45	60	80
		Cerebrum	120	49	28	40	49	57
		All sequences	238	56	38	42	51	64
	DLP (mGy cm)[b]	Whole exam	118	694	40	561	643	787
	E (mSv)	Whole exam	118	1.5	40	1.2	1.3	1.7

TABLE C3 (continued)

Examination (indication)	Parameter	Scan region	Characteristic data[a] for the distribution of each parameter (all scanners)					
			No.	Mean	%CV	25th	50th	75th
Abdomen (liver metastases)	No. of sequences	Whole exam	81	1.4	44	1.0	1.0	2.0
	Pitch	Abdo/ Pelvis	44	1.4	17	1.4	1.5	1.5
		Liver	73	1.4	14	1.4	1.5	1.5
		All sequences	117	1.4	15	1.4	1.5	1.5
	Imaged slice thickness (mm)	Abdo/ Pelvis	42	7.0	35	5.0	7.0	9.5
		Liver	69	7.0	31	5.0	7.0	8.0
		All sequences	111	7.0	32	5.0	7.0	8.0
	Scan length (mm)	Abdo/ Pelvis	44	254	37	195	195	340
		Liver	73	175	23	161	161	161
		All sequences	117	205	37	161	161	195
		Whole exam	81	295	51	161	216	375
	$CTDI_w$ (mGy)[c]	Abdo/ Pelvis	44	17	34	12	15	22
		Liver	73	16	23	13	15	19
		All sequences	117	16	28	13	15	20
	$CTDI_{vol}$ (mGy)[c]	Abdo/ Pelvis	44	12	33	8.8	12	14
		Liver	73	12	34	9.1	11	13
		All sequences	117	12	33	9.1	11	14
	DLP (mGy cm)[c]	Whole exam	81	352	67	175	276	472
	E (mSv)	Whole exam	81	5.3	67	2.6	4.1	7.1
Abdomen & pelvis (abscess)	No. of sequences	Whole exam	97	1.2	33	1.0	1.0	1.0
	Pitch	All sequences	115	1.4	16	1.4	1.5	1.5
	Imaged slice thickness (mm)	All sequences	105	8.1	29	7.0	8.0	10
	Scan length (mm)	All sequences	115	348	27	375	375	375
		Whole exam	97	412	26	375	375	403
	$CTDI_w$ (mGy)[c]	All sequences	115	16	31	13	15	19
	$CTDI_{vol}$ (mGy)[c]	All sequences	115	11	36	8.7	11	13
	DLP (mGy cm)[c]	Whole exam	97	473	47	356	422	534
	E (mSv)	Whole exam	97	7.1	47	5.3	6.3	8.0

TABLE C3 (continued)

Examination (indication)	Parameter	Scan region	Characteristic data[a] for the distribution of each parameter (all scanners)					
			No.	Mean	%CV	25th	50th	75th
Chest, abdomen & pelvis (lymphoma staging or follow up)	No. of sequences	Whole exam	98	1.8	33	1.0	2.0	2.0
	Pitch	Lung	68	1.4	14	1.4	1.5	1.5
		Abdo/ Pelvis	79	1.4	15	1.3	1.5	1.5
		All sequences	179	1.4	15	1.4	1.5	1.5
	Imaged slice thickness (mm)	Lung	61	7.6	29	6.5	7.5	10
		Abdo/ Pelvis	69	7.7	27	7.0	8.0	10
		All sequences	160	7.7	28	7.0	8.0	10
	Scan length (mm)	Lung	68	245	24	209	250	250
		Abdo/ Pelvis	79	345	33	292	375	375
		All sequences	179	348	44	222	333	388
		Whole exam	98	636	19	584	597	626
	$CTDI_w$ (mGy)[c]	Lung	68	12	37	8.9	11	15
		Abdo/ pelvis	79	16	27	13	15	18
		All sequences	179	14	34	11	14	17
	$CTDI_{vol}$ (mGy)[c]	Lung	68	8.8	44	5.9	7.9	11
		Abdo/ pelvis	79	12	35	9.0	11	13
		All sequences	179	10	40	7.2	9.9	12
	DLP (mGy cm)[c]	Whole exam	98	668	40	482	618	786
	E (mSv)	Whole exam	98	9.9	40	7.1	9.2	12

TABLE C3 (continued)

Examination (indication)	Parameter	Scan region	Characteristic data[a] for the distribution of each parameter (all scanners)					
			No.	Mean	%CV	25th	50th	75th
Chest (lung cancer: known, suspected or metastases)	No. of sequences	Whole exam	110	1.7	34	1.0	2.0	2.0
	Pitch	Lung	88	1.4	16	1.4	1.5	1.5
		Liver	56	1.4	15	1.3	1.5	1.5
		All sequences	185	1.4	14	1.4	1.5	1.5
	Imaged slice thickness (mm)	Lung	79	7.2	31	5.0	7.0	10
		Liver	48	7.3	30	6.5	7.5	10
		All sequences	165	7.3	32	5.0	7.5	10
	Scan length (mm)	Lung	88	225	25	209	250	250
		Liver	56	175	19	161	161	175
		All sequences	185	234	37	161	209	250
		Whole exam	110	393	23	370	370	411
	$CTDI_w$ (mGy)[c]	Lung	88	12	37	8.9	11	15
		Liver	56	15	26	13	15	18
		All sequences	185	14	35	11	14	17
	$CTDI_{vol}$ (mGy)[c]	Lung	88	8.9	44	6.0	8.0	11
		Liver	56	11	34	8.7	11	13
		All sequences	185	10	40	7.2	9.6	12
	DLP (mGy cm)[c]	Whole exam	110	402	47	267	375	488
	E (mSv)	Whole exam	110	5.8	47	3.9	5.3	6.9
Chest: Hi-resolution (diffuse lung disease)	No. of sequences	Whole exam	108	1.2	36	1.0	1.0	1.0
	Pitch	All sequences	127	10	55	7.5	10	10
	Imaged slice thickness (mm)	All sequences	123	1.4	128	1.0	1.0	1.5
	Scan length (mm)	All sequences	127	232	23	240	250	250
		Whole exam	108	273	29	250	250	250
	$CTDI_w$ (mGy)[c]	All sequences	127	25	63	13	20	33
	$CTDI_{vol}$ (mGy)[c]	All sequences	127	3.2	84	1.4	2.4	4.0
	DLP (mGy cm)[c]	Whole exam	108	88	87	38	62	104
	E (mSv)	Whole exam	108	1.2	87	0.5	0.9	1.5

TABLE C3 (continued)

Examination (indication)	Parameter	Scan region	Characteristic data[a] for the distribution of each parameter (all scanners)					
			No.	Mean	%CV	25th	50th	75th
Paediatric patients								
Chest (detection of malignancy): 0-1 y old	No. of sequences	Whole exam	20	1.1	21	1.0	1.0	1.0
	Pitch	All sequences	21	1.4	21	1.4	1.5	1.5
	Imaged slice thickness (mm)	All sequences	21	5.5	36	5.0	5.0	5.0
	Scan length (mm)	All sequences	21	141	21	133	133	133
		Whole exam	20	148	24	133	133	159
	$CTDI_w$ (mGy)[b]	All sequences	21	15	68	7.2	12	23
	$CTDI_{vol}$ (mGy)[b]	All sequences	21	11	76	5.1	9.5	12
	DLP (mGy cm)[b]	Whole exam	20	159	78	68	128	204
	E (mSv)	Whole exam	20	6.3	79	2.6	5.0	7.9
Chest (detection of malignancy): 5 y old	No. of sequences	Whole exam	19	1.0	-	1.0	1.0	1.0
	Pitch	All sequences	19	1.4	17	1.4	1.5	1.5
	Imaged slice thickness (mm)	All sequences	18	6.9	39	5.0	6.8	10
	Scan length (mm)	All sequences	19	172	20	158	158	167
		Whole exam	19	172	20	158	158	167
	$CTDI_w$ (mGy)[b]	All sequences	19	16	53	10	15	20
	$CTDI_{vol}$ (mGy)[b]	All sequences	19	11	58	7.6	10	13
	DLP (mGy cm)[b]	Whole exam	19	198	60	119	192	228
	E (mSv)	Whole exam	19	3.6	60	2.1	3.5	4.1
Chest (detection of malignancy): 10 y old	No. of sequences	Whole exam	21	1.0	-	1.0	1.0	1.0
	Pitch	All sequences	21	1.4	16	1.4	1.5	1.5
	Imaged slice thickness (mm)	All sequences	21	8.0	28	7.0	8.0	10
	Scan length (mm)	All sequences	21	221	19	205	205	205
		Whole exam	21	221	19	205	205	205
	$CTDI_w$ (mGy)[b]	All sequences	21	19	46	13	17	26
	$CTDI_{vol}$ (mGy)[b]	All sequences	21	14	53	9.5	12	17
	DLP (mGy cm)[b]	Whole exam	21	303	57	174	287	368
	E (mSv)	Whole exam	21	3.9	57	2.3	3.7	4.8

TABLE C3 (continued)

Examination (indication)	Parameter	Scan region	Characteristic data[a] for the distribution of each parameter (all scanners)					
			No.	Mean	%CV	25th	50th	75th
Head (trauma including non-accidental injury): 0–1 y old	No. of sequences	Whole exam	56	1.6	39	1.0	2.0	2.0
	Pitch	Post fossa	28	1.0	17	1.0	1.0	1.0
		Cerebrum	32	1.0	5.0	1.0	1.0	1.0
		All sequences	89	1.0	14	1.0	1.0	1.0
	Imaged slice thickness (mm)	Post fossa	28	4.4	28	3.6	4.3	5.0
		Cerebrum	32	7.7	20	7.0	7.5	8.3
		All sequences	89	6.0	33	5.0	5.0	7.0
	Scan length (mm)	Post fossa	28	26	37	17	30	30
		Cerebrum	32	63	30	59	63	76
		All sequences	89	61	49	30	63	93
		Whole exam	56	98	16	93	93	96
	$CTDI_w$ (mGy)[b]	Post fossa	28	30	44	23	26	34
		Cerebrum	32	23	49	17	21	28
		All sequences	89	24	48	16	22	28
	$CTDI_{vol}$ (mGy)[b]	Post fossa	28	29	47	21	26	34
		Cerebrum	32	23	49	17	21	28
		All sequences	89	25	49	16	22	28
	DLP (mGy cm)[b]	Whole exam	56	230	46	160	201	270
	E (mSv)	Whole exam	56	2.5	46	1.8	2.2	3.0

TABLE C3 (continued)

Examination (indication)	Parameter	Scan region	Characteristic data[a] for the distribution of each parameter (all scanners)					
			No.	Mean	%CV	25th	50th	75th
Head (trauma including non-accidental injury): 5 y old	No. of sequences	Whole exam	55	1.8	40	1.0	2.0	2.0
	Pitch	Post fossa	34	1.1	20	1.0	1.0	1.0
		Cerebrum	46	1.0	4.2	1.0	1.0	1.0
		All sequences	101	1.0	16	1.0	1.0	1.0
	Imaged slice thickness (mm)	Post fossa	34	4.3	24	3.0	5.0	5.0
		Cerebrum	46	8.5	19	7.0	8.0	10
		All sequences	101	6.5	37	5.0	7.0	8.0
	Scan length (mm)	Post fossa	34	30	34	20	33	36
		Cerebrum	46	64	43	40	74	89
		All sequences	101	62	57	33	54	91
		Whole exam	55	114	15	110	110	113
	$CTDI_w$ (mGy)[b]	Post fossa	34	42	37	30	37	50
		Cerebrum	46	33	42	21	29	42
		All sequences	101	35	41	24	33	43
	$CTDI_{vol}$ (mGy)[b]	Post fossa	34	39	38	30	36	49
		Cerebrum	46	32	43	21	29	42
		All sequences	101	34	41	24	33	43
	DLP (mGy cm)[b]	Whole exam	55	383	37	280	385	465
	E (mSv)	Whole exam	55	1.5	37	1.1	1.5	1.9

TABLE C3 (continued)

Examination (indication)	Parameter	Scan region	Characteristic data[a] for the distribution of each parameter (all scanners)					
			No.	Mean	%CV	25th	50th	75th
Head (trauma including non-accidental injury): 10 y old	No. of sequences	Whole exam	49	2.0	35	2.0	2.0	2.0
	Pitch	Post fossa	35	1.1	18	1.0	1.0	1.0
		Cerebrum	49	1.0	-	1.0	1.0	1.0
		All sequences	97	1.0	13	1.0	1.0	1.0
	Imaged slice thickness (mm)	Post fossa	35	4.2	21	3.0	5.0	5.0
		Cerebrum	49	8.7	20	8.0	10	10
		All sequences	97	6.8	38	5.0	7.0	10
	Scan length (mm)	Post fossa	35	30	35	21	31	38
		Cerebrum	49	68	45	38	78	95
		All sequences	97	61	59	30	50	95
		Whole exam	49	120	17	116	116	120
	$CTDI_w$ (mGy)[b]	Post fossa	35	56	38	40	51	68
		Cerebrum	49	38	37	29	37	46
		All sequences	97	44	43	31	40	52
	$CTDI_{vol}$ (mGy)[b]	Post fossa	35	53	35	40	50	65
		Cerebrum	49	38	37	29	37	46
		All sequences	97	44	39	32	40	51
	DLP (mGy cm)[b]	Whole exam	49	508	34	402	479	619
	E (mSv)	Whole exam	49	1.6	34	1.3	1.5	2.0

Notes:

[a]Including sample size, mean, coefficient of variation (%CV) and percentile points (25th, 50th and 75th) for each parameter.

[b]For examinations of the adult head and children, calculated values of $CTDI_w$, $CTDI_{vol}$ and DLP relate to the 16 cm diameter CT dosimetry phantom.

[c]For examinations of the adult trunk, calculated values of $CTDI_w$, $CTDI_{vol}$ and DLP relate to the 32 cm diameter CT dosimetry phantom.

TABLE C4 Comparison of calculated and reported (displayed) dose values for individual scanners

Examination (indication)	Dose quantity[a, b]	Analysis[c] of ratios of calculated to reported doses							
		No.	Mean	%CV	Min	25th	50th	75th	Max
Standard examination protocols (adults)									
Routine head (acute stroke)	$CTDI_{vol}$ per sequence	136	1.01	13	0.74	0.89	1.01	1.09	1.53
	DLP per sequence	24	1.06	16	0.87	0.89	1.07	1.20	1.53
	DLP per *Routine* protocol[d]	22	1.03	30	0.34	0.89	1.01	1.12	1.89
Abdomen (liver metastases)	$CTDI_{vol}$ per sequence	61	1.00	14	0.72	0.94	1.01	1.02	1.47
	DLP per sequence	5	0.95	8.1	0.86	0.86	1.00	1.00	1.01
	DLP per *Routine* protocol[d]	9	0.89	17	0.65	0.74	1.00	1.00	1.01
Abdomen & pelvis (abscess)	$CTDI_{vol}$ per sequence	63	0.97	14	0.72	0.85	0.99	1.02	1.47
	DLP per sequence	5	0.97	7.1	0.85	0.99	1.00	1.01	1.01
	DLP per *Routine* protocol[d]	10	0.97	7.7	0.83	0.99	1.00	1.01	1.06
Chest, abdomen & pelvis (lymphoma staging or follow up)	$CTDI_{vol}$ per sequence	96	0.98	13	0.72	0.88	0.99	1.02	1.47
	DLP per sequence	18	0.94	10	0.80	0.85	0.94	1.00	1.13
	DLP per *Routine* protocol[d]	22	0.96	14	0.52	0.85	1.00	1.04	1.11
Chest (lung cancer: known, suspected or metastases)	$CTDI_{vol}$ per sequence	99	0.97	11	0.72	0.86	0.99	1.02	1.37
	DLP per sequence	16	0.92	15	0.63	0.85	0.91	1.00	1.13
	DLP per *Routine* protocol[d]	21	0.93	16	0.56	0.83	1.00	1.00	1.15
Chest: Hi-resolution (diffuse lung disease)	$CTDI_{vol}$ per sequence	64	1.02	36	0.21	0.76	0.89	1.11	2.03
	DLP per sequence	10	0.88	21	0.71	0.75	0.82	0.96	1.25
	DLP per *Routine* protocol[d]	18	0.82	20	0.50	0.75	0.81	0.98	1.11
Standard examination protocols (children)									
Chest (detection of malignancy): 0-1 y old	$CTDI_{vol}$ per sequence	9	1.78	42	0.67	0.98	2.15	2.16	2.52
	DLP per sequence	-	-	-	-	-	-	-	-
	DLP per *Routine* protocol[d]	-	-	-	-	-	-	-	-

