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Doses from Computed Tomography (CT) Examinations in the UK – 2011 Review

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Doses from Computed Tomography (CT) Examinations in the UK – 2011 Review

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ABSTRACT

A third national computed tomography (CT) survey for the UK has provided a useful snapshot of patient doses for 2011. Scan details for some 47,000 individual patients (rather than standard protocols as principally studied for the previous national surveys) relating to 13 common types of CT examination on adults, and also head examinations on children, were collected by electronic questionnaires voluntarily submitted by CT centres for a widely distributed sample of 182 scanners. This represented nearly a third of all UK scanners, all of which now include multi-detector-row (MDCT) technology. Typical practice at each CT centre has been characterised by mean values of the standard dose indices $CTDI_{vol}$ and DLP determined for samples of patients for each examination. Wide variations are still apparent in typical practice between CT centres for similar procedures, highlighting the need for continuing attention to the optimisation of protection and the use of specific scanning protocols for each patient group (with due account of size) and clinical indication, particularly in relation to children. Whereas typical values of $CTDI_{vol}$ have remained relatively constant (and broadly within ±10%) relative to previous results for overall national practice – that included both single-slice (SSCT) and MDCT – for 2003, typical values of DLP have presently increased by some tens of per cent.

The report includes summaries of the dose distributions observed and, on the basis of third quartile values for the distributions of typical (mean) doses, presents national reference doses for examinations on adults and children. Separate values are included for high resolution examinations of the chest using axial-only or helical-only scanning (with values for the latter being relatively higher by more than a factor of three). In a reversal of trends between the first two national CT surveys, national reference values for DLP are now broadly larger than those for MDCT in 2003 (particularly so for the lower trunk and paediatric head) and levels are now quite similar to those observed for 1999. The updated central dose database at PHE will continue to represent a sustainable national resource for monitoring developments in CT practice through the ongoing collation of further local survey data, following the streamlining of methods to make the best use of information already held by CT centres in electronic form.

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1 INTRODUCTION

Periodic national reviews and surveys concerning frequency and dose for medical and dental X-ray procedures in the UK, conducted over the last 35 years by Public Health England (PHE) and previously by the National Radiological Protection Board (NRPB) (up to March 2005) and the Health Protection Agency (HPA) (up to March 2013), have provided unique insight into national trends in population exposure (Hart et al, 2010). These surveys have also formed the basis since 1989 for setting national reference doses (Shrimpton et al, 1989, 1990, 2005; Hart et al, 2012; Shrimpton and Ng, 2013) as a quality improvement tool in promotion of the optimisation of patient protection. Such dose data is similar in purpose to national diagnostic reference levels, DRLs (ICRP, 1996, 2007b), and informs their formal setting for the UK by the Department of Health (2007) in compliance with the Ionising Radiation (Medical Exposure) Regulations 2000 (Department of Health, 2000; IPEM, 2004).

Continuing advances in computed tomography (CT) technology, including improvements in multi-row detector arrays and computer processing, have facilitated the development of rapid scanning and information acquisition for sub-millimetre sections with almost instantaneous image reconstruction and options for multi-planar and three-dimensional (3-D) imaging (Prokop, 2005; Mori et al, 2006; Kalender, 2011). CT examinations have thus become more tolerable for patients, with associated possibilities for increased scanned volumes and potential for repeated exposures. Further developments – for example, in relation to tube-current modulation and image reconstruction – have allowed beneficial improvements in dose, image quality and patient protection (Pickhardt et al, 2012; Tack et al, 2012).

Such technological advances have fuelled a steady growth in the application of CT in clinical practice and its expansion to provide new and more complex imaging procedures (Golding, 2005; Lowe and Kay, 2006; Meeson et al, 2012). The resultant ongoing trend has therefore been for increasing annual numbers of CT examination, as illustrated in Figure 1 for the National Health Service (NHS) in England (Department of Health, 2011).

Whereas CT examinations that are properly justified and carefully performed provide a net benefit for patient healthcare, their number and relatively high patient doses ensure that CT represents a significant source of exposure for populations. In many developed countries, CT is the dominant source of population dose from diagnostic X-rays (European Commission, 2008), providing, for example, contributions of around 70% in both the US (NCRP, 2009) and the UK (Hart et al, 2010). This pattern serves merely to identify CT as a particular focus for patient protection initiatives, rather than representing any useful indicator for radiological protection purposes.

Notwithstanding the enormous increase (by more than a factor of two) in the annual number of all X-ray examinations in the UK over last 50 years, the mean dose per head of population from this source has remained remarkably constant at around 0.3 mSv to 0.4 mSv per year (Hart et al, 2010; Wall BF, HPA, personal communication, 2010), as illustrated in Figure 2. A more detailed analysis for this pattern (in Figure 3) reveals the underlying, quite different trends for each of four broad categories of X-ray procedure. Whereas the per caput dose from CT has increased steadily over the last 25 years to its present dominant position, this has largely been off-set by a corresponding reduction in relation to conventional radiographic and fluoroscopic procedures. This latter trend for reduced population dose reflects significant improvements in patient protection for conventional X-ray procedures owing to changes in imaging practice.

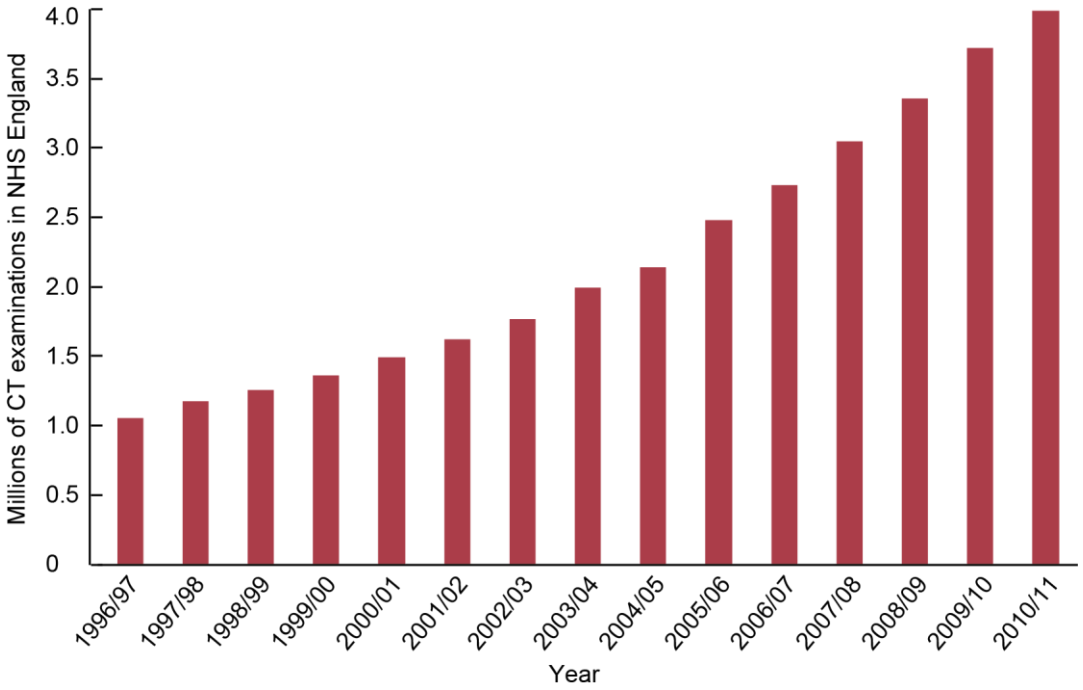

FIGURE 1 Annual numbers of CT examination performed in the NHS in England (Department of Health, 2011)

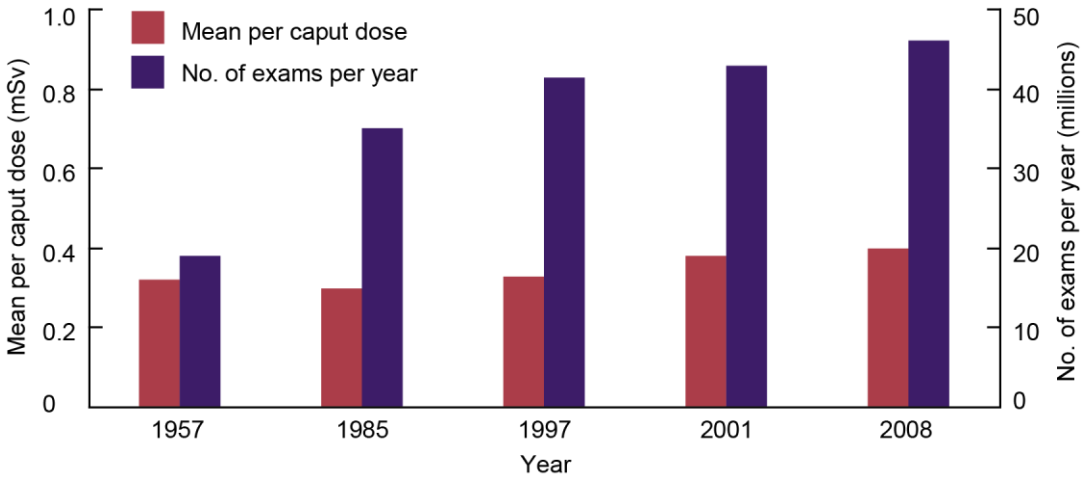

FIGURE 2 Trends in annual population exposure from X-rays in the UK over the last 50 years

These have been facilitated by the process of comparison and review prompted by the application, within a coherent framework for patient protection, of examination-specific national DRLs, which in turn have typically fallen by more than a factor of two over the last 25 years (Hart et al, 2012). Figure 3 also illustrates the growth in population dose from interventional and angiographic procedures, although the overall per caput dose from all types of X-ray examination has thus far remained fairly flat within uncertainties of estimate at around 0.4 mSv per year.