TABLE C4 (continued)

Examination (indication)	Dose quantity[a, b]	Analysis[c] of ratios of calculated to reported doses							
		No.	Mean	%CV	Min	25th	50th	75th	Max
Chest (detection of malignancy): 5 y old	$CTDI_{vol}$ per sequence	9	1.75	44	0.46	0.98	2.09	2.15	2.71
	DLP per sequence	-	-	-	-	-	-	-	-
	DLP per *Routine* protocol[d]	-	-	-	-	-	-	-	-
Chest (detection of malignancy): 10 y old	$CTDI_{vol}$ per sequence	9	2.08	30	0.98	1.77	1.95	2.37	3.19
	DLP per sequence	-	-	-	-	-	-	-	-
	DLP per *Routine* protocol[d]	-	-	-	-	-	-	-	-
Head (trauma including non-accidental injury): 0–1 y old	$CTDI_{vol}$ per sequence	49	1.04	19	0.71	0.92	1.01	1.11	2.03
	DLP per sequence	2	1.20	4.0	1.16	-	-	-	1.23
	DLP per *Routine* protocol[d]	4	1.06	15	0.85	0.96	1.09	1.19	1.19
Head (trauma including non-accidental injury): 5 y old	$CTDI_{vol}$ per sequence	55	1.05	21	0.71	0.93	1.02	1.12	1.98
	DLP per sequence	2	1.14	2.4	1.12	-	-	-	1.16
	DLP per *Routine* protocol[d]	4	1.05	13	0.89	0.97	1.07	1.15	1.19
Head (trauma including non-accidental injury): 10 y old	$CTDI_{vol}$ per sequence	45	1.03	12	0.71	0.98	1.03	1.12	1.25
	DLP per sequence	2	1.14	2.4	1.12	-	-	-	1.16
	DLP per *Routine* protocol[d]	4	1.05	13	0.89	0.97	1.07	1.15	1.19
Individual patients (adults)									
Routine head (acute stroke)	$CTDI_{vol}$ per sequence	371	0.98	9.4	0.85	0.89	0.97	1.03	1.23
	DLP per sequence	218	0.96	12	0.78	0.88	0.89	1.06	1.23
	DLP per patient	86	1.05	21	0.80	0.89	1.02	1.12	2.15
Abdomen (liver metastases)	$CTDI_{vol}$ per sequence	105	0.94	17	0.56	0.88	0.99	1.03	1.64
	DLP per sequence	34	0.92	13	0.75	0.87	0.90	0.96	1.47
	DLP per patient	25	0.95	13	0.75	0.89	0.92	0.97	1.47
Abdomen & pelvis (abscess)	$CTDI_{vol}$ per sequence	150	0.94	17	0.48	0.85	1.01	1.02	1.65
	DLP per sequence	28	0.83	16	0.53	0.75	0.87	0.96	0.98
	DLP per patient	35	0.89	21	0.53	0.75	0.90	0.97	1.46

TABLE C4 (continued)

Examination (indication)	Dose quantity[a, b]	Analysis[c] of ratios of calculated to reported doses							
		No.	Mean	%CV	Min	25th	50th	75th	Max
Chest, abdomen & pelvis (lymphoma staging or follow up)	$CTDI_{vol}$ per sequence	251	0.90	19	0.43	0.84	0.90	1.02	1.82
	DLP per sequence	120	0.86	9.8	0.64	0.84	0.85	0.90	1.06
	DLP per patient	46	0.91	15	0.65	0.82	0.89	1.02	1.14
Chest (lung cancer: known, suspected or metastases)	$CTDI_{vol}$ per sequence	302	0.93	14	0.39	0.85	0.96	1.02	1.13
	DLP per sequence	132	0.84	8.3	0.66	0.79	0.85	0.88	0.99
	DLP per patient	77	0.93	18	0.62	0.83	0.91	0.97	1.75
Chest: Hi-resolution (diffuse lung disease)	$CTDI_{vol}$ per sequence	179	0.93	30	0.51	0.76	0.83	0.99	1.77
	DLP per sequence	71	0.77	11	0.53	0.71	0.81	0.83	0.94
	DLP per patient	61	0.89	26	0.49	0.68	0.91	1.00	1.53
Individual patients (children)									
Chest (detection of malignancy)	$CTDI_{vol}$ per sequence	12	1.77	12	1.24	1.77	1.77	1.77	2.14
	DLP per sequence	1	1.24	-	1.24	-	-	-	1.24
	DLP per patient	1	1.24	-	1.24	-	-	-	1.24
Head (trauma including non-accidental injury)	$CTDI_{vol}$ per sequence	35	1.06	8.8	0.79	1.02	1.08	1.14	1.19
	DLP per sequence	10	1.07	16	0.75	1.12	1.12	1.16	1.16
	DLP per patient	5	1.06	16	0.75	1.14	1.14	1.14	1.15
ALL	$CTDI_{vol}$ per sequence	2121	0.98	23	0.21	0.86	0.98	1.03	3.19
	DLP per sequence	703	0.90	14	0.53	0.84	0.88	0.96	1.53
	DLP per examination	454	0.95	20	0.34	0.85	0.94	1.03	2.15

Notes:

[a]For examinations of the adult head and children, calculated values of $CTDI_{vol}$ and DLP relate to the 16 cm diameter CT dosimetry phantom.

[b]For examinations of the adult trunk, calculated values of $CTDI_{vol}$ and DLP relate to the 32 cm diameter CT dosimetry phantom.

[c]Including sample size, mean, coefficient of variation (%CV), minimum, maximum and percentile points (25th, 50th and 75th) for each dose quantity.

[d]DLP for standard examination protocol based on *Routine* sequences only.

TABLE C5 Comparison[a] by scanner slice class of techniques for standard examination protocols[b]

Scan region	Slice[c] class	No. of sequences						Pitch						Imaged slice width (mm)						Scan length (mm)					
		No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th
Adult patients																									
Routine head (acute stroke)																									
Post fossa	1	-	-	-	-	-	-	60	1.2	24	1.0	1.0	1.3	59	4.3	29	3.0	5.0	5.0	60	32	27	24	37	40
	2	-	-	-	-	-	-	5	1.0	-	1.0	1.0	1.0	5	4.6	19	5.0	5.0	5.0	5	29	32	22	22	40
	4	-	-	-	-	-	-	20	1.0	5.5	1.0	1.0	1.0	20	4.0	27	4.0	4.0	5.0	20	31	28	24	34	40
	8+	-	-	-	-	-	-	7	1.0	3.0	1.0	1.0	1.0	7	4.4	22	4.1	5.0	5.0	7	31	34	23	35	39
	ALL	-	-	-	-	-	-	92	1.1	21	1.0	1.0	1.0	91	4.2	28	3.0	5.0	5.0	92	32	28	24	35	40
Cerebrum	1	-	-	-	-	-	-	79	1.0	3.2	1.0	1.0	1.0	79	9.3	16	10	10	10	79	73	44	50	82	93
	2	-	-	-	-	-	-	5	1.0	-	1.0	1.0	1.0	5	7.8	23	8.0	8.0	8.0	5	90	12	82	93	99
	4	-	-	-	-	-	-	26	1.0	-	1.0	1.0	1.0	26	7.2	30	7.5	7.5	8.0	26	75	39	61	82	96
	8+	-	-	-	-	-	-	10	1.0	2.5	1.0	1.0	1.0	10	8.2	13	7.5	7.5	8.6	10	68	48	38	69	95
	ALL	-	-	-	-	-	-	120	1.0	2.7	1.0	1.0	1.0	120	8.7	21	7.9	10	10	120	74	42	57	82	96
Whole exam	1	74	2.1	37	2.0	2.0	2.0	152	1.1	18	1.0	1.0	1.0	151	7.3	39	5.0	8.0	10	74	126	22	122	122	126
	2	6	1.8	22	2.0	2.0	2.0	11	1.0	-	1.0	1.0	1.0	11	6.1	34	5.0	5.0	8.0	6	116	7.2	115	118	122
	4	30	1.9	37	1.3	2.0	2.0	57	0.99	7.6	1.0	1.0	1.0	57	5.7	38	4.0	5.0	7.5	30	132	29	120	124	126
	8+	8	2.3	31	2.0	2.0	3.0	18	0.98	15	1.0	1.0	1.0	18	6.4	35	5.0	7.5	7.5	8	128	4.3	126	126	127
	ALL	118	2.0	36	2.0	2.0	2.0	238	1.0	16	1.0	1.0	1.0	237	6.8	39	5.0	7.0	10	118	127	23	122	122	126

TABLE C5 (continued)

Scan region	Slice[c] class	No. of sequences						Pitch						Imaged slice width (mm)						Scan length (mm)					
		No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th
Abdomen (liver metastases)																									
Abdo/ Pelvis	1	-	-	-	-	-	-	23	1.5	13	1.5	1.5	1.5	21	8.3	21	7.0	8.0	10	23	260	37	195	195	352
	2	-	-	-	-	-	-	2	1.5	-	-	-	-	2	5.0	-	-	-	-	2	403	1.1	-	-	-
	4	-	-	-	-	-	-	15	1.3	14	1.3	1.4	1.5	15	6.1	39	5.0	6.5	7.5	15	241	40	195	195	197
	8+	-	-	-	-	-	-	4	1.0	21	0.89	0.95	1.1	4	4.4	63	2.4	3.8	5.8	4	195	-	195	195	195
	ALL	-	-	-	-	-	-	44	1.4	17	1.4	1.5	1.5	42	7.0	35	5.0	7.0	9.5	44	254	37	195	195	340
Liver	1	-	-	-	-	-	-	54	1.4	14	1.4	1.5	1.5	50	7.2	29	5.0	7.0	9.5	54	170	19	161	161	161
	2	-	-	-	-	-	-	4	1.4	8.7	1.4	1.5	1.5	4	5.8	26	5.0	5.0	5.8	4	181	22	161	161	181
	4	-	-	-	-	-	-	14	1.3	13	1.3	1.4	1.5	14	6.6	34	5.0	5.8	7.5	14	179	21	161	161	161
	8+	-	-	-	-	-	-	1	1.4	-	-	-	-	1	5.0	-	-	-	-	1	366	-	-	-	-
	ALL	-	-	-	-	-	-	73	1.4	14	1.4	1.5	1.5	69	7.0	31	5.0	7.0	8.0	73	175	23	161	161	161
Whole exam	1	51	1.5	43	1.0	1.0	2.0	77	1.4	14	1.4	1.5	1.5	71	7.5	27	5.0	8.0	10	51	297	45	161	322	375
	2	5	1.2	37	1.0	1.0	1.0	6	1.5	7.0	1.5	1.5	1.5	6	5.5	22	5.0	5.0	5.0	5	306	71	161	161	400
	4	20	1.5	47	1.0	1.0	2.0	29	1.3	13	1.3	1.4	1.5	29	6.3	36	5.0	6.5	7.5	20	306	62	195	197	379
	8+	5	1.0	-	1.0	1.0	1.0	5	1.1	22	0.90	1.0	1.4	5	4.5	53	2.5	5.0	5.0	5	229	33	195	195	195
	ALL	81	1.4	44	1.0	1.0	2.0	117	1.4	15	1.4	1.5	1.5	111	7.0	32	5.0	7.0	8.0	81	295	51	161	216	375
Abdomen & pelvis (abscess)																									
Whole exam	1	64	1.2	35	1.0	1.0	1.0	79	1.4	16	1.5	1.5	1.5	71	8.8	16	8.0	10	10	64	414	24	375	375	411
	2	4	1.0	-	1.0	1.0	1.0	4	1.4	8.7	1.4	1.5	1.5	4	7.3	21	7.3	8.0	8.0	4	390	7.6	375	375	390
	4	22	1.1	31	1.0	1.0	1.0	25	1.3	12	1.3	1.4	1.5	23	7.2	48	5.8	7.5	7.8	22	413	36	375	375	376
	8+	7	1.0	-	1.0	1.0	1.0	7	1.3	20	1.2	1.4	1.4	7	5.0	45	3.8	5.0	6.3	7	405	6.5	388	388	430
	ALL	97	1.2	33	1.0	1.0	1.0	115	1.4	16	1.4	1.5	1.5	105	8.1	29	7.0	8.0	10	97	412	26	375	375	403

TABLE C5 (continued)

Scan region	Slice[c] class	No. of sequences						Pitch						Imaged slice width (mm)						Scan length (mm)					
		No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th
Chest, abdomen & pelvis (lymphoma staging or follow up)																									
Lung	1	-	-	-	-	-	-	41	1.4	16	1.4	1.5	1.5	34	8.7	17	7.3	10	10	41	236	25	209	210	250
	2	-	-	-	-	-	-	3	1.6	9.1	1.5	1.5	1.6	3	6.0	29	5.0	5.0	6.5	3	250	-	250	250	250
	4	-	-	-	-	-	-	18	1.4	10	1.3	1.5	1.5	18	6.3	38	5.0	6.5	7.5	18	268	25	222	250	273
	8+	-	-	-	-	-	-	6	1.4	13	1.4	1.4	1.6	6	5.9	36	5.0	6.3	7.5	6	235	9.8	220	249	250
	ALL	-	-	-	-	-	-	68	1.4	14	1.4	1.5	1.5	61	7.6	29	6.5	7.5	10	68	245	24	209	250	250
Abdo/ pelvis	1	-	-	-	-	-	-	51	1.4	16	1.5	1.5	1.5	41	8.7	16	7.0	10	10	51	312	31	195	375	375
	2	-	-	-	-	-	-	3	1.4	10	1.4	1.5	1.5	3	6.0	29	5.0	5.0	6.5	3	361	6.6	354	375	375
	4	-	-	-	-	-	-	19	1.3	11	1.3	1.3	1.5	19	6.4	36	5.0	6.5	7.5	19	421	34	364	375	383
	8+	-	-	-	-	-	-	6	1.4	18	1.4	1.4	1.6	6	5.9	36	5.0	6.3	7.5	6	372	8.5	345	381	388
	ALL	-	-	-	-	-	-	79	1.4	15	1.3	1.5	1.5	69	7.7	27	7.0	8.0	10	79	345	33	292	375	375
Whole exam	1	58	1.9	36	1.3	2.0	2.0	111	1.5	16	1.5	1.5	1.5	92	8.8	16	7.8	10	10	58	625	16	584	584	626
	2	4	1.8	29	1.8	2.0	2.0	7	1.5	9.6	1.5	1.5	1.5	7	5.9	25	5.0	5.0	6.5	4	613	3.2	608	621	626
	4	28	1.7	28	1.0	2.0	2.0	47	1.4	10	1.3	1.5	1.5	47	6.4	35	5.0	6.5	7.5	28	665	25	584	591	654
	8+	8	1.8	26	1.8	2.0	2.0	14	1.4	18	1.4	1.4	1.7	14	5.8	38	5.0	6.3	7.5	8	617	7.6	594	623	638
	ALL	98	1.8	33	1.0	2.0	2.0	179	1.4	15	1.4	1.5	1.5	160	7.7	28	7.0	8.0	10	98	636	19	584	597	626

TABLE C5 (continued)