This pattern for the UK is in stark contrast, for example, to the corresponding increase by a factor of five observed in the annual per caput dose from X-rays in the US that has risen from

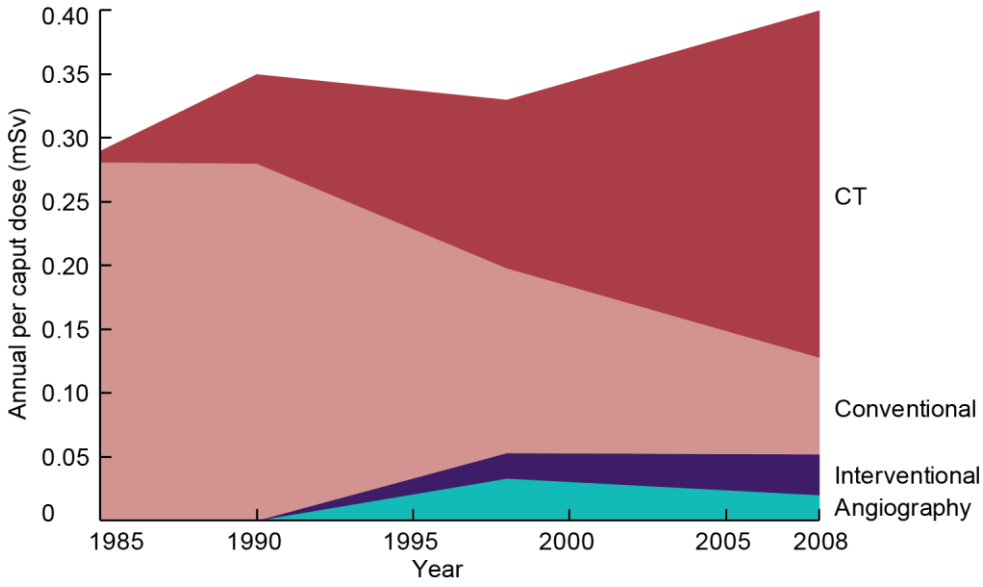

FIGURE 3 Trends in contributions to UK annual per caput dose from X-ray examinations by broad category of procedure

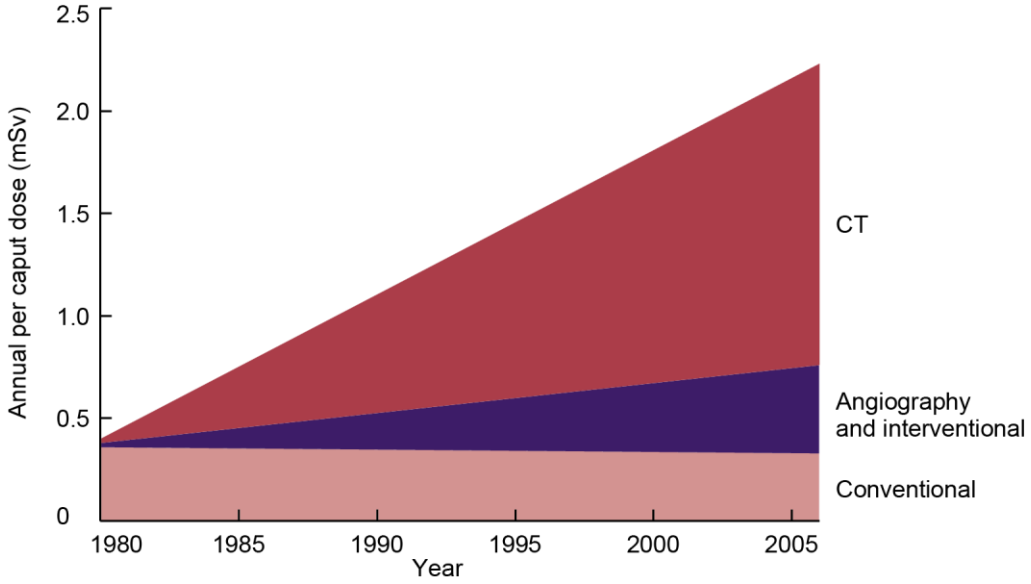

FIGURE 4 Trends in contributions to US annual per caput dose from X-ray examinations by broad category of procedure

0.4 mSv to 2.2 mSv over a similar period (NCRP, 2009). Figure 4 illustrates the underlying enormous growth in US CT, together with a significant rise in angiographic and interventional procedures, and little change in the pattern for conventional X-rays.

Such analyses serve to highlight the importance of CT in medical radiology and its need for special attention in relation to justification of examinations and optimisation of patient protection. Accordingly, two national CT dose surveys for the UK have already provided valuable snapshots of practice (Figure 5). The first survey was conducted around 1989 when UK practice largely involved single-slice, non-helical CT scanners (Shrimpton et al, 1991a,b;

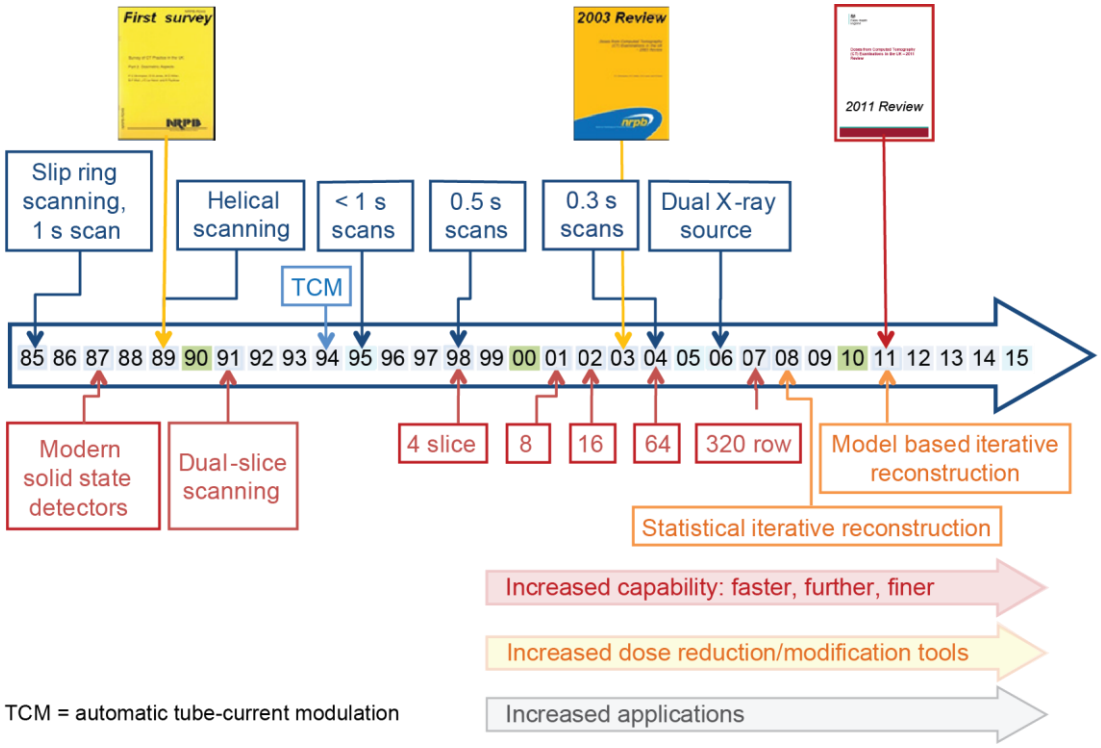

FIGURE 5 Timeline showing the schedule of national CT dose surveys in relation to technological advances in CT, 1985–2014 (figure supplied by Sue Edyvean, PHE)

Jones and Shrimpton, 1991). Using data from 83% of all UK scanners, this seminal survey provided estimates of typical organ and effective doses for standard protocols and established, for the first time, both the relatively high patient doses and also the importance of CT as a source of population dose (Shrimpton and Wall, 1993). It also demonstrated significant variations in practice between CT centres for similar types of examination and hence the scope for improvement in patient protection (Shrimpton and Wall, 1992). In addition, the work underpinned the development of specific reference dose quantities for CT (Shrimpton, 1997; Shrimpton et al, 1998) and provided some initial values for Europe as part of quality criteria for CT (European Commission, 1999).