Scan region	Slice[c] class	No. of sequences						Pitch						Imaged slice width (mm)						Scan length (mm)					
		No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th
Chest (lung cancer: known, suspected or metastases)																									
Lung	1	-	-	-	-	-	-	59	1.4	16	1.4	1.5	1.5	51	8.2	21	7.0	8.0	10	59	215	28	209	210	250
	2	-	-	-	-	-	-	5	1.5	12	1.5	1.5	1.5	5	4.8	9.3	5.0	5.0	5.0	5	235	28	250	250	250
	4	-	-	-	-	-	-	18	1.4	15	1.3	1.5	1.5	17	5.7	35	5.0	5.0	7.5	18	248	16	212	250	250
	8+	-	-	-	-	-	-	6	1.4	21	1.4	1.4	1.6	6	4.5	44	3.1	5.0	5.0	6	243	14	235	250	250
	ALL	-	-	-	-	-	-	88	1.4	16	1.4	1.5	1.5	79	7.2	31	5.0	7.0	10	88	225	25	209	250	250
Liver	1	-	-	-	-	-	-	37	1.5	15	1.5	1.5	1.5	30	8.3	19	7.0	8.0	10	37	170	14	161	161	161
	2	-	-	-	-	-	-	1	1.5	-	-	-	-	1	5.0	-	-	-	-	1	197	-	-	-	-
	4	-	-	-	-	-	-	15	1.3	11	1.3	1.3	1.4	14	5.9	36	5.0	6.5	7.5	15	186	28	161	161	188
	8+	-	-	-	-	-	-	3	1.3	30	1.1	1.4	1.5	3	4.8	57	3.5	5.0	6.3	3	175	7.7	168	176	182
	ALL	-	-	-	-	-	-	56	1.4	15	1.3	1.5	1.5	48	7.3	30	6.5	7.5	10	56	175	19	161	161	175
Whole exam	1	69	1.7	36	1.0	2.0	2.0	118	1.4	14	1.5	1.5	1.5	101	8.4	19	7.0	8.0	10	69	381	24	370	370	411
	2	5	1.8	25	2.0	2.0	2.0	9	1.5	8.3	1.5	1.5	1.5	9	5.2	21	5.0	5.0	5.0	5	441	25	370	445	501
	4	29	1.6	32	1.0	2.0	2.0	46	1.4	13	1.3	1.4	1.5	43	5.7	37	5.0	5.0	7.5	29	408	22	370	404	411
	8+	7	1.7	28	1.5	2.0	2.0	12	1.4	20	1.4	1.4	1.7	12	4.5	42	2.5	5.0	5.0	7	414	20	386	453	470
	ALL	110	1.7	34	1.0	2.0	2.0	185	1.4	14	1.4	1.5	1.5	165	7.3	32	5.0	7.5	10	110	393	23	370	370	411
Chest: Hi-resolution (diffuse lung disease)																									
Whole exam	1	67	1.2	40	1.0	1.0	1.0	81	10	52	7.5	10	10	80	1.4	62	1.0	1.0	1.5	67	280	29	250	250	250
	2	5	1.0	-	1.0	1.0	1.0	5	8.5	49	5.0	7.5	10	5	1.0	-	1.0	1.0	1.0	5	214	30	218	250	250
	4	29	1.1	31	1.0	1.0	1.0	33	9.6	63	8.0	8.0	10	30	1.8	195	1.0	1.0	1.3	29	274	27	250	250	250
	8+	7	1.1	33	1.0	1.0	1.0	8	7.3	19	7.3	8.0	8.0	8	1.1	24	0.94	1.3	1.3	7	235	13	220	250	250
	ALL	108	1.2	36	1.0	1.0	1.0	127	10	55	7.5	10	10	123	1.4	128	1.0	1.0	1.5	108	273	29	250	250	250

TABLE C5 (continued)

Scan region	Slice[c] class	No. of sequences						Pitch						Imaged slice width (mm)						Scan length (mm)					
		No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th
Paediatric patients																									
Chest (detection of malignancy): 0-1 y old																									
Whole exam	1	14	1.1	25	1.0	1.0	1.0	15	1.5	20	1.4	1.5	1.5	15	5.9	30	5.0	5.0	6.0	14	145	26	133	133	133
	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	4	4	1.0	-	1.0	1.0	1.0	4	1.4	7.4	1.3	1.4	1.4	4	5.3	38	4.6	5.0	5.8	4	165	22	133	165	196
	8+	2	1.0	-	-	-	-	2	0.95	7.4	-	-	-	2	2.5	28	-	-	-	2	140	7.1	-	-	-
	ALL	20	1.1	21	1.0	1.0	1.0	21	1.4	21	1.4	1.5	1.5	21	5.5	36	5.0	5.0	5.0	20	148	24	133	133	159
Chest (detection of malignancy): 5 y old																									
Whole exam	1	13	1.0	-	1.0	1.0	1.0	13	1.5	14	1.5	1.5	1.5	12	7.9	30	5.0	9.0	10	13	165	19	158	158	158
	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	4	4	1.0	-	1.0	1.0	1.0	4	1.4	7.4	1.3	1.4	1.4	4	6.1	23	5.0	5.8	6.9	4	196	22	158	196	233
	8+	2	1.0	-	-	-	-	2	0.95	7.4	-	-	-	2	2.5	28	-	-	-	2	167	7.2	-	-	-
	ALL	19	1.0	-	1.0	1.0	1.0	19	1.4	17	1.4	1.5	1.5	18	6.9	39	5.0	6.8	10	19	172	20	158	158	167
Chest (detection of malignancy): 10 y old																									
Whole exam	1	13	1.0	-	1.0	1.0	1.0	13	1.5	14	1.5	1.5	1.5	13	8.8	16	7.0	10	10	13	216	18	205	205	205
	2	1	1.0	-	-	-	-	1	1.5	-	-	-	-	1	8.0	-	-	-	-	1	205	-	-	-	-
	4	5	1.0	-	1.0	1.0	1.0	5	1.4	6.4	1.4	1.4	1.4	5	8.4	19	7.5	8.0	10	5	237	26	205	205	303
	8+	2	1.0	-	-	-	-	2	0.95	7.4	-	-	-	2	2.5	28	-	-	-	2	216	7.2	-	-	-
	ALL	21	1.0	-	1.0	1.0	1.0	21	1.4	16	1.4	1.5	1.5	21	8.0	28	7.0	8.0	10	21	221	19	205	205	205

TABLE C5 (continued)

Scan region	Slice[c] class	No. of sequences						Pitch						Imaged slice width (mm)						Scan length (mm)					
		No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th
Head (trauma including non-accidental injury): 0–1 y old																									
Post fossa	1	-	-	-	-	-	-	17	1.1	21	1.0	1.0	1.0	17	4.6	32	3.0	5.0	5.0	17	27	36	17	30	30
	2	-	-	-	-	-	-	2	1.0	-	-	-	-	2	5.0	-	-	-	-	2	24	35	-	-	-
	4	-	-	-	-	-	-	6	1.0	-	1.0	1.0	1.0	6	3.7	16	3.8	3.9	4.0	6	21	42	13	21	29
	8+	-	-	-	-	-	-	3	1.0	-	1.0	1.0	1.0	3	4.4	14	4.1	4.5	4.8	3	34	27	29	30	38
	ALL	-	-	-	-	-	-	28	1.0	17	1.0	1.0	1.0	28	4.4	28	3.6	4.3	5.0	28	26	37	17	30	30
Cerebrum	1	-	-	-	-	-	-	21	1.0	6.2	1.0	1.0	1.0	21	7.8	21	7.0	7.0	10	21	57	36	49	63	68
	2	-	-	-	-	-	-	2	1.0	-	-	-	-	2	8.0	-	-	-	-	2	71	15	-	-	-
	4	-	-	-	-	-	-	6	1.0	-	1.0	1.0	1.0	6	7.3	16	7.5	7.5	7.9	6	76	12	75	77	83
	8+	-	-	-	-	-	-	3	1.0	-	1.0	1.0	1.0	3	8.0	33	7.0	9.0	9.5	3	69	15	64	68	74
	ALL	-	-	-	-	-	-	32	1.0	5.0	1.0	1.0	1.0	32	7.7	20	7.0	7.5	8.3	32	63	30	59	63	76
Whole exam	1	35	1.6	43	1.0	1.0	2.0	56	1.0	13	1.0	1.0	1.0	56	6.3	32	5.0	7.0	7.0	35	96	11	93	93	96
	2	3	1.7	35	1.5	2.0	2.0	5	1.0	-	1.0	1.0	1.0	5	6.2	27	5.0	5.0	8.0	3	92	5.0	90	93	95
	4	14	1.5	35	1.0	1.5	2.0	21	0.98	14	1.0	1.0	1.0	21	5.3	30	4.0	5.0	6.5	14	101	25	93	95	96
	8+	4	1.8	29	1.8	2.0	2.0	7	0.90	29	1.0	1.0	1.0	7	5.8	46	4.1	5.0	7.0	4	102	15	95	96	103
	ALL	56	1.6	39	1.0	2.0	2.0	89	1.0	14	1.0	1.0	1.0	89	6.0	33	5.0	5.0	7.0	56	98	16	93	93	96

TABLE C5 (continued)

Scan region	Slice[c] class	No. of sequences						Pitch						Imaged slice width (mm)						Scan length (mm)					
		No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th
Head (trauma including non-accidental injury): 5 y old																									
Post fossa	1	-	-	-	-	-	-	24	1.1	23	1.0	1.0	1.0	24	4.3	26	3.0	5.0	5.0	24	30	32	20	34	26
	2	-	-	-	-	-	-	2	1.0	-	-	-	-	2	5.0	-	-	-	-	2	29	34	-	-	-
	4	-	-	-	-	-	-	5	1.0	-	1.0	1.0	1.0	5	3.9	23	4.0	4.0	4.0	5	22	41	14	22	24
	8+	-	-	-	-	-	-	3	1.0	-	1.0	1.0	1.0	3	4.8	6.0	4.8	5.0	5.0	3	41	21	37	40	45
	ALL	-	-	-	-	-	-	34	1.1	20	1.0	1.0	1.0	34	4.3	24	3.0	5.0	5.0	34	30	34	20	33	36
Cerebrum	1	-	-	-	-	-	-	35	1.0	4.8	1.0	1.0	1.0	35	8.5	20	7.0	10	10	35	61	48	33	70	82
	2	-	-	-	-	-	-	2	1.0	-	-	-	-	2	8.0	-	-	-	-	2	83	15	-	-	-
	4	-	-	-	-	-	-	5	1.0	-	1.0	1.0	1.0	5	8.2	13	7.5	8.0	8.0	5	89	13	80	91	99
	8+	-	-	-	-	-	-	4	1.0	-	1.0	1.0	1.0	4	8.5	28	8.0	9.5	10	4	55	35	40	50	65
	ALL	-	-	-	-	-	-	46	1.0	4.2	1.0	1.0	1.0	46	8.5	19	7.0	8.0	10	46	64	43	40	74	89
Whole exam	1	35	2.0	40	1.0	2.0	2.0	69	1.0	15	1.0	1.0	1.0	69	6.8	36	5.0	7.0	10	35	114	11	110	110	113
	2	3	1.7	35	1.5	2.0	2.0	5	1.0	-	1.0	1.0	1.0	5	6.2	27	5.0	5.0	8.0	3	109	4.2	107	110	112
	4	13	1.5	36	1.0	1.0	2.0	19	0.98	14	1.0	1.0	1.0	19	5.6	33	4.5	5.0	7.0	13	118	26	110	110	113
	8+	4	2.0	41	1.8	2.0	2.3	8	0.93	23	1.0	1.0	1.0	8	6.4	43	4.9	5.0	9.3	4	114	3.7	112	113	115
	ALL	55	1.8	40	1.0	2.0	2.0	101	1.0	16	1.0	1.0	1.0	101	6.5	37	5.0	7.0	8.0	55	114	15	110	110	113

TABLE C5 (continued)

Scan region	Slice[c] class	No. of sequences						Pitch						Imaged slice width (mm)						Scan length (mm)					
		No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th
Head (trauma including non-accidental injury): 10 y old																									
Post fossa	1	-	-	-	-	-	-	25	1.1	20	1.0	1.0	1.0	25	4.2	23	3.0	5.0	5.0	25	30	32	21	31	38
	2	-	-	-	-	-	-	2	1.0	-	-	-	-	2	5.0	-	-	-	-	2	31	35	-	-	-
	4	-	-	-	-	-	-	6	1.0	-	1.0	1.0	1.0	6	3.9	20	4.0	4.0	4.0	6	25	46	16	22	34
	8+	-	-	-	-	-	-	2	1.0	-	-	-	-	2	5.0	-	-	-	-	2	48	7.4	-	-	-
	ALL	-	-	-	-	-	-	35	1.1	18	1.0	1.0	1.0	35	4.2	21	3.0	5.0	5.0	35	30	35	21	31	38
Cerebrum	1	-	-	-	-	-	-	38	1.0	-	1.0	1.0	1.0	38	8.8	20	8.0	10	10	38	65	48	32	74	90
	2	-	-	-	-	-	-	2	1.0	-	-	-	-	2	8.0	-	-	-	-	2	88	15	-	-	-
	4	-	-	-	-	-	-	6	1.0	-	1.0	1.0	1.0	6	8.2	11	7.6	8.0	8.0	6	94	13	84	96	104
	8+	-	-	-	-	-	-	3	1.0	-	1.0	1.0	1.0	3	8.3	35	7.5	10	10	3	40	25	35	40	45
	ALL	-	-	-	-	-	-	49	1.0	-	1.0	1.0	1.0	49	8.7	20	8.0	10	10	49	68	45	38	78	95
Whole exam	1	31	2.2	32	2.0	2.0	2.5	67	1.0	13	1.0	1.0	1.0	67	7.1	38	5.0	7.0	10	31	119	9.7	116	116	120
	2	2	2.0	-	-	-	-	4	1.0	-	1.0	1.0	1.0	4	6.5	27	5.0	6.5	8.0	2	118	2.4	-	-	-
	4	13	1.5	34	1.0	2.0	2.0	20	0.98	7.3	1.0	1.0	1.0	20	5.9	36	4.0	5.0	7.6	13	127	27	116	116	120
	8+	3	2.0	50	1.5	2.0	2.5	6	0.90	27	1.0	1.0	1.0	6	6.3	46	5.0	5.0	8.8	3	112	17	105	120	123
	ALL	49	2.0	35	2.0	2.0	2.0	97	1.0	13	1.0	1.0	1.0	97	6.8	38	5.0	7.0	10	49	120	17	116	116	120

Notes:

[a]Including sample size, mean, coefficient of variation (%CV) and percentile points (25th, 50th and 75th) for each data distribution.

[b]Including only *Routine* sequences.

[c]Slice class refers to the maximum number of simultaneous tomographic sections acquired per rotation (i.e. the maximum number of detector channels available for simultaneous data acquisition).

TABLE C6 Comparison[a] by scanner slice class of doses for standard examination protocols[b]

Scan region	Slice[c] class	$CTDI_w$ (mGy)[d, e]						$CTDI_{vol}$ (mGy)[d, e]						DLP (mGy cm)[d, e]						E (mSv)					
		No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th
Adult patients																									
Routine head (acute stroke)																									
Post fossa	1	60	61	33	50	59	71	60	54	34	42	50	64	60	177	45	122	157	228	60	0.4	45	0.3	0.3	0.5
	2	5	48	15	41	50	53	5	48	15	41	50	53	5	141	37	112	117	162	5	0.3	37	0.2	0.2	0.3
	4	20	89	25	68	85	100	20	88	24	68	85	99	20	277	37	215	255	366	20	0.6	37	0.5	0.5	0.8
	8+	7	98	36	72	106	124	7	97	37	72	98	124	7	307	49	210	311	428	7	0.6	49	0.4	0.7	0.9
	ALL	92	69	37	50	63	82	92	65	40	45	60	80	92	207	50	125	198	254	92	0.4	50	0.3	0.4	0.5
Cerebrum	1	79	47	27	38	49	56	79	47	27	37	49	56	79	357	54	218	381	476	79	0.7	54	0.5	0.8	1.0
	2	5	44	25	37	45	50	5	44	25	37	45	50	5	386	22	300	426	450	5	0.8	22	0.6	0.9	0.9
	4	26	54	31	46	49	62	26	54	31	46	49	62	26	408	45	351	407	546	26	0.9	45	0.7	0.9	1.1
	8+	10	58	22	54	55	70	10	57	21	54	55	66	10	383	49	212	406	529	10	0.8	49	0.4	0.9	1.1
	ALL	120	49	28	40	49	57	120	49	28	40	49	57	120	371	50	230	390	491	120	0.8	50	0.5	0.8	1.0
Whole exam	1	152	53	33	40	50	63	152	51	31	39	50	59	74	639	34	497	609	760	74	1.3	34	1.0	1.3	1.6
	2	11	47	19	41	50	55	11	47	19	41	50	55	6	532	18	486	561	576	6	1.1	18	1.0	1.2	1.2
	4	57	67	37	49	63	79	57	67	36	49	63	80	30	831	46	655	693	895	30	1.7	46	1.4	1.5	1.9
	8+	18	71	47	54	59	85	18	72	43	54	59	85	8	820	30	629	871	1015	8	1.7	30	1.3	1.8	2.1
	ALL	238	57	38	45	53	66	238	56	38	42	51	64	118	694	40	561	643	787	118	1.5	40	1.2	1.3	1.7

TABLE C6 (continued)

Scan region	Slice[c] class	$CTDI_w$ (mGy)[d, e]						$CTDI_{vol}$ (mGy)[d, e]						DLP (mGy cm)[d, e]						E (mSv)					
		No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th
Abdomen (liver metastases)																									
Abdo/ Pelvis	1	23	16	39	10	14	23	23	11	42	6.7	9.5	15	23	287	64	141	224	337	23	4.3	64	2.1	3.4	5.1
	2	2	14	16	13	14	14	2	9.1	16	8.6	9.1	9.6	2	368	14	349	368	386	2	5.5	14	5.2	5.5	5.8
	4	15	18	20	17	18	21	15	14	14	13	13	14	15	328	38	259	274	346	15	4.9	38	3.9	4.1	5.2
	8+	4	14	62	9.6	10	15	4	13	37	11	11	13	4	257	37	208	211	261	4	3.9	37	3.1	3.2	3.9
	ALL	44	17	34	12	15	22	44	12	33	8.8	12	14	44	302	51	208	267	358	44	4.5	51	3.1	4.0	5.4
Liver	1	54	16	25	13	15	19	54	12	38	8.9	10	13	54	199	43	145	175	219	54	3.0	43	2.2	2.6	3.3
	2	4	14	5.3	14	14	15	4	10	13	9.2	9.7	11	4	181	18	159	178	199	4	2.7	18	2.4	2.7	3.0
	4	14	17	15	16	16	19	14	13	19	11	13	14	14	230	26	199	205	274	14	3.5	26	3.0	3.1	4.1
	8+	1	20	-	-	-	-	1	15	-	-	-	-	1	533	-	-	-		1	8.0	-	-	-	-
	ALL	73	16	23	13	15	19	73	12	34	9.1	11	13	73	209	42	149	189	222	73	3.1	42	2.2	2.8	3.3
Whole exam	1	77	16	30	13	15	20	77	11	39	7.9	10	13	51	340	73	161	263	455	51	5.1	73	2.4	3.9	6.8
	2	6	14	8.4	14	14	15	6	9.8	13	9.2	9.7	10	5	292	61	163	192	405	5	4.4	61	2.4	2.9	6.1
	4	29	18	18	16	18	20	29	13	17	12	13	14	20	407	59	264	329	484	20	6.1	59	4.0	4.9	7.3
	8+	5	15	52	9.6	11	20	5	13	32	11	11	15	5	312	47	208	215	399	5	4.7	47	3.1	3.2	6.0
	ALL	117	16	28	13	15	20	117	12	33	9.1	11	14	81	352	67	175	276	472	81	5.3	67	2.6	4.1	7.1
Abdomen & pelvis (abscess)																									
Whole exam	1	79	15	31	12	14	18	79	11	40	7.9	9.5	13	64	450	53	297	396	508	64	6.8	53	4.5	5.9	7.6
	2	4	15	14	14	14	16	4	11	16	9.2	11	12	4	410	13	378	419	451	4	6.2	13	5.7	6.3	6.8
	4	25	17	29	15	17	21	25	13	28	11	13	14	22	539	36	420	476	557	22	8.1	36	6.3	7.1	8.4
	8+	7	17	38	12	15	20	7	13	29	11	11	13	7	518	28	421	429	573	7	7.8	28	6.3	6.4	8.6
	ALL	115	16	31	13	15	19	115	11	36	8.7	11	13	97	473	47	356	422	534	97	7.1	47	5.3	6.3	8.0

TABLE C6 (continued)

Scan region	Slice[c] class	$CTDI_w$ (mGy)[d, e]						$CTDI_{vol}$ (mGy)[d, e]						DLP (mGy cm)[d, e]						E (mSv)					
		No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th
Chest, abdomen & pelvis (lymphoma staging or follow up)																									
Lung	1	41	11	41	7.7	10	12	41	8.0	52	5.3	6.6	10	41	187	55	117	170	229	41	2.6	55	1.6	2.4	3.2
	2	3	12	8.2	12	13	13	3	7.9	12	7.4	7.6	8.3	3	198	12	185	190	207	3	2.8	12	2.6	2.7	2.9
	4	18	14	22	12	14	17	18	10	22	8.6	10	12	18	270	29	229	268	309	18	3.8	29	3.2	3.8	4.3
	8+	6	15	46	11	14	14	6	11	50	7.7	8.4	10	6	254	56	177	196	251	6	3.6	56	2.5	2.7	3.5
	ALL	68	12	37	8.9	11	15	68	8.8	44	5.9	7.9	11	68	215	48	133	199	250	68	3.0	48	1.9	2.8	3.5
Abdo/ pelvis	1	51	15	28	12	15	17	51	11	40	7.9	9.6	12	51	321	45	226	297	367	51	4.8	45	3.4	4.5	5.5
	2	3	16	16	14	15	17	3	11	16	10	12	12	3	397	15	367	399	428	3	6.0	15	5.5	6.0	6.4
	4	19	18	18	16	18	20	19	14	20	12	13	14	19	574	36	430	494	669	19	8.6	36	6.4	7.4	10
	8+	6	18	31	16	17	18	6	13	31	11	11	13	6	475	34	386	425	467	6	7.1	34	5.8	6.4	7.0
	ALL	79	16	27	13	15	18	79	12	35	9.0	11	13	79	396	49	265	366	464	79	6.0	49	4.0	5.5	7.0
Whole exam	1	111	13	35	9.8	13	17	111	9.6	44	6.5	8.7	12	58	596	41	429	535	762	58	8.8	41	6.4	7.9	11
	2	7	14	19	12	13	14	7	9.1	24	7.4	8.9	10	4	554	16	528	569	596	4	8.2	15	7.7	8.3	8.8
	4	47	17	26	14	17	19	47	12	29	11	12	13	28	823	34	685	748	966	28	12	34	10	11	14
	8+	14	16	39	11	15	18	14	11	38	8.7	10	11	8	701	37	566	620	705	8	10	37	8.3	9.1	10
	ALL	179	14	34	11	14	17	179	10	40	7.2	9.9	12	98	668	40	482	618	786	98	9.9	40	7.1	9.2	12

TABLE C6 (continued)

Scan region	Slice[c] class	$CTDI_w$ (mGy)[d, e]						$CTDI_{vol}$ (mGy)[d, e]						DLP (mGy cm)[d, e]						E (mSv)					
		No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th
Chest (lung cancer: known, suspected or metastases)																									
Lung	1	59	11	37	7.7	11	13	59	8.0	48	5.2	7.2	9.6	59	174	53	118	159	218	59	2.4	53	1.7	2.2	3.1
	2	5	11	29	11	11	13	5	7.7	37	7.2	7.6	7.6	5	177	45	122	180	190	5	2.5	45	1.7	2.5	2.7
	4	18	15	18	14	15	18	18	11	24	10	11	13	18	284	29	246	271	291	18	4.0	29	3.4	3.8	4.1
	8+	6	15	51	10	14	19	6	11	48	7.5	9.4	12	6	266	53	180	202	317	6	3.7	53	2.5	2.8	4.4
	ALL	88	12	37	8.9	11	15	88	8.9	44	6.0	8.0	11	88	203	51	129	194	259	88	2.8	51	1.8	2.7	3.6
Liver	1	37	15	27	12	14	17	37	10	38	7.9	9.1	11	37	177	44	127	153	188	37	2.6	44	1.9	2.3	2.8
	2	1	11	-	-	-	-	1	7.6	-	-	-	-	1	149	-	-	-	-	1	2.2	-	-	-	-
	4	15	18	17	16	17	19	15	14	19	12	13	15	15	257	41	201	212	266	15	3.9	41	3.0	3.2	4.0
	8+	3	15	35	13	17	18	3	12	8.2	11	12	12	3	205	14	195	219	222	3	3.1	14	2.9	3.3	3.3
	ALL	56	15	26	13	15	18	56	11	34	8.7	11	13	56	199	45	145	178	225	56	3.0	45	2.2	2.7	3.4
Whole exam	1	118	13	37	9.6	12	16	118	9.2	44	6.4	8.3	11	69	356	52	235	314	427	69	5.1	52	3.4	4.5	6.2
	2	9	11	20	11	11	12	9	7.7	26	7.4	7.6	7.9	5	338	44	276	345	466	5	4.8	44	3.9	5.0	6.7
	4	46	17	20	15	16	18	46	12	24	11	12	13	29	503	30	392	482	575	29	7.2	30	5.7	6.8	8.3
	8+	12	16	41	13	16	20	12	12	38	9.7	10	12	7	479	47	366	407	536	7	6.8	46	5.3	5.9	7.6
	ALL	185	14	35	11	14	17	185	10	40	7.2	9.6	12	110	402	47	267	375	488	110	5.8	47	3.9	5.3	6.9
Chest: Hi-resolution (diffuse lung disease)																									
Whole exam	1	81	19	47	12	16	22	81	2.2	64	1.2	1.8	3.0	67	64	75	36	51	77	67	0.9	75	0.5	0.7	1.1
	2	5	15	58	9.8	12	24	5	1.8	40	1.6	2.0	2.4	5	39	55	20	35	61	5	0.5	55	0.3	0.5	0.9
	4	33	36	49	22	33	48	33	5.2	70	2.5	4.0	7.1	29	146	71	69	115	178	29	2.0	71	1.0	1.6	2.5
	8+	8	40	60	25	43	49	8	5.3	52	3.4	5.4	6.1	7	106	42	86	101	128	7	1.5	42	1.2	1.4	1.8
	ALL	127	25	63	13	20	33	127	3.2	84	1.4	2.4	4.0	108	88	87	38	62	104	108	1.2	87	0.5	0.9	1.5

TABLE C6 (continued)

Scan region	Slice[c] class	$CTDI_w$ (mGy)[d, e]						$CTDI_{vol}$ (mGy)[d, e]						DLP (mGy cm)[d, e]						E (mSv)					
		No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th
Paediatric patients																									
Chest (detection of malignancy): 0-1 y old																									
Whole exam	1	15	17	62	7.3	14	25	15	12	75	5.6	10	13	14	169	78	72	128	238	14	6.7	78	2.8	5.0	9.3
	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	4	4	14	62	9.6	14	18	4	10	61	7.6	11	13	4	176	70	128	174	221	4	6.8	70	5.0	6.8	8.6
	8+	2	3.8	93	-	-	-	2	4.1	97	-	-	-	2	60	101	-	-	-	2	2.3	101	-	-	-
	ALL	21	15	68	7.2	12	23	21	11	76	5.1	9.5	12	20	159	78	68	128	204	20	6.3	79	2.6	5.0	7.9
Chest (detection of malignancy): 5 y old																									
Whole exam	1	13	17	47	11	17	20	13	12	57	7.7	11	14	13	205	58	122	197	236	13	3.7	58	2.2	3.6	4.2
	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	4	4	15	44	11	14	18	4	11	44	8.4	11	13	4	222	57	165	206	263	4	4.0	57	3.0	3.7	4.7
	8+	2	5.5	102	-	-	-	2	6.0	105	-	-	-	2	104	108	-	-	-	2	1.9	108	-	-	-
	ALL	19	16	53	10	15	20	19	11	58	7.6	10	13	19	198	60	119	192	228	19	3.6	60	2.1	3.5	4.1
Chest (detection of malignancy): 10 y old																									
Whole exam	1	13	20	38	14	18	22	13	14	53	9.5	12	15	13	307	53	194	287	327	13	4.0	53	2.5	3.7	4.3
	2	1	27	-	-	-	-	1	18	-	-	-	-	1	368	-	-	-	-	1	4.8	-	-	-	-
	4	5	19	52	12	14	27	5	14	52	9.5	10	19	5	336	67	174	287	399	5	4.4	67	2.3	3.7	5.2
	8+	2	6.5	91	-	-	-	2	7.1	96	-	-	-	2	158	99	-	-	-	2	2.1	99	-	-	-
	ALL	21	19	46	13	17	26	21	14	53	9.5	12	17	21	303	57	174	287	368	21	3.9	57	2.3	3.7	4.8

TABLE C6 (continued)

Scan region	Slice[c] class	$CTDI_w$ (mGy)[d, e]						$CTDI_{vol}$ (mGy)[d, e]						DLP (mGy cm)[d, e]						E (mSv)					
		No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th
Head (trauma including non-accidental injury): 0–1 y old																									
Post fossa	1	17	32	44	24	28	36	17	31	49	24	28	36	17	82	60	47	73	99	17	0.9	60	0.5	0.8	1.1
	2	2	16	6.7	-	-	-	2	16	6.7	-	-	-	2	38	42	-	-	-	2	0.4	42	-	-	-
	4	6	30	44	25	27	33	6	30	44	25	27	33	6	61	48	45	72	74	6	0.7	48	0.5	0.8	0.8
	8+	3	28	28	26	32	33	3	28	28	26	32	33	3	99	45	77	100	122	3	1.1	45	0.8	1.1	1.3
	ALL	28	30	44	23	26	34	28	29	47	21	26	34	28	76	59	46	72	96	28	0.8	59	0.5	0.8	1.1
Cerebrum	1	21	25	50	18	21	28	21	25	51	18	21	28	21	151	66	87	127	216	21	1.7	66	1.0	1.4	2.4
	2	2	13	-	-	-	-	2	13	-	-	-	-	2	94	15	-	-	-	2	1.0	15	-	-	-
	4	6	20	46	14	19	29	6	20	46	14	19	29	6	156	51	108	125	213	6	1.7	50	1.2	1.4	2.3
	8+	3	21	7.8	20	20	21	3	21	7.8	20	20	21	3	143	13	133	134	149	3	1.6	13	1.5	1.5	1.6
	ALL	32	23	49	17	21	28	32	23	49	17	21	28	32	148	60	95	129	188	32	1.6	60	1.0	1.4	2.1
Whole exam	1	56	27	47	19	24	28	56	26	49	19	23	28	35	244	47	176	201	277	35	2.7	47	1.9	2.2	3.0
	2	5	14	9.0	13	14	15	5	14	9.0	13	14	15	3	129	3.0	128	130	132	3	1.4	3.0	1.4	1.4	1.4
	4	21	21	50	14	18	28	21	22	49	14	24	28	14	199	41	150	196	254	14	2.2	41	1.7	2.2	2.8
	8+	7	23	32	19	20	27	7	27	34	20	22	33	4	286	35	222	271	335	4	3.1	35	2.4	3.0	3.7
	ALL	89	24	48	16	22	28	89	25	49	16	22	28	56	230	46	160	201	270	56	2.5	46	1.8	2.2	3.0

TABLE C6 (continued)

Scan region	Slice[c] class	$CTDI_w$ (mGy)[d, e]						$CTDI_{vol}$ (mGy)[d, e]						DLP (mGy cm)[d, e]						E (mSv)					
		No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th
Head (trauma including non-accidental injury): 5 y old																									
Post fossa	1	24	40	39	30	36	45	24	37	40	29	36	42	24	110	55	62	104	134	24	0.4	55	0.2	0.4	0.5
	2	2	27	14	-	-	-	2	27	14	-	-	-	2	77	21	-	-	-	2	0.3	21	-	-	-
	4	5	53	29	50	50	51	5	53	29	50	50	51	5	116	48	72	86	173	5	0.5	48	0.3	0.3	0.7
	8+	3	48	7.6	46	47	49	3	48	7.6	46	47	49	3	197	27	166	178	218	3	0.8	27	0.7	0.7	0.9
	ALL	34	42	37	30	37	50	34	39	38	30	36	49	34	117	53	70	104	152	34	0.5	53	0.3	0.4	0.6
Cerebrum	1	35	33	45	21	29	43	35	33	46	21	29	43	35	207	66	85	205	272	35	0.8	66	0.3	0.8	1.1
	2	2	20	-	-	-	-	2	20	-	-	-	-	2	164	15	-	-	-	2	0.7	15	-	-	-
	4	5	34	27	27	32	41	5	34	27	27	32	41	5	298	27	265	304	314	5	1.2	27	1.1	1.2	1.3
	8+	4	33	30	28	29	34	4	33	30	28	29	34	4	192	66	112	146	226	4	0.8	66	0.4	0.6	0.9
	ALL	46	33	42	21	29	42	46	32	43	21	29	42	46	214	61	115	200	297	46	0.9	61	0.5	0.8	1.2
Whole exam	1	69	35	42	24	35	43	69	34	42	24	33	42	35	387	37	286	398	465	35	1.5	37	1.1	1.6	1.9
	2	5	25	23	20	25	30	5	25	23	20	25	30	3	275	21	241	247	294	3	1.1	21	1.0	1.0	1.2
	4	19	35	44	24	32	43	19	36	42	26	34	43	13	368	43	258	377	442	13	1.5	43	1.0	1.5	1.8
	8+	8	36	34	28	37	47	8	40	26	29	46	47	4	471	15	423	480	528	4	1.9	15	1.7	1.9	2.1
	ALL	101	35	41	24	33	43	101	34	41	24	33	43	55	383	37	280	385	465	55	1.5	37	1.1	1.5	1.9

TABLE C6 (continued)