The second national CT dose survey was conducted for 2003 on the basis of data collected from a sample of 27% of all UK scanners, of which 37% were multi-detector-row CT (MDCT) scanners (Shrimpton et al, 2005, 2006, 2007). The survey included scan information in relation to both standard protocols and also individual patients and provided updated typical effective doses and national reference doses (DRLs). Wide variations in practice were still apparent between CT centres, with doses from MDCT (four+ detector-row) scanners being in general slightly higher than those from single-slice scanners, although the study did demonstrate an initial trend for reduction by 10–40% in national reference doses for some common CT procedures since the previous UK survey for 1989.

Following further significant changes in UK CT practice, including increasing numbers of examination (Figure 1) and the implementation of new technology (Figure 5) since 2003, a third national survey has been conducted for 2011 to provide updated information concerning typical doses for an expanded range of contemporary examinations and an assessment of present

trends. Whereas this review was initiated by the HPA, it has been completed by PHE and this latter designation is used throughout the remainder of this report to encompass all phases of the work. The principal purpose of this survey is to provide updated national reference doses (and in due course national DRLs) in order to promote improvements in patient protection, rather than provide detailed information in relation to the optimisation of CT technique. However, the updated PREDICT (Patient Radiation Exposure and Dose in CT) database so established should also prove useful as an ongoing national resource in support of the management of patient dose following further developments in UK CT practice.

2 SURVEY METHODS

2.1 Data Collection

2.1.1 Survey design

In order to ensure representative results, a successful national survey requires the timely collection of essential scan data from a robust sample in relation to a core of key examinations covering common CT practice. Being necessarily voluntary in nature, surveys by PHE (and previously by the HPA and NRPB) unfortunately risk a potential for bias in the self-selected sample, although this is unlikely to be a significant problem in practice for the present purposes of promoting patient protection. This risk can also be ameliorated by encouraging widespread participation through ensuring ease of data submission for information collected either prospectively or retrospectively to meet local preferences. Furthermore, data received from CT centres was guaranteed to be published only in anonymous form, although all participants were to be gratefully acknowledged. Participation was also promoted as a valid activity in continuing professional development (CPD), with, in particular, endorsement by the College of Radiographers via CPD Now and the use of this logo in survey documentation (Landau M, College of Radiographers, personal communication, 2010).

The focus for this third CT survey has been on collecting sets of data in relation to individual patients (with a suggested sample size of 20 patients per type of examination), rather than settings for standard protocols, so as to provide better indications of typical practice at each CT centre. In the interests of simplifying data collection relative to the previous CT survey for 2003, it was planned to make better use of electronic systems and use widely available software. Accordingly, two electronic files were required by participants to perform the survey: a Microsoft Excel spreadsheet (MS Office 97-2007, PC-compatible; Microsoft Corporation, Redmond WA) with a macro to record the data electronically; and an Adobe PDF file (Adobe Systems Incorporated, San Jose CA) containing the printable data acquisition form and guidance notes (see Appendix A).

An invitation to take part in the national CT dose survey was hosted by the CT Users Group (CTUG) on its website (www.ctug.org.uk) in October 2010. The CTUG home page contained a link to register an interest in the survey and allow users to download the electronic files required to take part in the survey. Registration was performed online using the electronic questionnaire tool SurveyMonkey (www.surveymonkey.com), which allowed PHE to review interest in the survey and potential participants to download the files. The survey was widely advertised through a range of actions throughout its duration in order to promote active participation.

2.1.2 Protocol selection

The dose survey sought to focus on diagnostic rather than cancer staging examinations and so included common CT protocols that were undertaken as part of a patient's initial diagnosis following referral from a medical practitioner and in response to recognised clinical indications. Whereas there was a need to review doses for the high throughput protocols studied in the 2003 review, new CT applications that had subsequently become established practice also merited consideration. On a pragmatic note, around a dozen protocols for adult patients was thought to provide a reasonable balance between coverage of practice and associated effort by participants. Head examinations on children (in three age bands) were also included, as being the most frequent CT procedure for this patient group and a part of the previous review. However, in view of the particular importance of radiological protection for children, paediatric CT is the subject of a separate ongoing detailed collaborative dose survey involving PHE (Owens CM, Great Ormond Street Hospital for Children, personal communication, 2010).

TABLE 1 CT protocols and their specific clinical indications selected for study in the present (third) national CT survey

CT protocol	Clinical indication[a]
Head	Acute stroke
Cervical spine (C-spine)	Fracture
Chest	Lung cancer
Chest – high resolution	Interstitial lung disease
CT angiography (CTA)	Abdominal aorta/blood vessels
CT pulmonary angiography (CTPA)	Pulmonary embolism
Abdomen	Liver metastases
Abdomen and pelvis	Abscess
Virtual colonoscopy (VC)	Polyps/tumour
Enteroclysis	Crohn's disease
Kidney-ureters-bladder (KUB)	Stones/colic
Urogram	Stones/colic or tumour
Chest-abdomen-pelvis (CAP)[b]	Cancer
Paediatric head (<1 year old)[c]	Trauma
Paediatric head (1–4 year old)[c]	Trauma
Paediatric head (5–12 year old)[c]	Trauma

Notes
(a) See further details in the survey guidance notes included in Appendix A.
(b) Not part of the initial selection but included retrospectively.
(c) Age bandings for paediatric head examinations were revised slightly during data analysis (see Section 3).

The protocols selected for the present survey, together with their specific clinical indications, are listed in Table 1. These were chosen after due consultation including the views of expert radiologists, CT centres that had shown early interest in taking part in the survey and requests to PHE for guidance on newer applications such as virtual colonoscopy, and the list of the most frequently undertaken X-ray examinations in the UK (Hart et al, 2010). Whereas cardiac CT was, at the time of planning the survey, an examination of increasing interest (IAEA, 2008; Halliburton, 2009; Min et al, 2010), it was also felt that UK practice was still evolving and not yet widely established in general CT centres (Morgan-Hughes et al, 2002; Hassan et al, 2011). Accordingly, this particular procedure was not included in the 2011 review, although, following a period of further maturation (NICE, 2012; Sun et al, 2012; Mittal et al, 2013), it will probably merit study in future national surveys.

The aim of the present survey was to address different patient groups (adults and children) and cover a range of body regions and a variety of examinations, including disorders of the head and neck, chest, vasculature, abdomen and pelvis, bowels, and urinary system. The suitability of the list was further investigated as part of an e-Poster presentation at UKRC 2010 (Meeson et al, 2010a).

After the survey had been launched, it was decided retrospectively to include chest-abdomen-pelvis (CAP) examinations. A number of participating CT centres reported high usage of the single CAP scan in preference to separate examinations of the chest, chest and abdomen or abdomen and pelvis when looking for cancer or malignancy. CAP was not selected initially due to the high number of such examinations that were undertaken for cancer staging rather than initial diagnosis, combined with the already high coverage of the chest, abdomen and pelvis by other examinations in the survey. However, CT centres that queried the omission of CAP were invited to submit their data and this was included in the survey and is reported upon.

2.1.3 Dosimetry

The principal purpose of the survey is to provide updated national reference doses (and, in due course, to facilitate revised national DRLs) in order to promote optimisation of patient protection (IPEM, 2004), rather than being concerned with the quantitative assessment of radiation risk from CT. The standard framework for CT dosimetry is already well established (European Commission 1999; ICRP, 2007a), with monitoring of performance as part of routine quality assurance being based on the practical dose quantities of weighted CT dose index ($CTDI_w$), volume weighted CT dose index ($CTDI_{vol}$) and dose-length product (DLP) (IPEM, 2005; IAEA, 2007; IEC, 2011; Platten et al, 2013; Kalender, 2014). Values of $CTDI_{vol}$ and DLP relating to each examination are generally displayed on the scanner console and also commonly recorded in picture archiving and communication systems (PACS) and radiology information systems (RIS) (IEC, 2011). Detailed analysis undertaken during the previous national review of CT for 2003 (Shrimpton et al, 2005) has suggested that this data is probably sufficiently accurate for direct use in dose audit, provided validation checks are carried out as part of local quality control measures.