Scan region	Slice[c] class	$CTDI_w$ (mGy)[d, e]						$CTDI_{vol}$ (mGy)[d, e]						DLP (mGy cm)[d, e]						E (mSv)					
		No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th	No.	Mean	%CV	25th	50th	75th
Head (trauma including non-accidental injury): 10 y old																									
Post fossa	1	25	53	40	38	50	64	25	49	33	38	48	63	25	154	51	92	141	223	25	0.5	51	0.3	0.5	0.7
	2	2	37	16	-	-	-	2	37	16	-	-	-	2	109	20	-	-	-	2	0.4	20	-	-	-
	4	6	72	29	58	80	84	6	72	29	58	80	84	6	177	54	126	172	180	6	0.6	54	0.4	0.6	0.6
	8+	2	65	15	-	-	-	2	65	15	-	-	-	2	308	7.7	-	-	-	2	1.0	7.7	-	-	-
	ALL	35	56	38	40	51	68	35	53	35	40	50	65	35	164	52	100	143	231	35	0.5	52	0.3	0.5	0.7
Cerebrum	1	38	38	40	28	37	45	38	38	40	28	37	45	38	255	63	108	264	383	38	0.8	63	0.3	0.8	1.2
	2	2	28	6.7	-	-	-	2	28	6.7	-	-	-	2	245	22	-	-	-	2	0.8	22	-	-	-
	4	6	46	28	35	47	49	6	46	28	35	47	49	6	428	31	348	413	502	6	1.4	31	1.1	1.3	1.6
	8+	3	40	11	37	39	42	3	40	11	37	39	42	3	163	36	132	156	190	3	0.5	36	0.4	0.5	0.6
	ALL	49	38	37	29	37	46	49	38	37	29	37	46	49	270	60	141	270	386	49	0.9	60	0.5	0.9	1.2
Whole exam	1	67	43	43	32	40	51	67	42	39	32	40	50	31	494	32	415	479	575	31	1.6	32	1.3	1.5	1.8
	2	4	32	19	29	31	35	4	32	19	29	31	35	2	355	9.1	-	-	-	2	1.1	9.1	-	-	-
	4	20	50	42	32	48	58	20	50	41	32	48	58	13	554	38	407	563	635	13	1.8	38	1.3	1.8	2.0
	8+	6	45	41	37	42	55	6	49	27	40	46	55	3	555	19	504	560	608	3	1.8	19	1.6	1.8	1.9
	ALL	97	44	43	31	40	52	97	44	39	32	40	51	49	508	34	402	479	619	49	1.6	34	1.3	1.5	2.0

Notes:

[a]Including sample size, mean, coefficient of variation (%CV) and percentile points (25th, 50th and 75th) for each data distribution.

[b]Including only *Routine* sequences.

[c]Slice class refers to the maximum number of simultaneous tomographic sections acquired per rotation (i.e. the maximum number of detector channels available for simultaneous data acquisition).

[d]For examinations of the adult head and children, calculated values of $CTDI_w$, $CTDI_{vol}$ and DLP relate to the 16 cm diameter CT dosimetry phantom.

[e]For examinations of the adult trunk, calculated values of $CTDI_w$, $CTDI_{vol}$ and DLP relate to the 32 cm diameter CT dosimetry phantom.

TABLE C7 Comparison[a] between single- and multi-slice scanners of doses for standard examination protocols[b]

Examination (indication)	Scan region	Slice group[c]	Scan length (mm)			$CTDI_{vol}$ (mGy)[d, e]			DLP (mGy cm)[d, e]			E (mSv)		
			No.	Mean	%CV	No.	Mean	%CV	No.	Mean	%CV	No.	Mean	%CV
Adult patients														
Routine head (acute stroke)	Post fossa	S	60	32	27	60	54	34	60	177	45	60	0.4	45
		D	5	29	32	5	48	15	5	141	37	5	0.3	37
		M	27	31	29	27	90	28	27	285	40	27	0.6	40
	Cerebrum	S	79	73	44	79	47	27	79	357	54	79	0.7	54
		D	5	90	12	5	44	25	5	386	22	5	0.8	22
		M	36	73	41	36	54	28	36	401	46	36	0.8	46
	Whole exam	S	74	126	22	152	51	31	74	639	34	74	1.3	34
		D	6	116	7.2	11	47	19	6	532	18	6	1.1	18
		M	38	131	26	75	68	38	38	828	43	38	1.7	43
Abdomen (liver metastases)	Abdo/ Pelvis	S	23	260	37	23	11	42	23	287	64	23	4.3	64
		D	2	403	1.1	2	9.1	16	2	368	14	2	5.5	14
		M	19	231	37	19	14	19	19	313	38	19	4.7	38
	Liver	S	54	170	19	54	12	38	54	199	43	54	3.0	43
		D	4	181	22	4	10	13	4	181	18	4	2.7	18
		M	15	191	31	15	13	19	15	250	39	15	3.8	39
	Whole exam	S	51	297	45	77	11	39	51	340	73	51	5.1	73
		D	5	306	71	6	9.8	13	5	292	61	5	4.4	61
		M	25	290	60	34	13	19	25	388	58	25	5.8	58
Abdomen & pelvis (abscess)	Whole exam	S	64	414	24	79	11	40	64	450	53	64	6.8	53
		D	4	390	7.6	4	11	16	4	410	13	4	6.1	13
		M	29	411	31	32	13	27	29	534	34	29	8.0	34

TABLE C7 (continued)

Examination (indication)	Scan region	Slice group[c]	Scan length (mm)			$CTDI_{vol}$ (mGy)[d, e]			DLP (mGy cm)[d, e]			E (mSv)		
			No.	Mean	%CV	No.	Mean	%CV	No.	Mean	%CV	No.	Mean	%CV
Chest, abdomen & pelvis (lymphoma staging or follow up)	Lung	S	41	236	25	41	8.0	52	41	187	55	41	2.6	55
		D	3	250	-	3	7.9	12	3	198	12	3	2.8	12
		M	24	259	23	24	10	31	24	266	35	24	3.7	35
	Abdo/ pelvis	S	51	312	31	51	11	40	51	321	45	51	4.8	45
		D	3	361	6.6	3	11	16	3	397	15	3	6.0	15
		M	25	409	31	25	13	22	25	550	36	25	8.2	36
	Whole exam	S	58	625	16	111	9.6	44	58	596	41	58	8.8	41
		D	4	613	3.2	7	9.1	24	4	554	16	4	8.2	15
		M	36	654	23	61	12	31	36	796	34	36	12	34
Chest (lung cancer: known, suspected or metastases)	Lung	S	59	215	28	59	8.0	48	59	174	53	59	2.4	53
		D	5	235	28	5	7.7	37	5	177	45	5	2.5	45
		M	24	247	15	24	11	30	24	280	35	24	3.9	35
	Liver	S	37	170	14	37	10	38	37	177	44	37	2.6	44
		D	1	197	-	1	7.6	-	1	149	-	1	2.2	-
		M	18	184	26	18	13	19	18	248	39	18	3.7	39
	Whole exam	S	69	381	24	118	9.2	44	69	356	52	69	5.1	52
		D	5	441	25	9	7.7	26	5	338	44	5	4.8	44
		M	36	409	21	58	12	27	36	499	33	36	7.1	33
Chest: Hi-resolution (diffuse lung disease)	Whole exam	S	67	280	29	81	2.2	64	67	64	75	67	0.9	75
		D	5	214	30	5	1.8	40	5	39	55	5	0.5	55
		M	36	267	26	41	5.2	66	36	138	70	36	1.9	70
Paediatric patients														
Chest (detection of malignancy): 0-1 y old	Whole exam	S	14	145	26	15	12	75	14	169	78	14	6.7	78
		D	-	-	-	-	-	-	-	-	-	-	-	-
		M	6	156	20	6	8.1	74	6	137	85	6	5.3	85
Chest (detection of malignancy): 5 y old	Whole exam	S	13	165	19	13	12	57	13	205	58	13	3.7	58
		D	-	-	-	-	-	-	-	-	-	-	-	-
		M	6	186	20	6	9.3	57	6	183	69	6	3.3	69

TABLE C7 (continued)

Examination (indication)	Scan region	Slice group[c]	Scan length (mm)			$CTDI_{vol}$ (mGy)[d, e]			DLP (mGy cm)[d, e]			E (mSv)		
			No.	Mean	%CV	No.	Mean	%CV	No.	Mean	%CV	No.	Mean	%CV
Chest (detection of malignancy): 10 y old	Whole exam	S	13	216	18	13	14	53	13	307	53	13	4.0	53
		D	1	205	-	1	18	-	1	368	-	1	4.8	-
		M	7	231	22	7	12	61	7	285	75	7	3.7	75
Head (trauma including non-accidental injury): 0–1 y old	Post fossa	S	17	27	36	17	31	49	17	82	60	17	0.9	60
		D	2	24	35	2	16	6.7	2	38	42	2	0.4	42
		M	9	25	43	9	29	38	9	73	51	9	0.8	51
	Cerebrum	S	21	57	36	21	25	51	21	151	66	21	1.7	66
		D	2	71	15	2	13	-	2	94	15	2	1.0	15
		M	9	74	13	9	21	37	9	152	42	9	1.7	42
	Whole exam	S	35	96	11	56	26	49	35	244	47	35	2.7	47
		D	3	92	5.0	5	14	9.0	3	129	3.0	3	1.4	3.0
		M	18	101	23	28	23	45	18	218	42	18	2.4	42
Head (trauma including non-accidental injury): 5 y old	Post fossa	S	24	30	32	24	37	40	24	110	55	24	0.4	55
		D	2	29	34	2	27	14	2	77	21	2	0.3	21
		M	8	29	44	8	51	24	8	146	45	8	0.6	45
	Cerebrum	S	35	61	48	35	33	46	35	207	66	35	0.8	66
		D	2	83	15	2	20	-	2	164	15	2	0.7	15
		M	9	74	31	9	33	27	9	251	44	9	1.0	44
	Whole exam	S	35	114	11	69	34	42	35	387	37	35	1.5	37
		D	3	109	4.2	5	25	23	3	275	21	3	1.1	21
		M	17	117	23	27	37	37	17	393	37	17	1.6	37

TABLE C7 (continued)

Examination (indication)	Scan region	Slice group[c]	Scan length (mm)			$CTDI_{vol}$ (mGy)[d, e]			DLP (mGy cm)[d, e]			E (mSv)		
			No.	Mean	%CV	No.	Mean	%CV	No.	Mean	%CV	No.	Mean	%CV
Head (trauma including non-accidental injury): 10 y old	Post fossa	S	25	30	32	25	49	33	25	154	51	25	0.5	51
		D	2	31	35	2	37	16	2	109	20	2	0.4	20
		M	8	31	47	8	70	26	8	210	48	8	0.7	48
	Cerebrum	S	38	65	48	38	38	40	38	255	63	38	0.8	63
		D	2	88	15	2	28	6.7	2	245	22	2	0.8	22
		M	9	76	38	9	44	25	9	339	51	9	1.1	51
	Whole exam	S	31	119	9.7	67	42	39	31	494	32	31	1.6	32
		D	2	118	2.4	4	32	19	2	355	9.1	2	1.1	9.1
		M	16	124	26	26	50	38	16	554	35	16	1.8	35

Notes:

[a]Including sample size, mean, coefficient of variation (%CV) and percentile points (25^{th}, 50^{th} and 75^{th}) for each data distribution.

[b]Including only *Routine* sequences.

[c]Slice group refers to single (S), dual (D) or multislice (4+) (M) scan capability.

[d]For examinations of the adult head and children, calculated values of $CTDI_{vol}$ and DLP relate to the 16 cm diameter CT dosimetry phantom.

[e]For examinations of the adult trunk, calculated values of $CTDI_{vol}$ and DLP relate to the 32 cm diameter CT dosimetry phantom.

TABLE C8 Analysis by examination type of the ratio of the mean dose for a group of adult patients relative to the dose for the corresponding standard protocol at each individual CT scanner

Examination (indication)	Dose quantity	Analysis[a] of dose ratios (Mean patient group/ Protocol) for individual CT scanners							
		No.	Mean	%CV	Min	25th	50th	75th	Max
Including only Routine sequences in each Standard protocol									
Routine head (acute stroke)	DLP per exam	55	1.10	32	0.51	0.98	1.03	1.12	3.14
Abdomen (liver metastases)	DLP per exam	24	1.48	67	0.59	1.04	1.21	1.57	5.32
Abdomen & pelvis (abscess)	DLP per exam	30	1.10	18	0.82	1.01	1.11	1.15	1.78
Chest, abdomen & pelvis (lymphoma staging or follow up)	DLP per exam	36	1.00	15	0.65	0.91	1.00	1.09	1.35
Chest (lung cancer: known, suspected or metastases)	DLP per exam	49	1.06	33	0.52	0.90	1.02	1.14	2.82
Chest: Hi-resolution (diffuse lung disease)	DLP per exam	42	1.11	35	0.15	0.95	1.05	1.19	2.67
ALL	DLP per exam	236	1.12	40	0.15	0.94	1.04	1.17	5.32
Including all sequences (Routine and Ad-hoc) in each Standard protocol									
Routine head (acute stroke)	$CTDI_w$ per sequence	92	1.02	11	0.66	1.00	1.00	1.00	1.51
	$CTDI_{vol}$ per sequence	92	1.02	11	0.66	1.00	1.00	1.00	1.51
	DLP per exam	55	0.94	30	0.35	0.81	1.00	1.07	1.76
Abdomen (liver metastases)	$CTDI_w$ per sequence	21	1.03	20	0.71	1.00	1.00	1.02	1.71
	$CTDI_{vol}$ per sequence	21	1.02	13	0.80	1.00	1.00	1.00	1.48
	DLP per exam	24	1.45	69	0.59	1.02	1.20	1.54	5.32
Abdomen & pelvis (abscess)	$CTDI_w$ per sequence	32	0.99	15	0.50	1.00	1.00	1.00	1.30
	$CTDI_{vol}$ per sequence	32	1.01	13	0.62	1.00	1.00	1.01	1.30
	DLP per exam	30	1.04	23	0.43	0.91	1.08	1.14	1.78
Chest, abdomen & pelvis (lymphoma staging or follow up)	$CTDI_w$ per sequence	57	0.99	9.5	0.71	1.00	1.00	1.00	1.46
	$CTDI_{vol}$ per sequence	57	0.99	8.7	0.73	0.99	1.00	1.00	1.46
	DLP per exam	36	1.00	15	0.65	0.91	1.00	1.09	1.35

TABLE C8 (continued)

Examination (indication)	Dose quantity	Analysis[a] of dose ratios (Mean patient group/ Protocol) for individual CT scanners							
		No.	Mean	%CV	Min	25th	50th	75th	Max
Chest (lung cancer: known, suspected or metastases)	$CTDI_w$ per sequence	77	1.00	8.0	0.76	1.00	1.00	1.00	1.25
	$CTDI_{vol}$ per sequence	77	1.00	13	0.57	1.00	1.00	1.00	1.55
	DLP per exam	49	1.02	35	0.46	0.85	1.00	1.14	2.82
Chest: Hi-resolution (diffuse lung disease)	$CTDI_w$ per sequence	42	1.00	9.2	0.66	1.00	1.00	1.00	1.27
	$CTDI_{vol}$ per sequence	42	0.99	20	0.10	1.00	1.00	1.00	1.37
	DLP per exam	42	1.07	38	0.15	0.84	1.02	1.17	2.67
ALL	$CTDI_w$ per sequence	321	1.00	12	0.50	1.00	1.00	1.00	1.71
	$CTDI_{vol}$ per sequence	321	1.01	13	0.10	1.00	1.00	1.00	1.55
	DLP per exam	236	1.05	43	0.15	0.88	1.02	1.14	5.32

Note:

[a]Including sample size, mean, coefficient of variation (%CV), minimum, maximum and percentile points (25th, 50th and 75th) for each data distribution.