The strategy for the survey was therefore to collect sufficient information on recorded dose in order to characterise practice at each CT centre. For the present purposes, CT examinations are taken to comprise a number of separate scan sequences, each representing the acquisition of a series of imaging data using a particular set of exposure conditions. Dose

assessment has therefore focused on recorded values of $CTDI_{vol}$ and DLP per scan sequence, and total DLP per examination, taking into account, where appropriate, the effects of any tube-current modulation during scanning (McCollough et al, 2006). Data from each sample of patients was used to derive mean values of dose by type of examination for each participating CT centre, as being representative of its typical practice (see Section 3.3). Further statistical analyses were carried out in relation to the national distributions over such mean doses from patient samples.

In addition to such practical CT dose monitoring quantities, typical values of effective dose (*E*) (ICRP, 2007b) can also be derived for complete CT examinations on the basis, for example, of mean levels of DLP using appropriate dose coefficients (Shrimpton et al, 2005; Kalender, 2014). Such estimates of *E* can be useful for broad comparison with those for other types of radiological procedure and also, using specific risk coefficients developed for this purpose, the estimation of associated typical lifetime risks of radiation-induced cancer for populations of patients of particular age band and sex undergoing standard scan protocols (Wall et al, 2011). However, such analyses are not the focus of the present report, which is more concerned with the setting of national reference doses (where *E* plays no part) in support of improving the optimisation of patient protection. Accordingly, whereas estimates of *E* were previously included for illustrative purpose in relation to the 2003 national review of CT (Shrimpton et al, 2005), such updated data is not reported here. Rather, this complex topic is planned to be addressed in due detail in a separate publication (Shrimpton et al: Updated estimates of typical effective doses for common CT examinations in the UK following the 2011 national review; *in preparation*). This will include revised values of typical *E* based not only on updated data concerning mean DLPs for national practice, but also on changes in the definition of *E* (ICRP, 1991, 2007b) and the reference patient (ICRP, 2009) recommended for the calculation of representative organ doses (Jansen and Shrimpton, 2011).

2.1.4 Data acquisition form

The collection of data for samples of patients undergoing each of the selected types of CT procedure could be performed either retrospectively or prospectively (but involving common requirements) to match local circumstances. The previous recommendation for the 2003 CT review had been for sample sizes of at least 10 patients of average size, excluding those who were excessively small or large (Shrimpton et al, 2005), but this was increased simply to 20 patients for the present study in order to provide a better indication of typical practice. The suggested typical study period for each CT centre was about three months, although this could be somewhat longer for low frequency examinations and involve up to one year of records in the case of retrospective analysis. Two electronic files – a data collection form and a spreadsheet for the return of results – were required for data collection.

The printed data acquisition form (see Appendix A) was designed to fit on a single sheet of A4-sized paper in order to record the information required for each patient. This included the healthcare facility, patient descriptors, CT scanner type, examination parameters and exposure data. Whereas the local examination accession number was recorded on the printed form, this information was not subsequently included in the spreadsheet submitted to PHE, in which only the sample number for the specific protocol was transferred. These sample numbers were used to allow healthcare workers retrospectively to trace records for particular examinations should queries arise at PHE.

Since the first national CT survey in 1989 (Shrimpton et al, 1991b), the rise in obesity has become an international concern (Wardle and Boniface, 2008) and what is meant by average patient build may well have changed accordingly. It has therefore been recommended (Meeson et al, 2010b) that estimates of cross-sectional area should be included in dose surveys to inform results in relation to patient size. It was decided in the present work to record both body mass, where known, and also patient dimensions in the imaged region as the basis for estimating cross-sectional area by approximating the human profile to an ellipse (Maltz et al, 2007), which is a reasonable assumption in medical CT studies. The guidance notes in Appendix A include a worked example of the measurements of transverse and antero-posterior (AP) patient width required for subsequent calculation of the cross-sectional area. These dimensions were estimated once for each patient using an image from the middle of the first main imaging sequence.

The data acquisition form was primarily designed to record up to three imaging scan sequences for each patient, although completion of the 'page 2' box allowed the option to capture up to six sequences so as to include repeats and extra exposures that were performed during the patient's visit to the scanner. Indeed, as the complexity of CT scanning and protocols has increased, it is now becoming common to perform additional scans such as timing scans, pre-scans and position checking scans for many examinations. If survey participants wished to record these, they were encouraged to do so, provided this practice was recorded in the spreadsheet notes under 'Your details' and 'Notable protocol differences/ comments'. Such additional, non-image sequences (even if not specifically listed) will provide (albeit probably small) contributions to the values of total DLP recorded on the form for each complete examination.

In addition to the printable data acquisition form, the guidance notes for the survey (see Appendix A) included itemised instructions for participating in the survey, together with: worked examples for the measurements of transverse and antero-posterior patient width; keywords in relation to patient referral by clinical indication and CT protocol; generic examples of how to search Radiology Information Systems (RIS); illustrated examples of the CT protocols sought for inclusion in the survey; and a tick-sheet to facilitate the collection of 20 patients for each examination.

The aim was for participants to keep printed records on-site, including scan accession numbers (that are traceable within local systems), and to transmit patient data to PHE in anonymous form only. Collected data could be added to the spreadsheet in stages or batches. Batch data entry was recommended since once all parameters had been typed in and added for the first time for a given protocol, a number of these parameters remained active in the form. Adding data for the same protocol in batches therefore meant that data entry should be reduced, with no more than verification required for some parameters. At the end of data collection, the saved spreadsheet file was returned to PHE by e-mail.

Data collection methods were tested and refined in a pilot survey kindly performed by a hospital trust. This process addressed all aspects of the survey, from protocol selection to suitability and ease of use of the data acquisition form, and also data recording using the spreadsheet and its macro. This valuable exercise was reported upon at UKRC in 2010 (Meeson et al, 2010a) and was followed up by a presentation of early results from the survey at UKRC 2011 (Meeson et al, 2011).

2.2 Data Processing

Quality assurance measures in relation to both the raw data and their analysis represented an important aspect of data management for the third national CT survey in order to underpin confidence in reported results.

Survey data was processed using two Microsoft application programs (Microsoft Corporation, Redmond WA), namely an Access 97 database and Excel 2003 spreadsheets, with there being automatic processes for the transfer of data in order to eliminate transcription errors. Commands were issued to both of these applications by means of a purpose-built program written in Microsoft Visual Basic for Applications. This helped ensure that the data was processed consistently and also provided a record of how the data had been manipulated. The program code was documented with comments to clarify the purpose of each step of the program and progress was monitored by means of on-screen messages.

Once the survey Excel spreadsheets had been received by e-mail at PHE, the raw data was checked and, as necessary, queried with participants before being uploaded into a custom-built Access 97 database for subsequent analysis. This initial data validation was a semi-automated process and a program was developed to find, for example, typographical errors (such as character instead of numerical data), errors in units, missing key data, misplaced data and inconsistencies or contradictory data. Also, submitted data often needed to be assimilated into the correct format so that it could be uploaded into the database using a macro for auto-extraction that assumed the specific format of the survey spreadsheet. In addition, it was important to ensure the correct identification of each scan sequence as being, for example, an image or pre-scan sequence.

Following successful completion of these initial tests and resolution of any problems, each set of data was added to the database where further verification testing was then carried out. This included, for example, studying the range observed for each set of data and also the expected relationships between different quantities, in order to identify potentially erroneous data. These and subsequent analyses were accomplished using the recognised database language Structured Query Language (SQL, also known as SEQUEL), supported by Visual Basic for Applications and Access. The data and program files were stored on the secure PHE file server, 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 PHE network maintains comprehensive and up-to-date virus protection and is backed-up systematically on a daily basis.

Standard statistical data analyses – including sample size, mean, standard deviation, coefficient of variation, standard error of the mean, minimum, maximum and quartiles (25th, 50th and 75th percentiles) – were performed within the Access database and its associated (automatically generated) Excel spreadsheets for various sets and subsets of recorded and derived data. Such analyses were conducted in relation to the individual samples of patients for each protocol at each participating centre (in order to provide indicators of typical practice at the centre), all patients taken together for each protocol (see Section 3.2) and also the distributions of the various mean values derived for each centre (Section 3.3) in order, in particular, to establish updated national reference doses (Section 3.6). Histograms were also generated for visual display of frequency distribution for various key quantities in the survey. Finally, further specific detailed analyses were undertaken in relation to CT technique (Section 3.5) and potential correlations between dose and patient size (Section 3.4).

3 RESULTS

3.1 Survey Sample

3.1.1 Scanner distributions

The survey was launched in October 2010 with publication of information on the website of the CT Users Group (CTUG, 2010) that included a link for the electronic download of the survey documents. The project was also actively promoted among both its members and the wider UK medical physics community (IPEM, 2010; Medical-Physics-Engineering, 2010). The initial data collection period of four months was extended several times until December 2011 to maximise participation and finally allowed the submission to PHE of data in relation to 182 CT scanners located at 127 hospitals in the UK. Participating sites are marked schematically on the map in Figure 6 and listed alphabetically by country in Appendix B.

The substantial sample includes a reasonable geographical spread around the UK. Table 2 gives detailed analyses for the regional distribution of CT scanners in both the survey sample and the UK as a whole. Nearly four-fifths of the scanners in the survey sample were based in the NHS in England, with about a further tenth operating in the NHS in Scotland and about a twentieth in the NHS in Wales; the remaining twentieth was split between the NHS in Northern Ireland and scanners operating in the private sector. Overall, the sample included about 30% of the estimated total of 609 CT scanners in clinical service in the UK during 2011/12. This overall sampling rate is similar to the 27% achieved for the 2003 survey, although the present overall sample size of 182 is over 40% larger than that for 2003 owing to the presently increased number of operational CT scanners (up 30% from the total of 471 scanners estimated for 2003).

NHS England (with about 65% of all UK scanners) and NHS Wales (about 4% of the UK total) were somewhat over-represented in the sample, with sampling rates of about 77% and 6%, respectively, whereas the rates for NHS in Northern Ireland and Scotland were broadly appropriate. However, scanners included in the ‘Other’ category in the table were somewhat under-represented in the sample.

An analysis of the survey sample by scanner model is presented in Table 3, following broad classification by detector-row technology, together with some aggregation of models with similar performance characteristics, according to a scheme developed for the present purposes of summarising survey participation. The sample includes examples of 25 such different scanner groups. Overall, 29% of the 182 scanners in the survey were manufactured by GE, 14% by Philips, 38% by Siemens and 19% 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 view of the rapid pace of change in the provision for UK CT in recent years, all scanners included in the present survey had multi-slice capability, whereas only 37% had so in the previous review for 2003 (Shrimpton et al, 2005). Furthermore, over one-half of the scanners could be classified as being in detector-row class 64 or higher (Table 4), similar to the overall pattern for the NHS in the UK, although there was slight under-representation of the very highest classes (128 and >128) in the self-selected sample. 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.

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Map produced using HPAGIS. Contact HPAGIS Team, ERD/MRA, Porton Down, 01980-616937 or gis@hpa.org.uk

FIGURE 6 Geographical distribution of CT scanner sites in survey sample

TABLE 2 Geographical distribution of CT scanners in the survey sample and in the UK

		Scanners in region		Scanners in sample		
Domain	**Region**	**No.[a]**	**% in UK**	**No.**	**% in sample**	**% in region**
NHS England	East Midlands	25	4.1	1	0.5	4.0
	East of England	43	7.1	22	12.1	51.2
	London	76	12.5	18	9.9	23.7
	North East	23	3.8	13	7.1	56.5
	North West	59	9.7	23	12.6	39.0
	South Central	28	4.6	7	3.8	25.0
	South East Coast	26	4.3	7	3.8	26.9
	South West	36	5.9	22	12.1	61.1
	West Midlands	40	6.6	16	8.8	40.0
	Yorkshire and the Humber	40	6.6	12	6.6	30.0
	All (100%)	396	65.0	141	77.5	35.6
NHS Northern Ireland	All	14	2.3	6	3.3	42.9
NHS Scotland	All	51	8.4	17	9.3	33.3
NHS Wales	All	22	3.6	11	6.0	50.0
Other[b]	All	126	20.7	7	3.8	5.6
UK	NHS and Other	609	100	182	100	29.9

Notes

(a) Data on numbers of scanners refers to 2012 (Stonell K, HPA, personal communication, 2012).

(b) 'Other' category includes scanners in the private sector, mobile scanners and others in the defence sector.

3.1.2 Scan sequences

Whereas data collection for the survey was primarily focused on the submission of anonymous scan information in relation to samples of individual patients for each combination of examination protocol and scanner, a quarter of participating hospitals were able only to offer more-limited, pre-processed (mean) data for groups of patients (Table 5). This so-called 'group data' was subsequently assimilated with other similar mean data derived for the centres providing individual patient scan data in order to allow analyses of typical practice (Section 3.3). Such group data provided over one-fifth of all scanners in the study, but accounted for about three-fifths of the total number of patients. The substantial nature of the survey is summarised in Table 5, with information in relation to 47,000 patients, 24,000 scan sequences and nearly 900 examination protocol/scanner combinations.

TABLE 3 Analysis of scanner models in the survey sample

Manufacturer	Models	Detector-row class[a]	No. in survey	% total
General Electric	Lightspeed 4, Plus 4	4	6	3.3
	Lightspeed 8, Ultra	8	2	1.1
	Lightspeed 16, Pro 16, RT	16	11	6.0
	Lightspeed 32, Pro 32	32	4	2.2
	Lightspeed VCT, XT, XTE	64	28	15.4
	Discovery CT750 HD	64	2	1.1
	All		53	29.1
Philips	MX8000	4	1	0.5
	MX8000 IDT, Infinite	16	3	1.6
	Brilliance CT 16, 16 Power, Big bore	16	5	2.7
	Brilliance CT 40	40	4	2.2
	Brilliance CT 64	64	10	5.5
	Brilliance ICT	128	2	1.1
	All		25	13.7
Siemens	Somatom Sensation 4, Volume Zoom	4	9	4.9
	Somatom Sensation 10	10	1	0.5
	Somatom Sensation 16, 16 Straton, Emotion	16	23	12.6
	Somatom Sensation 40	40	1	0.5
	Somatom Sensation 64	64	11	6.0
	Somatom Definition, AS	64	9	4.9
	Somatom Definition, AS+, Flash	128	15	8.2
	All		69	37.9
Toshiba	Aquilion 4, Asteion VR	4	4	2.2
	Aquilion 16, LB	16	5	2.7
	Aquilion 32	32	1	0.5
	Aquilion 64	64	22	12.1
	Aquilion CX	128	2	1.1
	Aquilion One	320	1	0.5
	All		35	19.2
All	All		182	100

Note

(a) Broadly reflects the maximum number of tomographic sections acquired simultaneously.

TABLE 4 Analysis of detector-row technology for scanners in the survey sample and the NHS in the UK (circa 2012)

Detector-row class[a]	% survey sample	% UK NHS[b]
<16	13	14
16	26	21
>16–<64	5.5	4.3
64	45	43
128	10	14
>128	0.5	3.5
All	100	100

Notes
(a) Broadly reflects the maximum number of tomographic sections acquired simultaneously.
(b) Data for the NHS in the UK (Stonell K, HPA, personal communication, 2012).

TABLE 5 Broad scope of data within the survey sample

Type of survey data	No. hospitals	No. scanners	No. protocols	No. patients	No. sequences
Individual patients	96[a]	142[a]	682	18,818	23,619
Group data	32[a]	41[a]	189	28,120	0
All	127	182	871	46,938	23,619

Note
(a) One hospital submitted data for a single scanner in relation to both individual patients and groups of patients.

Information concerning patient gender is presented by type of examination in Table 6. This shows the percentages of individual patients recorded as being female (F) and male (M) relative to the total numbers included in the survey. Notwithstanding any potential for bias from instances where gender was not reported (accounting for 0–24% of the patient samples), the overall number of patients is split fairly evenly between females and males. However, more specific trends are apparent in the samples for particular examinations, such as a predominance of male patients for CTA, urogram and KUB examinations, whereas females predominate for VC. These trends might not necessarily be representative of clinical practice owing to the non-systematic sampling methods used for data collection in the survey.

Table 6 also includes analyses for individual scan sequences by type of examination in relation to scan mode (axial or helical) and the use of both contrast and automatic tube-current modulation (TCM). Once again, incomplete collection of full data for the samples has provided some potential for bias in the percentages shown (where the totals deviate from 100%). Helical scan mode sequences predominate for most examinations in the survey sample, with the exception of head and chest (high resolution) procedures, where axial scanning is more commonly used. Contrast media was reportedly used in relation to about one-half of all scan

TABLE 6 Analysis by examination type of individual scan sequences (Seqs) by mode – axial (A) or helical (H) – and use – yes (Y) or no (N) – of contrast and tube-current modulation (TCM)

	Number			Scan mode		Contrast		TCM	
Examination[a]	Scanners	Patients (% F / % M)[b]	Seqs	% A[c]	% H[c]	% Y[c]	% N[c]	% Y	% N
Head	119	3,151 (48/44)	3,231	61	35	4	86	42	58
C-spine	42	794 (41/56)	688	2	95	1	91	85	15
Chest	108	2,081 (39/52)	2,872	2	94	81	10	86	14
Chest – hi res	90	1,574 (47/47)	1,920	61	35	2	89	71	29
CTA	53	766 (27/71)	1,427	21	77	69	29	72	28
CTPA	98	1,681 (51/39)	2,818	30	65	68	21	63	37
Abdomen	59	844 (43/48)	1,432	0	100	70	19	96	4
Abdo and pelv	105	2,496 (54/39)	1,990	5	91	85	11	83	17
VC	55	1006 (63/35)	1,842	0	100	64	34	81	19
Enteroclysis	11	112 (54/46)	114	0	100	92	8	82	18
KUB	101	1,637 (35/58)	1,665	0	98	5	86	77	23
Urogram	71	1,074 (36/59)	2,230	0	100	56	42	90	10
CAP	12	764 (37/39)	326	0	98	66	4	100	0
Head (–1 y)[d]	25	305 (42/52)	348	53	39	0	87	19	81
Head (– 5 y)[d]	25	264 (39/54)	353	56	34	0	83	23	77
Head (>5 y)[d]	26	269 (34/60)	363	71	29	1	92	26	74
All	142	18,818 (45/48)	23,619	22	76	46	46	72	28

Notes

(a) See Table 1 for more complete descriptions of each examination type.