TABLE C9 Comparison by examination type between DLPs for standard protocols and DLPs observed for groups of individual patients (all scanners)

Examination (indication)	Data set[a]	Characteristic data[b] for DLP[c] (mGy cm) distribution (all scanners)					
		No.	Mean	%CV	25th	50th	75th
Adult patients							
Routine head (acute stroke)	Standard protocol (*Routine* sequences only)	118	694	40	561	643	787
	Standard protocol (All sequences)	118	829	45	596	698	980
	Patient groups (mean 8.3 patients per group)	57	743	27	605	700	860
	Individual patients	475	713	32	580	660	778
Abdomen (liver metastases)	Standard protocol (*Routine* sequences only)	81	352	67	175	276	472
	Standard protocol (All sequences)	81	371	64	192	328	483
	Patient groups (mean 6.7 patients per group)	28	550	65	268	475	690
	Individual patients	191	466	65	231	394	627
Abdomen & pelvis (abscess)	Standard protocol (*Routine* sequences only)	97	473	47	356	422	534
	Standard protocol (All sequences)	97	512	51	356	432	568
	Patient groups (mean 7.1 patients per group)	32	473	30	395	448	562
	Individual patients	234	473	35	354	444	574
Chest, abdomen & pelvis (lymphoma staging or follow up)	Standard protocol (*Routine* sequences only)	98	668	40	482	618	786
	Standard protocol (All sequences)	98	678	44	482	618	786
	Patient groups (mean 6.6 patients per group)	39	710	37	497	673	843
	Individual patients	256	711	40	479	663	913
Chest (lung cancer: known, suspected or metastases)	Standard protocol (*Routine* sequences only)	110	402	47	267	375	488
	Standard protocol (All sequences)	110	420	47	270	382	501
	Patient groups (mean 7.9 patients per group)	51	449	41	303	448	533
	Individual patients	404	435	48	290	403	533
Chest: Hi-resolution (diffuse lung disease)	Standard protocol (*Routine* sequences only)	108	88	87	38	62	104
	Standard protocol (All sequences)	108	93	90	40	62	105
	Patient groups (mean 7.2 patients per group)	44	85	68	49	64	113
	Individual patients	321	80	91	44	61	101

TABLE C9 (continued)

Examination (indication)	Data set[a]	Characteristic data[b] for DLP[c] (mGy cm) distribution (all scanners)					
		No.	Mean	%CV	25th	50th	75th
Paediatric patients							
Chest (detection of malignancy)	Standard protocol: 0-1 y (*Routine* sequences only)	20	159	78	68	128	204
	Standard protocol: 0-1 y (All sequences)	20	166	75	78	136	244
	Standard protocol: 5 y (*Routine* sequences only)	19	198	60	119	192	228
	Standard protocol: 5 y (All sequences)	19	208	57	122	197	264
	Standard protocol: 10 y (*Routine* sequences only)	21	303	57	174	287	368
	Standard protocol: 10 y (All sequences)	21	326	51	232	313	397
	Patient groups (mean 4.3 patients per group)	3	212	71	-	193	-
	Individual patients (mean age 8.1 y)	13	320	36	264	356	413
Head (trauma including non-accidental injury)	Standard protocol: 0-1 y (*Routine* sequences only)	56	230	46	160	201	270
	Standard protocol: 0-1 y (All sequences)	56	246	58	160	221	287
	Standard protocol: 5 y (*Routine* sequences only)	55	383	37	280	385	465
	Standard protocol: 5 y (All sequences)	55	397	42	282	391	470
	Standard protocol: 10 y (*Routine* sequences only)	49	508	34	402	479	619
	Standard protocol: 10 y (All sequences)	49	531	40	402	479	628
	Patient groups (mean 5.3 patients per group)	10	500	38	369	455	616
	Individual patients (mean age 6.1 y)	53	505	42	308	545	657

Notes:

[a]Data for Standard protocols include separate total DLPs calculated for *Routine* sequences only and for All potential sequences (*Routine* and *Ad-hoc*).

[b]Including sample size, mean, coefficient of variation (%CV) and percentile points (25th, 50th and 75th) for each data distribution.

[c]For examinations of the adult head and children, calculated values of DLP relate to the 16 cm diameter CT dosimetry phantom; for examinations of the adult trunk, calculated values of DLP relate to the 32 cm diameter CT dosimetry phantom.

TABLE C10 Comparison by examination type between numbers of sequences for standard protocols and for individual patients (all scanners)

Examination (indication)	Data set[a]	Distribution data[b] for number of sequences (all scanners)		
		No.	Mean	%CV
Adult patients				
Routine head (acute stroke)	Standard protocol (*Routine* sequences only)	118	2.0	36
	Standard protocol (All sequences)	118	2.4	40
	Individual patients	476	2.1	36
Abdomen (liver metastases)	Standard protocol (*Routine* sequences only)	81	1.4	44
	Standard protocol (All sequences)	81	1.5	41
	Individual patients	193	1.6	46
Abdomen & pelvis (abscess)	Standard protocol (*Routine* sequences only)	97	1.2	33
	Standard protocol (All sequences)	97	1.3	40
	Individual patients	239	1.3	39
Chest, abdomen & pelvis (lymphoma staging or follow up)	Standard protocol (*Routine* sequences only)	98	1.8	33
	Standard protocol (All sequences)	98	1.8	33
	Individual patients	256	1.9	36
Chest (lung cancer: known, suspected or metastases)	Standard protocol (*Routine* sequences only)	110	1.7	34
	Standard protocol (All sequences)	110	1.8	36
	Individual patients	407	1.7	41
Chest: Hi-resolution (diffuse lung disease)	Standard protocol (*Routine* sequences only)	108	1.2	36
	Standard protocol (All sequences)	108	1.3	43
	Individual patients	321	1.3	45
Paediatric patients				
Chest (detection of malignancy)	Standard protocol: 0-1 y (*Routine* sequences only)	20	1.1	21
	Standard protocol: 0-1 y (All sequences)	20	1.2	32
	Standard protocol: 5 y (*Routine* sequences only)	19	1.0	-
	Standard protocol: 5 y (All sequences)	19	1.1	29
	Standard protocol: 10 y (*Routine* sequences only)	21	1.0	-
	Standard protocol: 10 y (All sequences)	21	1.1	31
	Individual patients	16	1.1	24

TABLE C10 (continued)

Examination (indication)	Data set[a]	Distribution data[b] for number of sequences (all scanners)		
		No.	Mean	%CV
Head (trauma including non-accidental injury)	Standard protocol: 0-1 y (*Routine* sequences only)	56	1.6	39
	Standard protocol: 0-1 y (All sequences)	56	1.7	37
	Standard protocol: 5 y (*Routine* sequences only)	55	1.8	40
	Standard protocol: 5 y (All sequences)	55	1.9	39
	Standard protocol: 10 y (*Routine* sequences only)	49	2.0	35
	Standard protocol: 10 y (All sequences)	49	2.0	33
	Individual patients	56	1.8	42

Notes:

[a]Data for Standard protocols include separate total DLPs calculated for *Routine* sequences only and for All potential sequences (*Routine* and *Ad-hoc*).

[b]Including sample size, mean and coefficient of variation (%CV) .

APPENDIX D

FIGURES

FIGURE D1 Distributions over all scanners of $CTDI_w$ for *Routine* sequences of standard examination protocols for adult patients; vertical lines mark third quartile values.

FIGURE D2 Distributions over all scanners of $CTDI_{vol}$ for *Routine* sequences of standard examination protocols for adult patients; vertical lines mark third quartile values.

FIGURE D3 Distributions over all scanners of DLP for standard examination protocols for adult patients (including only *Routine* sequences); vertical lines mark third quartile values.

FIGURE D4 Distributions over all scanners of effective doses for standard examination protocols for adult patients (on the basis of only *Routine* sequences); vertical lines mark third quartile values.

FIGURE D5 Distributions over all scanners of $CTDI_w$ for *Routine* sequences of standard examination protocols for paediatric patients; vertical lines mark third quartile values.

FIGURE D6 Distributions over all scanners of $CTDI_{vol}$ for *Routine* sequences of standard examination protocols for paediatric patients; vertical lines mark third quartile values.

FIGURE D7 Distributions over all scanners of DLP for standard examination protocols for paediatric patients (including only *Routine* sequences); vertical lines mark third quartile values.

FIGURE D8 Distributions over all scanners of effective does for standard examination protocols for paediatric patients (including only *Routine* sequences); vertical lines mark third quartile values.

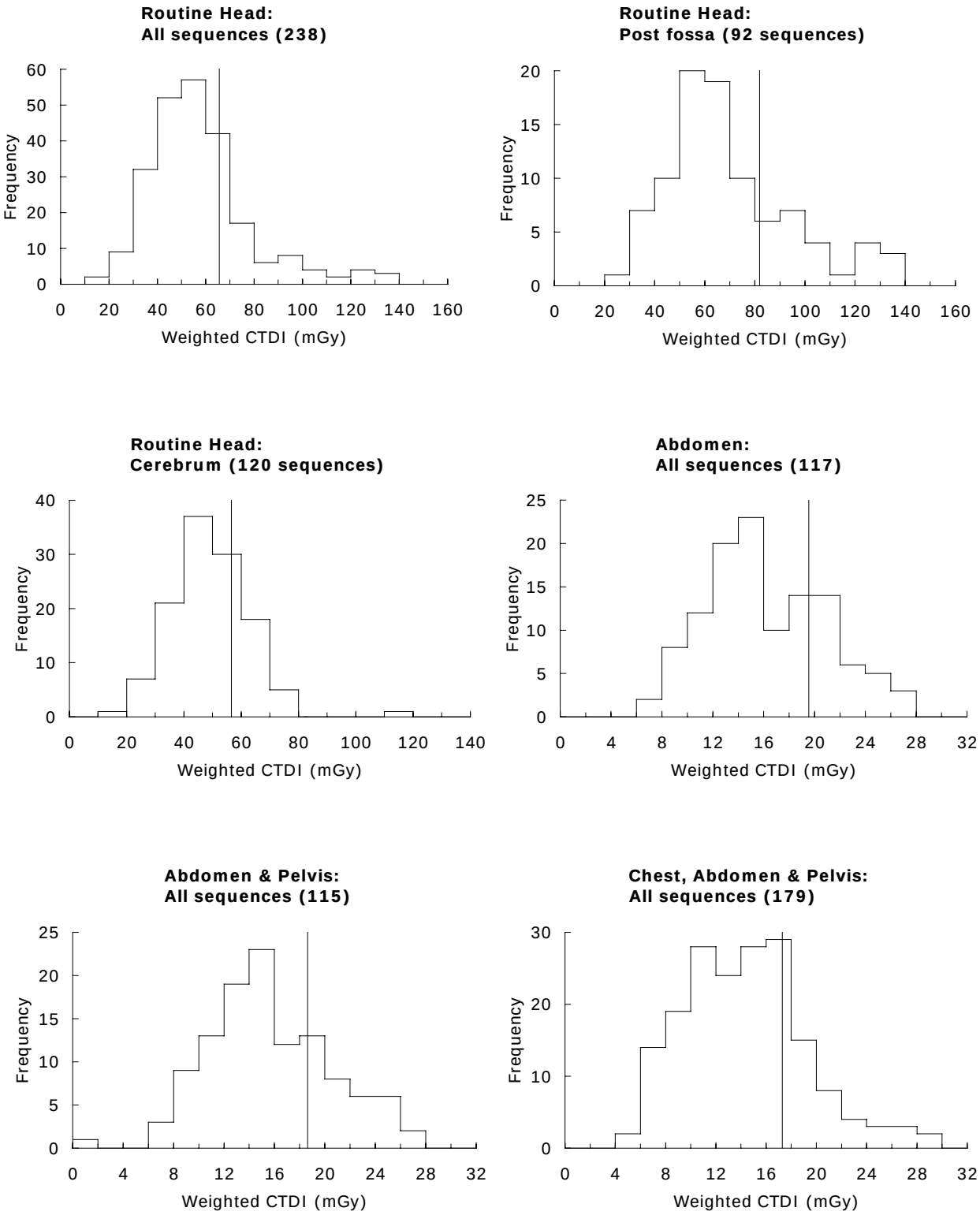
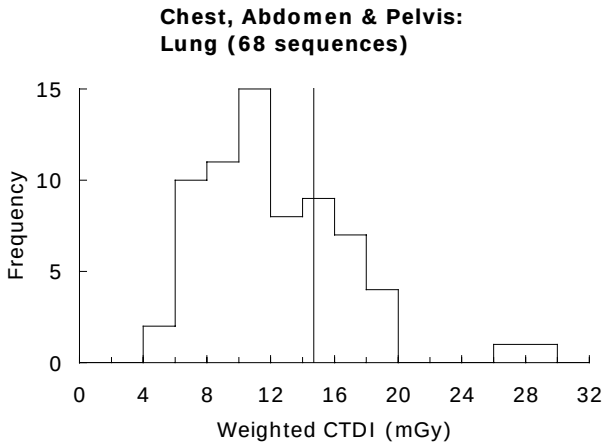
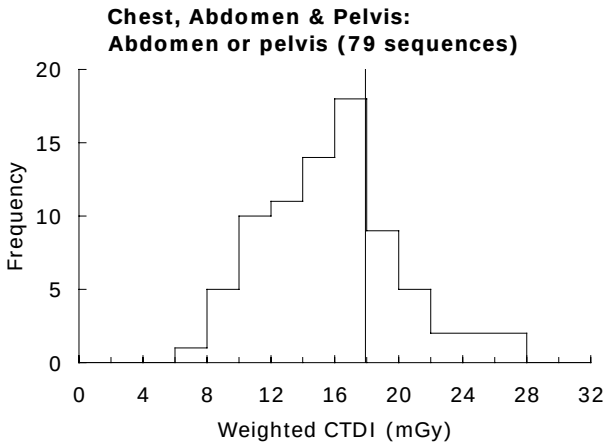
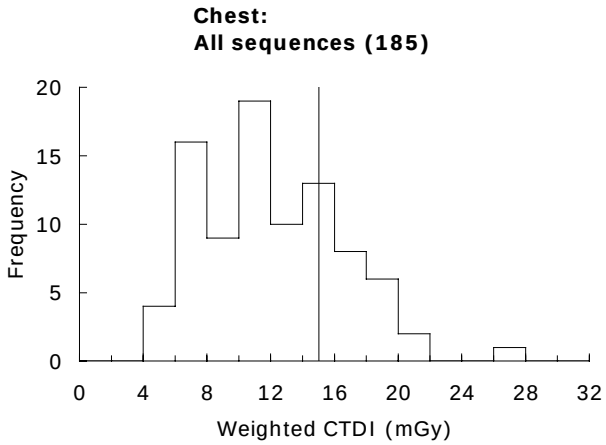
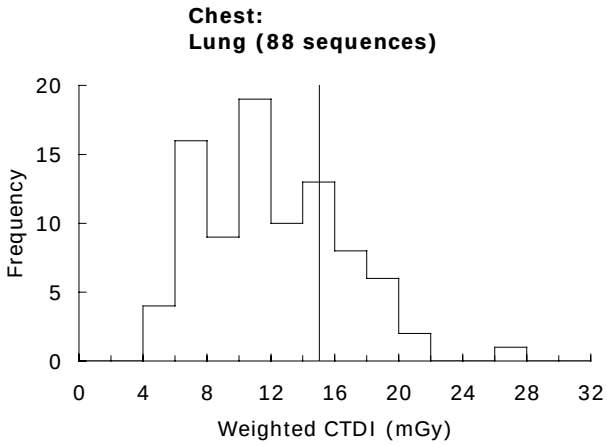


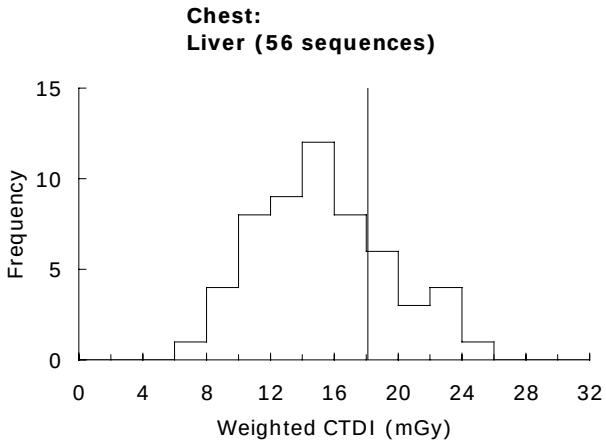
FIGURE D1 Distributions over all scanners of $CTDI_w$ for *Routine* sequences of standard examination protocols for adult patients; vertical lines mark third quartile values.