(b) Numbers in brackets represent percentages of patients recorded as being female or male (with remaining percentages (0–24%) representing data missing on submission form).

(c) Remaining percentages (0–30%) represent data missing on submission form.

(d) Slightly revised age ranges from those originally included in data submission forms.

sequences included in the survey, although, in terms of patterns between the different types of examination, contrast administration was less common in relation to head, cervical spine, chest (high resolution) and KUB procedures. The majority of sequences were acquired using TCM, although this was reportedly used less in relation to head examinations.

Limited amounts of information were collected in the survey in relation to TCM brand and values of the 'auto mA quality factor' used to determine image quality for each acquisition sequence. The bases for such settings vary between manufacturers and scanner models

(Lee et al, 2008) and so absolute values cannot be compared between different systems. Accordingly, analyses of TCM settings of auto mA quality factor reported for a selection of CT systems are summarised in Table 7 by examination and sequence type.

The analysis in Table 7 is presented in terms of modal (rather than mean) values of TCM setting, together with the associated ranges (of minimum and maximum values), so as to provide more meaningful indications of common practice. Furthermore, in order to ensure reasonably robust results, the combinations of scanner model and examination/sequence type were limited to those where sample sizes of TCM setting for auto mA quality factor were at least 40 and the reported modal values accounted for more than half of the data. These analyses are therefore intended to provide broad indications of the consensus view in relation to typical settings for some commonly reported CT systems.

3.2 Distributions of Data for Individual Patients in the Survey

Analyses of the distributions of data collected in relation to individual patients in the survey are summarised by examination type in Tables C2.1 to C2.16 (Appendix C). Information for examinations of the paediatric head is presented for three age bands: up to 1 year, up to 5 years and greater than 5 years. A key to the abbreviations used in the tables is shown in Appendix C. Graphical representations of the data are given in Figures D1.1 to D1.16 (Appendix D), as histograms where the scale points marked on each *x*-axis represent upper boundaries of the bins.

Individual patients are characterised in the tables in terms of recorded age, mass, lateral and antero-posterior (AP) dimensions, and cross-sectional area (CSA). In addition, information is included concerning the number of sequences and total DLP for each individual examination, together with values of $CTDI_{vol}$ and applied potential in relation to individual sequences. Dose data presented for head and neck examinations is assumed to refer to the 16 cm diameter standard CT dosimetry phantom, whereas that for the other examinations refers to the 32 cm diameter standard CT dosimetry phantom. Data distributions are summarised in terms of means, sample sizes, standard deviations and coefficients of variation (%), together with percentile values (5%, 10%, 25%, 50%, 75% and 95%), and minimum and maximum values. Unfortunately, the submission of requested data by participating CT centres was not comprehensive, as indicated by variations in recorded sample size between the different quantities under analysis for each examination.

This analysis of individual data includes in principle all types of scan sequence performed for an examination, in relation not only to imaging but also to preparatory scans (such as, for example, scan projection radiography and contrast timing). The extent of submission of such non-imaging scan data was variable between CT centres and this will have an impact on the number of recorded sequences and values of $CTDI_{vol}$ that will necessitate care in the interpretation of this particular data. Furthermore, notwithstanding all efforts to check and eliminate rogue data, submitted values of $CTDI_{vol}$ might sometimes have been recorded as maximum values of CTDI for sequences involving TCM, rather than mean ones, or potentially represent erroneous cumulative values of CTDI for an examination, as provided in the dose summaries reported by particular CT scanners (Tsalafoutas et al, 2012). Reported values of DLP for each complete examination will in general include contributions from all the scan sequences performed (both imaging and non-imaging that may or may not have been recorded), although the total dose will be dominated by the imaging sequences.

TABLE 7 Analysis by scanner model of tube-current modulation (TCM) settings used for selected types of examination and sequence

Scanner		Setting of auto mA quality factor in relation to TCM[a]				
Make	Model[b]	Sample size	Modal height	Modal value	Min value	Max value
Head (acute stroke): 'brain'						
Siemens	Somatom Definition AS+	88	47	420	350	420
	Somatom Sensation 16	69	41	320	260	320
Toshiba	Aquilion 64	112	59	2	1.4	2.25
Head (acute stroke): 'cerebrum'						
GE	Lightspeed Pro 32	48	28	3.6	3.5	3.6
Siemens	Somatom Sensation 16	61	40	360	260	360
Head (acute stroke): 'posterior fossa'						
GE	Lightspeed 16	52	31	3.5	3	3.5
	Lightspeed Pro 32	48	28	3.6	3.5	3.6
Siemens	Somatom Sensation 16	61	40	320	300	360
Chest (lung cancer)						
GE	Lightspeed 16	43	23	12	11.6	12
	Lightspeed Plus 4	57	38	11.6	9.5	11.6
	Lightspeed VCT	243	127	38	12	42
Philips	Brilliance CT 16	40	20	200	200	265
Siemens	Somatom Definition	168	104	110	110	210
	Somatom Sensation 10	40	20	120	120	180
	Somatom Sensation 16 Straton	56	36	100	100	200
Chest – high resolution (interstitial lung disease): axial						
GE	Lightspeed VCT	133	88	33	15	33
Siemens	Somatom Definition	40	26	110	100	110
	Somatom Sensation 16	216	146	100	84	160
Chest – high resolution (interstitial lung disease): helical						
Siemens	Somatom Sensation 64	61	38	340	100	342
CT angiography (abdominal aorta/blood vessels)						
Siemens	Somatom Sensation 16	109	75	140	90	200
Toshiba	Aquilion 64	45	24	10	1.6	12.5
CT pulmonary angiography (pulmonary embolism)						
GE	Lightspeed 16	71	40	21.4	14	21.4
	Lightspeed VCT XTE	40	20	30.4	30.4	38
Siemens	Somatom Definition AS+	40	23	110	110	210
	Somatom Sensation 16	258	140	140	80	200
	Somatom Sensation 16 Straton	50	30	100	100	140
Toshiba	Aquilion 64	86	58	12.5	1.6	17

TABLE 7 *(continued)* Analysis by scanner model of tube-current modulation (TCM) settings used for selected types of examination and sequence

Scanner		Setting of auto mA quality factor in relation to TCM[a]				
Make	Model[b]	Sample size	Modal height	Modal value	Min value	Max value
Abdomen (liver metastases)						
GE	Lightspeed 16	59	37	27.5	12	27.5
Siemens	Somatom Definition	180	148	210	200	210
	Somatom Sensation 16	171	85	200	120	200
Toshiba	Aquilion 64	43	35	10	10	178
Philips	Brilliance CT 64	60	40	230	106	420
Abdomen and pelvis (abscess)						
Siemens	Somatom Definition AS	58	58	210	210	210
	Somatom Definition AS+	43	23	210	200	210
	Somatom Sensation 16	207	106	200	160	220
	Somatom Sensation 16 Straton	41	41	160	160	160
Toshiba	Aquilion 64	144	84	12.5	1.6	13.5
Virtual colonoscopy (polyps/tumour)						
GE	Lightspeed 4	60	60	12.3	12.3	12.3
Philips	Brilliance CT 40	40	20	203	203	473
Siemens	Somatom Definition AS+	40	20	70	70	180
	Somatom Sensation 16 Straton	80	40	160	30	160
Toshiba	Aquilion 16	40	40	40	40	40
	Aquilion One	40	40	32	32	32
Kidneys-ureters-bladder (stones/colic)						
Siemens	Somatom Definition	44	28	150	100	210
Urogram (stones/colic or tumour)						
GE	Lightspeed Pro 32	41	21	25.8	25.8	35.6
	Lightspeed VCT XTE	52	40	35.9	33	51.8
Siemens	Somatom Definition	43	43	210	210	210
	Somatom Definition AS	42	21	210	70	210
	Somatom Sensation 64	69	64	505	280	505
Toshiba	Aquilion 16	43	35	18	18	32
	Aquilion CX	54	28	15	12.5	18
	Aquilion One	41	39	12	12	26

Notes

(a) The bases for this data vary between CT manufacturers/models such that values cannot be compared more widely.