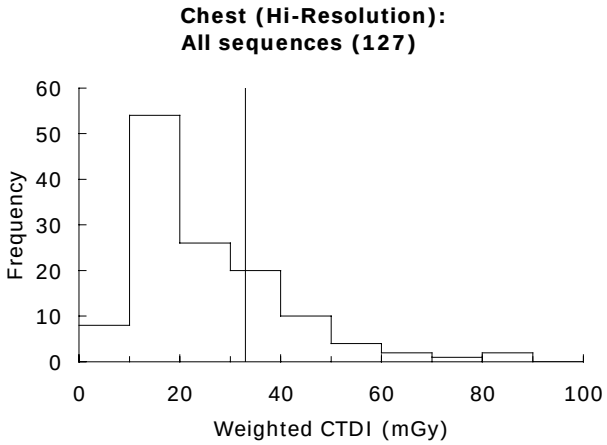


FIGURE D1 (continued)

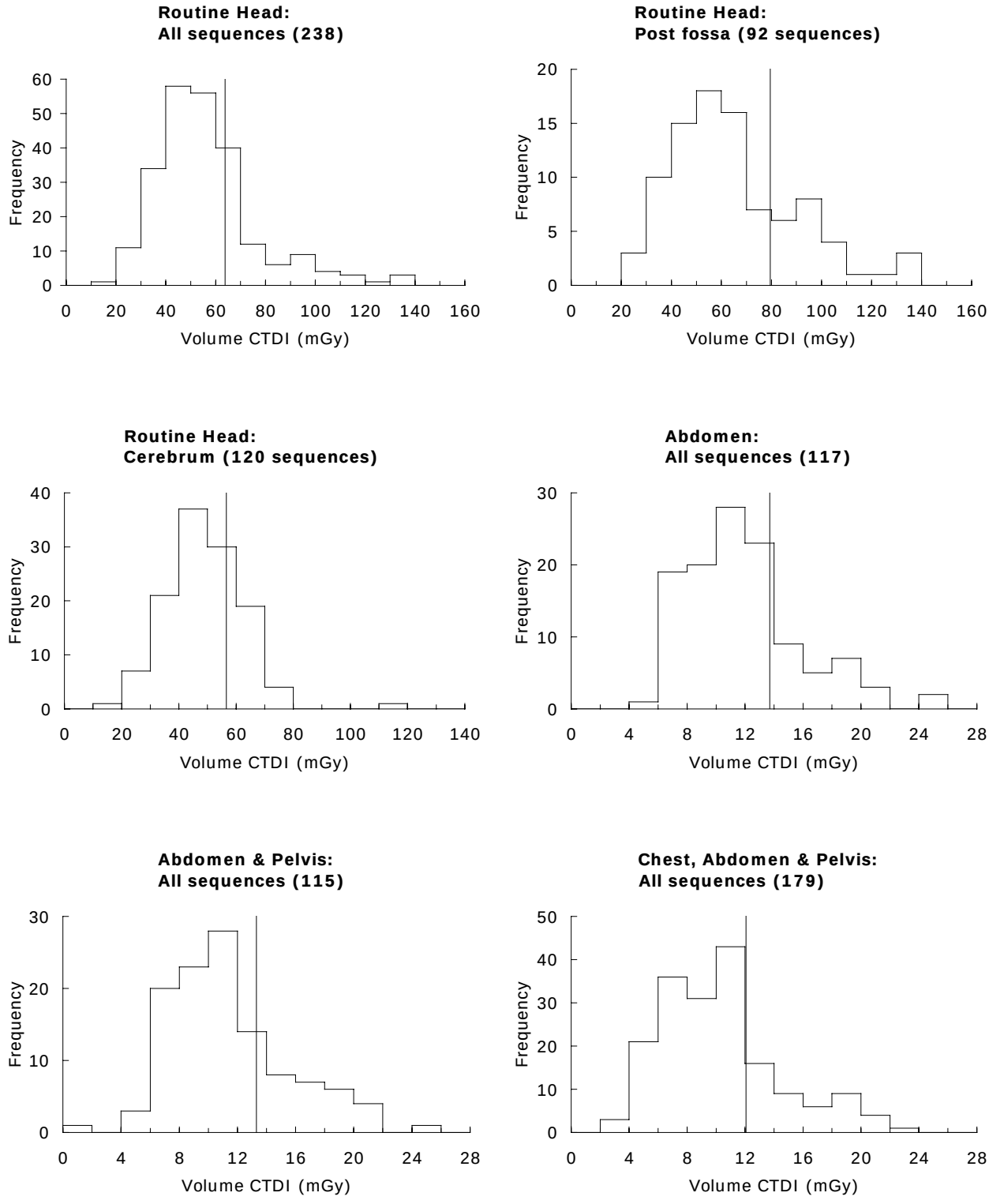
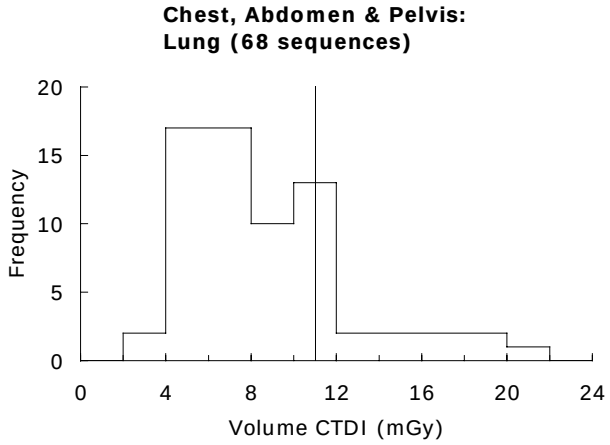
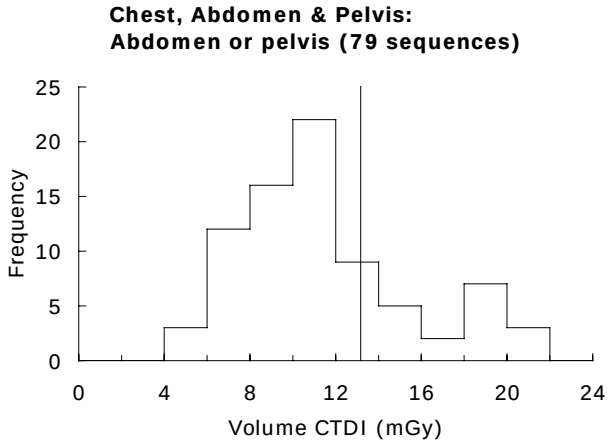
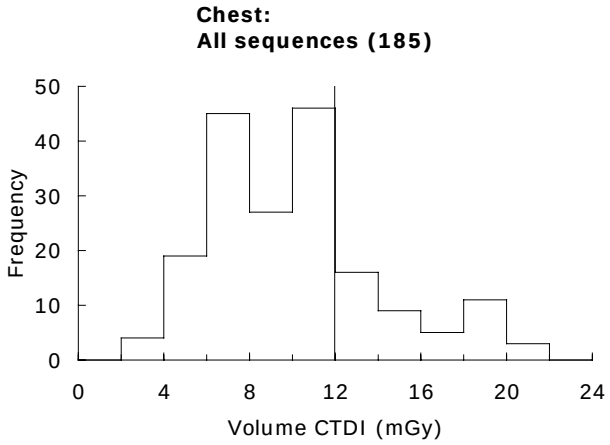
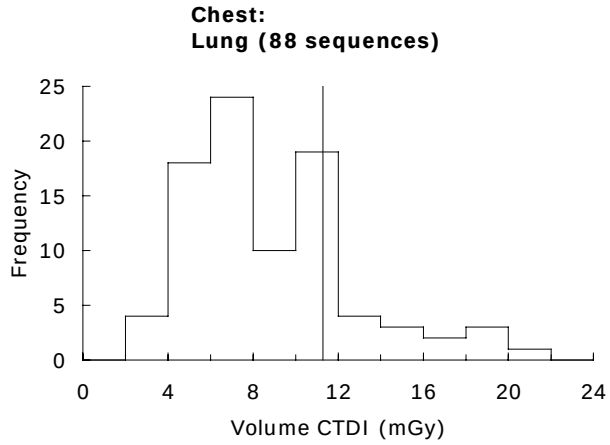


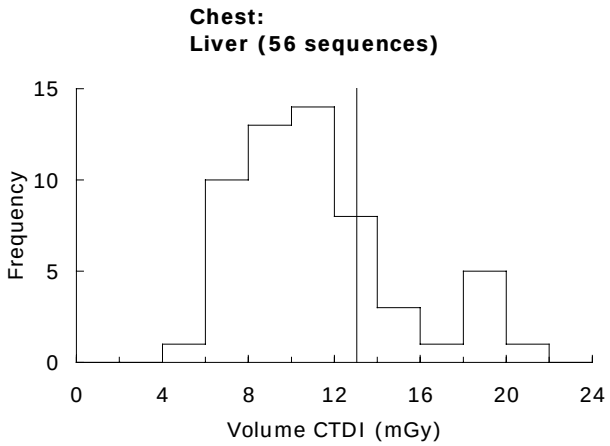
FIGURE D2 Distributions over all scanners of $CTDI_{vol}$ for *Routine* sequences of standard examination protocols for adult patients; vertical lines mark third quartile values.











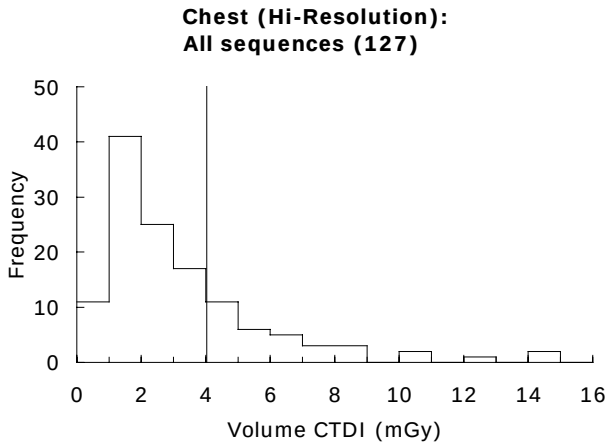


FIGURE D2 (continued)

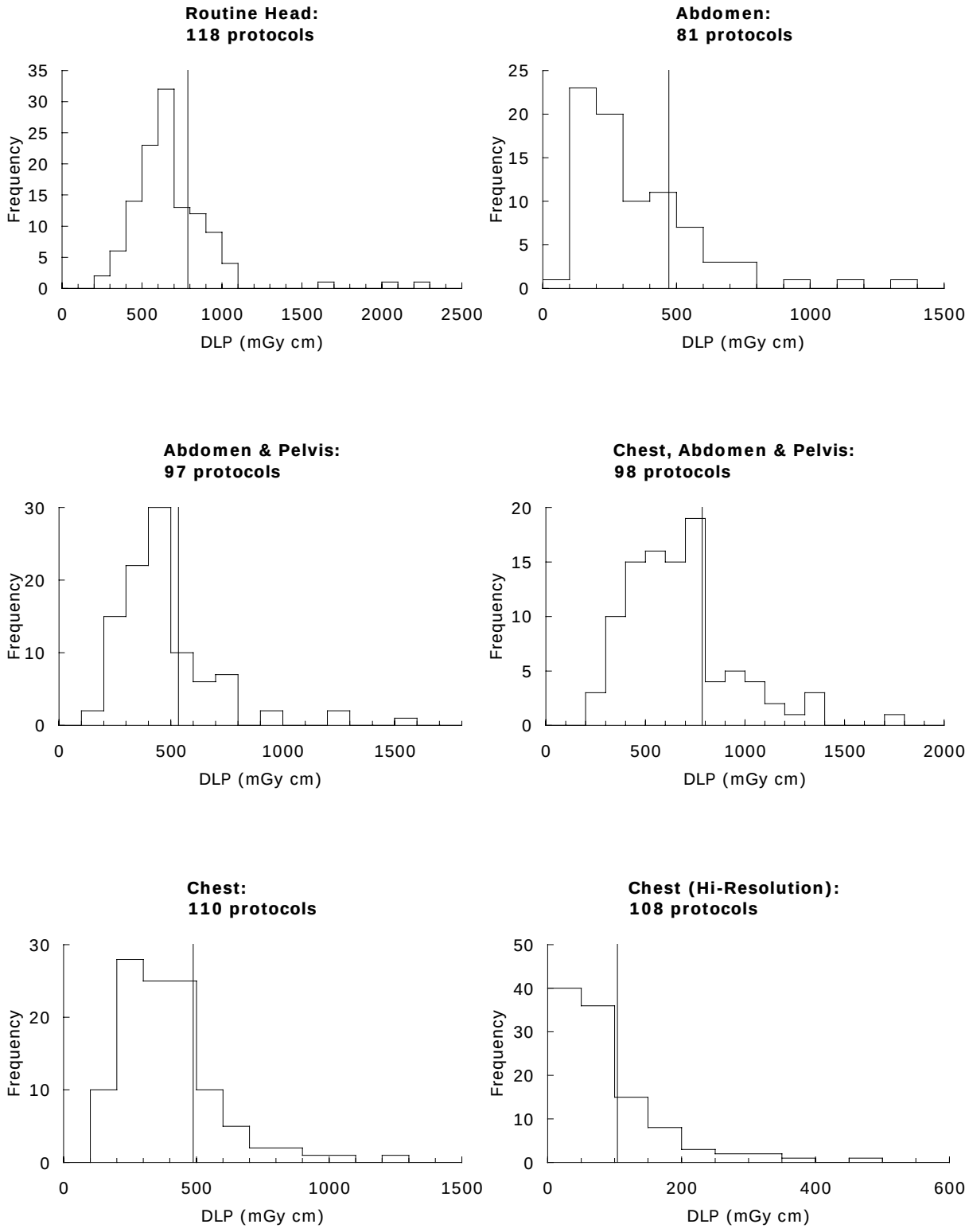


FIGURE D3 Distributions over all scanners of DLP for standard examination protocols for adult patients (including only *Routine* sequences); vertical lines mark third quartile values.

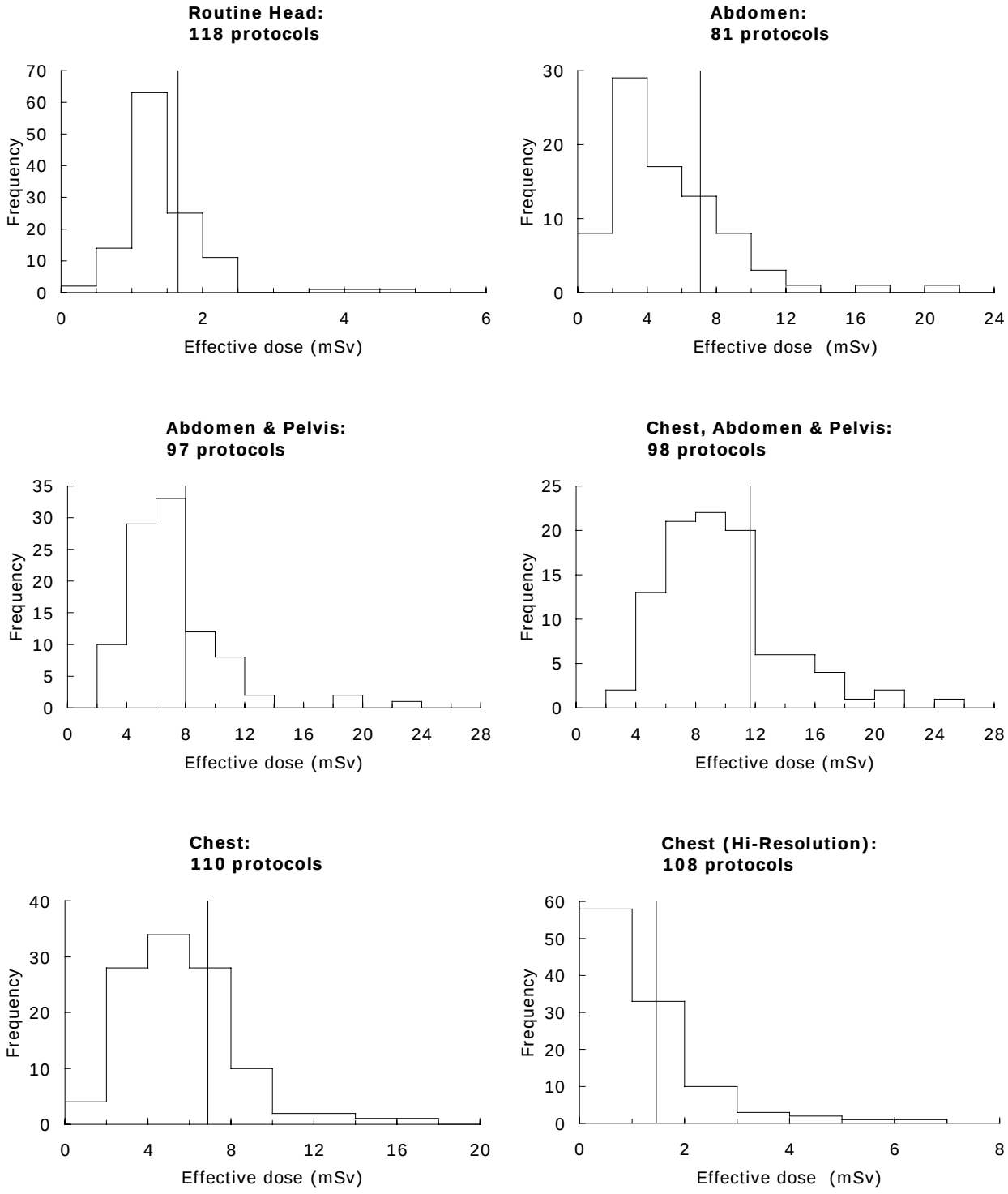


FIGURE D4 Distributions over all scanners of effective doses for standard examination protocols for adult patients (on the basis of only *Routine* sequences); vertical lines mark third quartile values.