(b) Some amalgamation of similar models with similar TCM systems has been undertaken for the purposes of this broad summary.

The data for each type of examination exhibits wide ranges in relation to patient age and size, $CTDI_{vol}$ and DLP. Since this survey data does not result from random sampling, caution should be exercised in interpreting any apparent differences in patient age or size between examinations that might not be reliable reflections of clinical practice. Furthermore, the survey did not seek specific information in relation to image quality and all exposures and levels of dose were assumed to be fit for purpose.

This analysis provides background information in relation to the ranges in practice observed for individual patients undergoing a selection of common types of CT examination. A more important objective for the survey, however, is to study variations in typical practice between CT centres in order to be able to set national reference doses, as discussed in the next section.

3.3 Distributions of Data for Typical Practice at Participating CT Centres

In order to focus on typical practice, data submitted for the samples of individual patients by each participating CT centre has been averaged for each type of examination so as to provide broad indications of the local mean patient characteristics and routine levels of exposure by scanner and procedure. This mean data has been supplemented by other mean values submitted directly by some CT centres as 'group data' (described in Section 3.1.2). Analyses of the resulting distributions of mean data collected from patient samples at CT centres in the survey are summarised (following the pattern described in Section 3.2) by examination type in Tables C3.1 to C3.18 (Appendix C). Dose data presented for head and neck examinations is once again assumed to refer to the 16 cm diameter standard CT dosimetry phantom, whereas that for the other examinations refers to the 32 cm diameter standard CT dosimetry phantom. Information is presented separately for high resolution examinations of the chest using only axial and only helical scanning, respectively, as well as for all scan techniques together, as discussed further in Section 3.5.2. The data submitted in relation to enteroclysis was in particular rather limited (with sufficient data being received from only seven centres). Graphical representations of all the mean data for patient samples are given in Figures D2.1 to D2.18 (Appendix D), as histograms where the scale points marked on each *x*-axis represent upper boundaries of the bins.

In order to ensure robust results from this analysis, data samples were first filtered to exclude those where sample sizes for the total DLP were less than five (relevant to the analyses presented for mean values of recorded age, mass, lateral and antero-posterior (AP) dimensions, cross-sectional area, DLP and sample size for DLP). Results are also presented in relation to the mean number of sequences per examination, which here include only those sequences identified as being for the acquisition of images. The reported information concerning mean values of $CTDI_{vol}$ similarly excludes any data from non-imaging sequences and relates to sample sizes of five or more. This approach is in contrast to the previous unfiltered analyses of sequences in relation to individual patients (Section 3.2), as summarised in Appendix C.

Further analyses were undertaken in relation to the specific imaging sequences associated with each type of examination. In order to aid the interpretation and comparison of similar types of sequence, all individual sequences in the survey were broadly classified, for the purposes of this analysis, by a sequence identifier label to reflect the general region of scan in

relation to the type of examination. As previously, mean values were calculated for the data submitted by each CT centre so as to provide broad indications of the local technique by type of sequence and examination. In the interest of robustness of results, data samples were once again filtered to exclude those where sample sizes for $CTDI_{vol}$ were less than five.

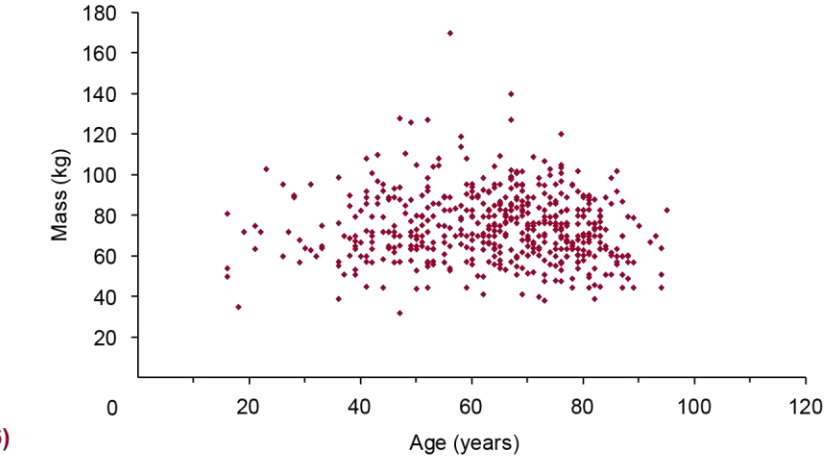
Analyses of the resulting distributions of mean data collected from patient samples at CT centres in the survey are summarised (following the pattern described in Section 3.2) by sequence identifier label for each examination type in Tables C4.1 to C4.19 (Appendix C). Summaries are presented for selected imaging sequences (with sufficient data) in relation to applied potential, pitch (as recorded for helical sequences only), beam collimation, scan length (as recorded), $CTDI_{vol}$ and DLP per sequence, together with sample size for the mean $CTDI_{vol}$. Data is given separately for three imaging scan sequence identifier labels associated with examinations of the head on adults ('brain', 'cerebrum' and 'posterior fossa') and two sequence labels in relation to high resolution scanning of the chest ('axial' and 'helical'). Graphical representations of the mean sequence data for samples of adult and paediatric patients undergoing examinations of the head are given in Figures D3.1 and D3.2 (Appendix D), as histograms where the scale points marked on each *x*-axis represent upper boundaries of the bins.

The analyses of the mean data for patient samples from participating CT centres that are presented in Appendix C, Sections C3 and C4, are to some extent less affected by any rogue data inadvertently submitted for individual sequences or patients that were discussed previously in Section 3.2. Accordingly, these particular summaries form the basis for updated assessments of typical practice in the UK (Section 4.4) and national reference doses (Section 3.6).

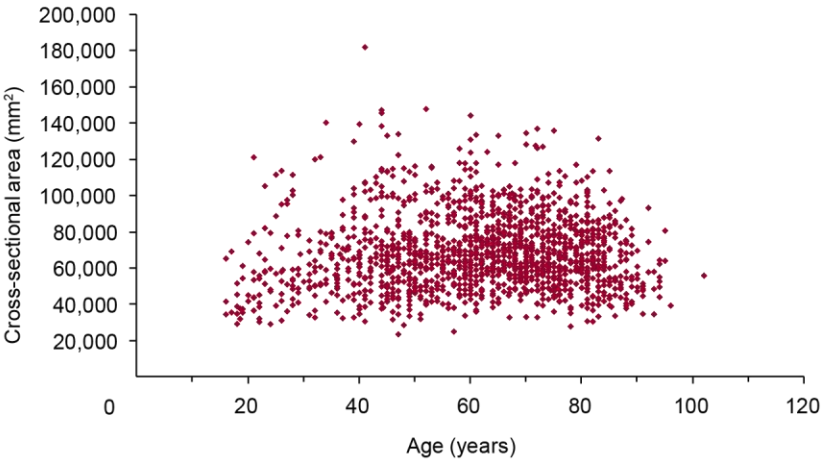
3.4 Correlations between Dose and Patient Size

In order to achieve optimised patient protection, the dose to the patient should be the lowest necessary to complete successfully the required clinical diagnostic task. Dose and image quality (noise) in CT are both dependent on patient size and therefore dose can be expected to vary with size when quality is kept broadly constant. Scanning protocols should be carefully selected for each patient group (with due account of size) and examination (with due account of clinical indication). Whereas the present survey has focused primarily on the mean data for samples of patients, as averaging over different sizes and providing broad indications of typical practice for standard technique, information was also sought in relation to individual patient size in order to study potential relationships between dose and size. Age, mass and cross-sectional area (CSA) were included as being reasonably readily available indicators for potentially characterising patient size.