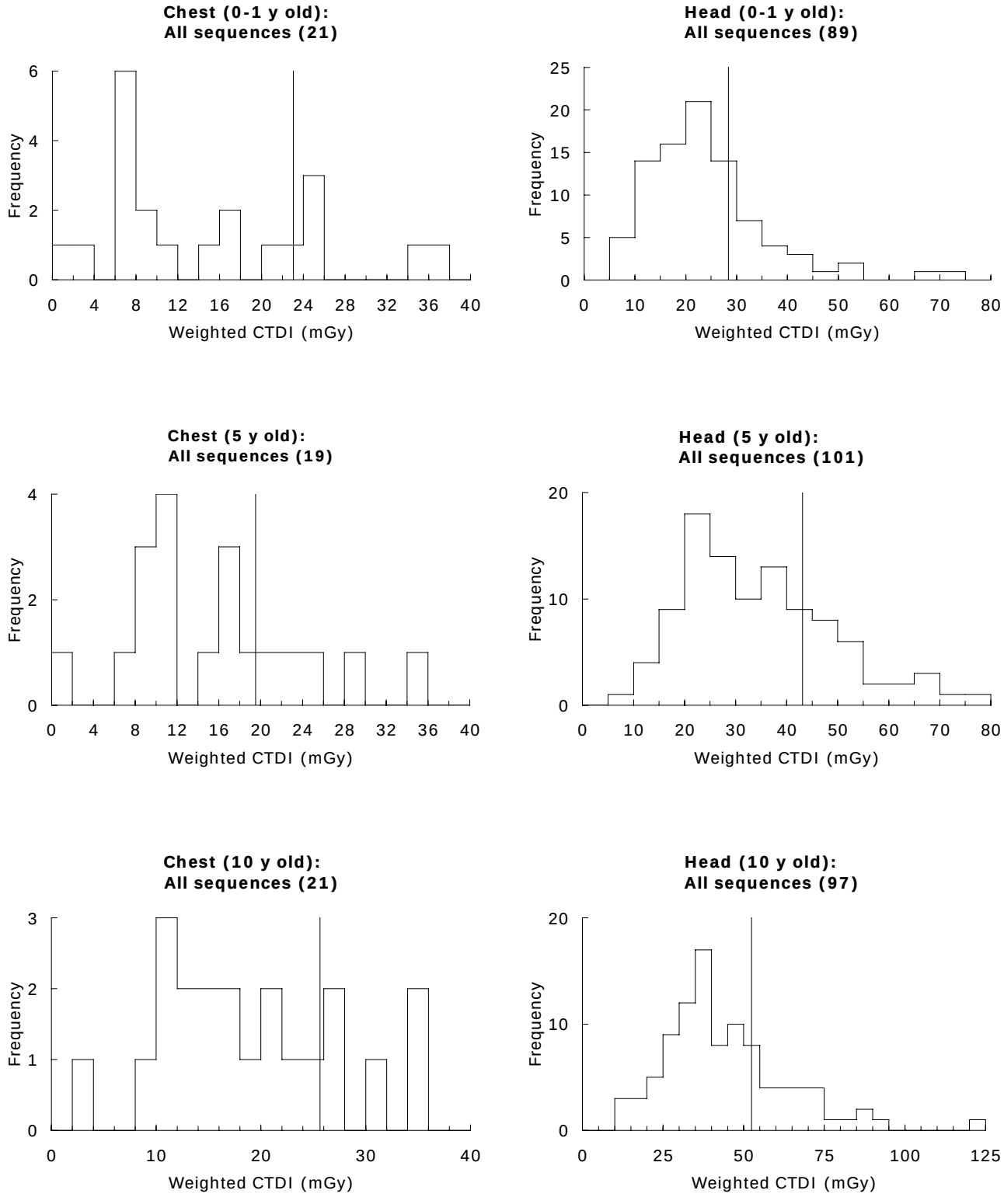


FIGURE D5 Distributions over all scanners of $CTDI_w$ for *Routine* sequences of standard examination protocols for paediatric patients; vertical lines mark third quartile values.

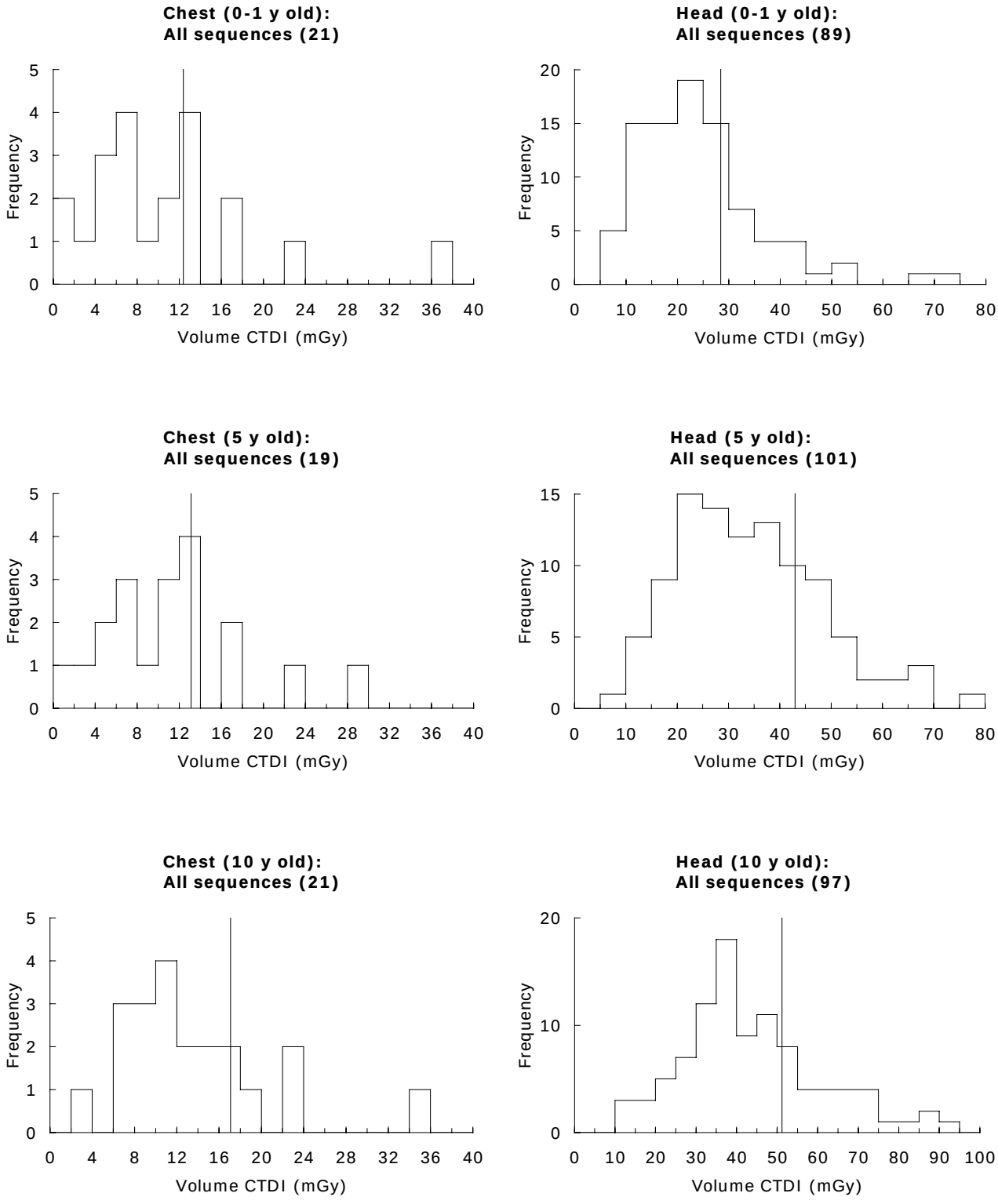


FIGURE D6 Distributions over all scanners of $CTDI_{vol}$ for *Routine* sequences of standard examination protocols for paediatric patients; vertical lines mark third quartile values.

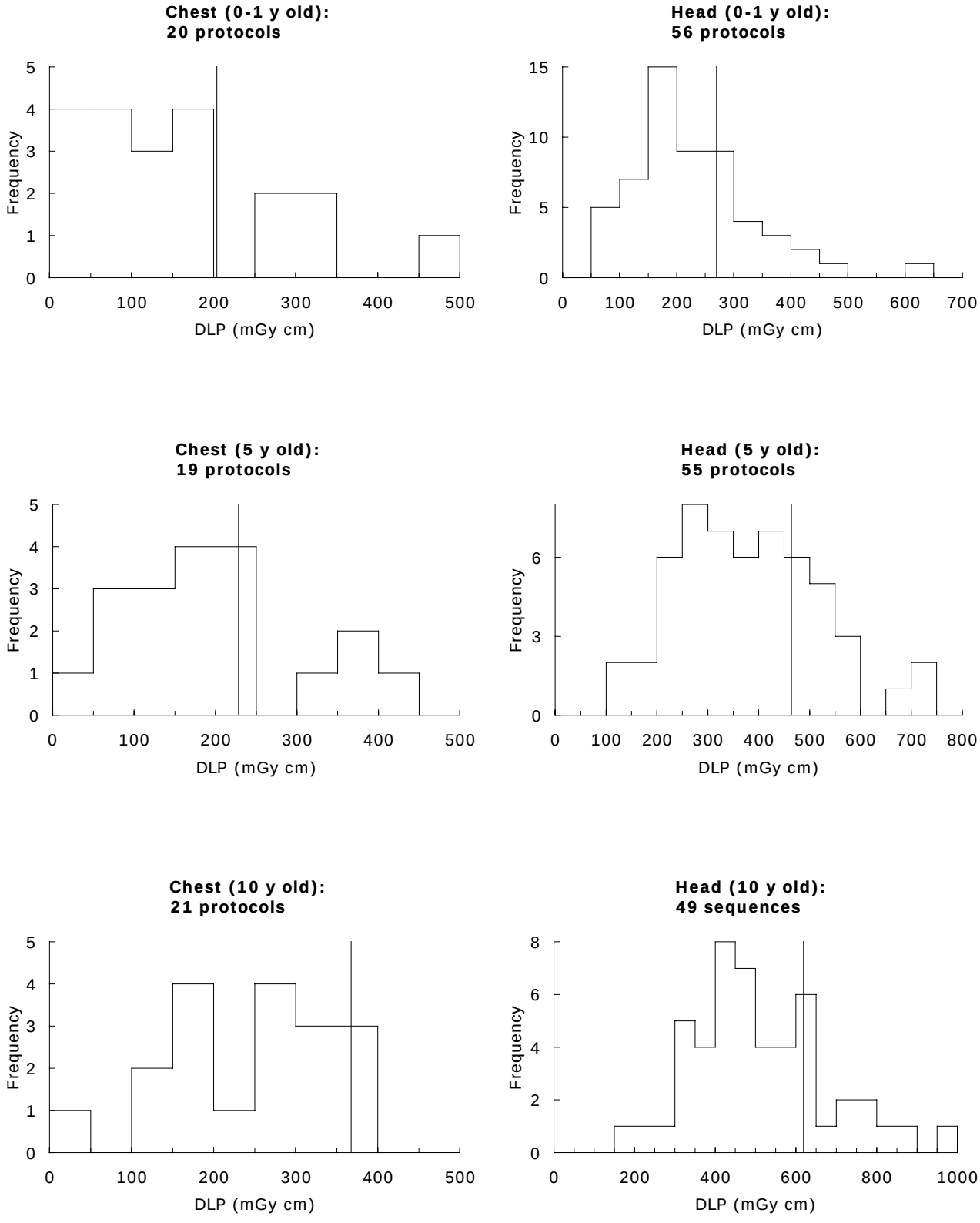


FIGURE D7 Distributions over all scanners of DLP for standard examination protocols for paediatric patients (including only *Routine* sequences); vertical lines mark third quartile values.

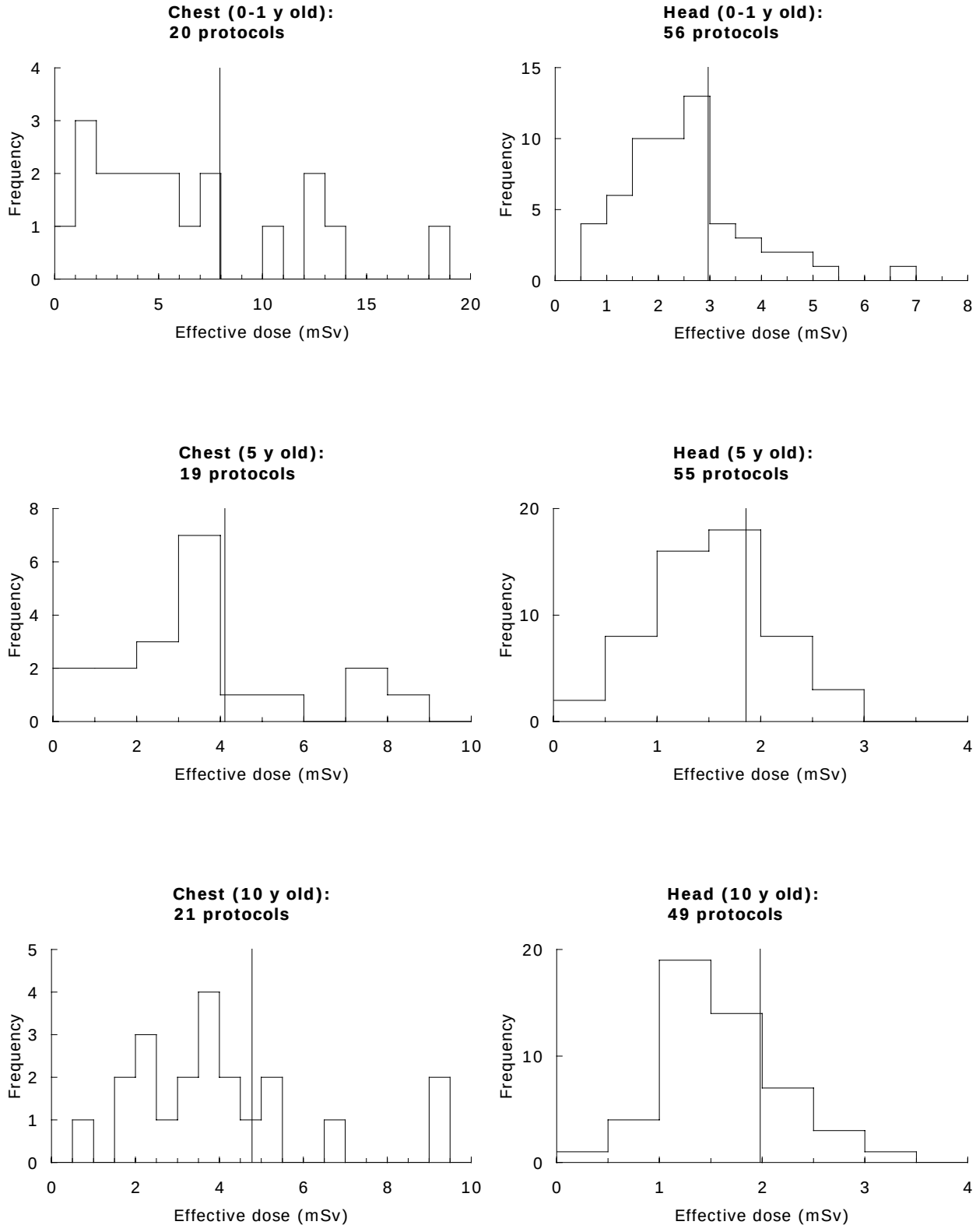


FIGURE D8 Distributions over all scanners of effective does for standard examination protocols for paediatric patients (including only *Routine* sequences); vertical lines mark third quartile values.