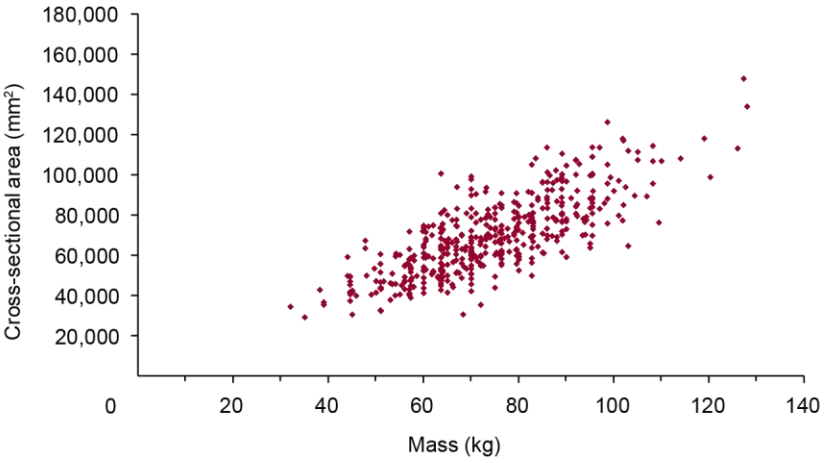
Relationships between these broad indicators of size and dose are explored in Figures 7 and 8 for individual patients undergoing, for the purposes of illustration, examination of the abdomen and pelvis (in relation to abscess) as providing representative data. Correlations between age and mass or CSA (as assessed from estimates of transverse and AP dimensions in the middle of the scan range) are, not surprisingly, poor (Figures 7a and 7b), whereas CSA and mass appear (Figure 7c) more reasonably correlated (correlation coefficient, R = 0.78). Correlations between values of total DLP per examination and patient mass (Figure 8c) or CSA (Figure 8d) appear relatively stronger than similar analyses (Figures 8a and 8b) involving $CTDI_{vol}$ (for all types of sequences), although all these relationships are relatively weak.



(a) Mass versus age (correlation coefficient R = –0.06)

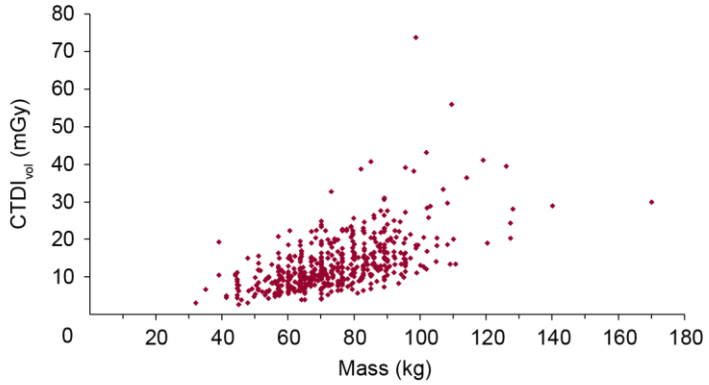


(b) Cross-sectional area (mid-scan range) versus age (correlation coefficient R = 0.04)

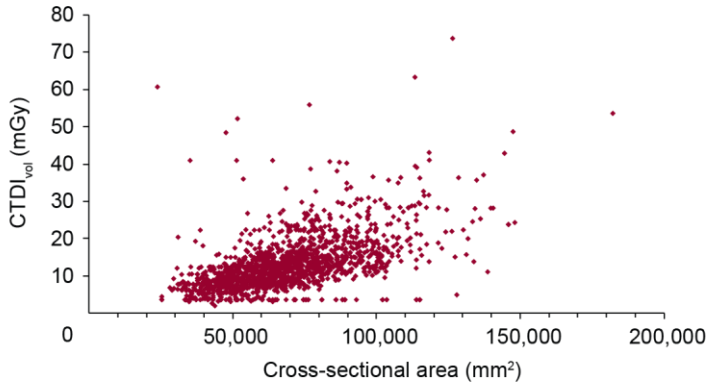


(c) Cross-sectional area (mid-scan range) versus mass (correlation coefficient R = 0.78)

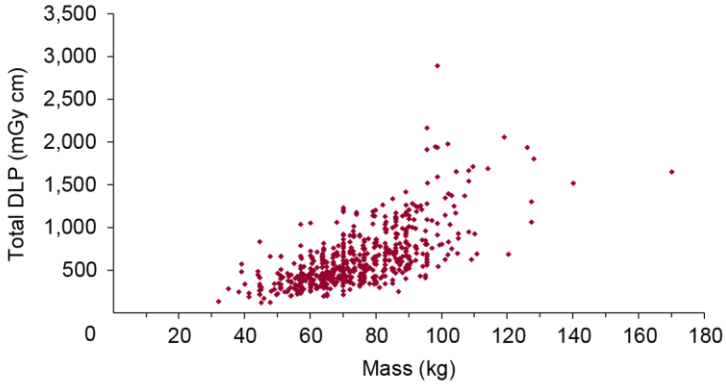
FIGURE 7 Correlations between age, mass and cross-sectional area for individual patients undergoing CT examinations of the abdomen and pelvis (abscess)



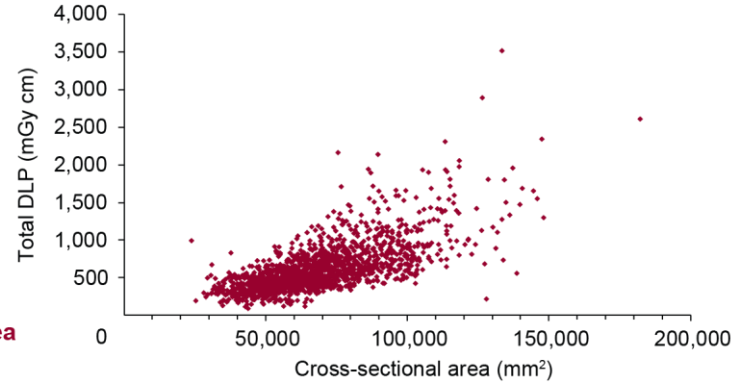
(a) $CTDI_{vol}$ versus mass (correlation coefficient R = 0.58)



(b) $CTDI_{vol}$ versus cross-sectional area (correlation coefficient R = 0.55)



(c) Total DLP versus mass (correlation coefficient R = 0.67)



(d) Total DLP versus cross-sectional area (correlation coefficient R = 0.69)

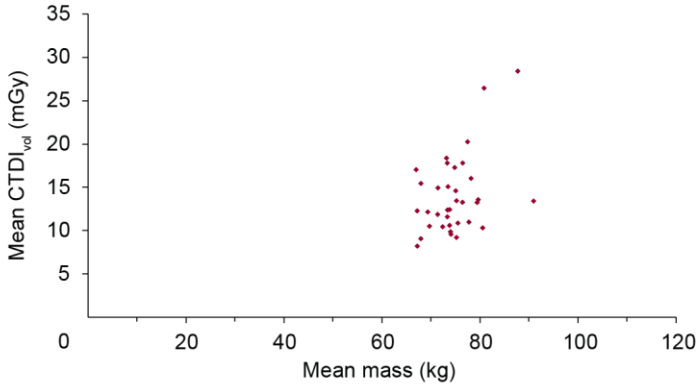
FIGURE 8 Correlations between dose ($CTDI_{vol}$ and total DLP) and mass and cross-sectional area for individual patients undergoing CT examinations of the abdomen and pelvis (abscess)

Further analyses involving mean data from patient samples (where $n > 4$ in relation to $CTDI_{vol}$ or DLP), rather than values for individual patients, do not provide any stronger evidence of relationships between mean total DLP and mean mass (Figure 9c) or mean CSA (Figure 9d), or between mean $CTDI_{vol}$ (for imaging sequences only) and mean mass (Figure 9a) or mean CSA (Figure 9b). The inconclusive nature of these figures in failing to demonstrate any firm relationships between dose and patient size could, perhaps, be interpreted in terms of a lack of uniform application of the principle concerning the optimisation of patient protection. However, such analyses are, of course, significantly confounded by other factors in addition to size that have an influence on dose, such as differences in CT technique, clinical imaging task and requirements for image quality. A more detailed analysis of this important topic is beyond the scope of the present national survey.

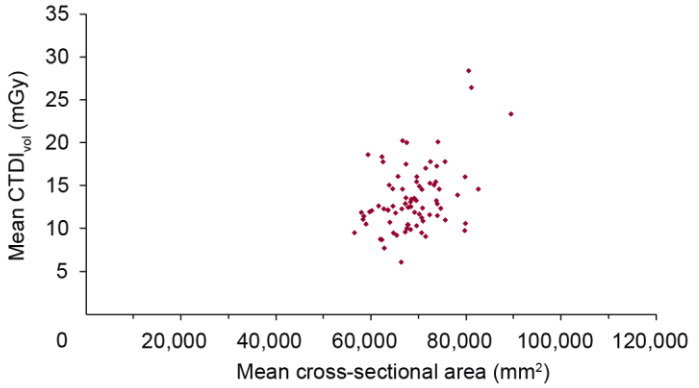
Similar investigations have also been undertaken using the information collected from the rather smaller number of paediatric patients undergoing CT examination of the head (in relation to trauma) (Figures 10–12). The relationship between CSA (of the head) and mass for the individual paediatric patients (Figure 10c) follows a similar pattern of reasonable correlation to that observed above for adults (undergoing CT of the abdomen and pelvis), whereas correlations between age and size are, of course, much improved in the case of the children. These latter relationships are illustrated in Figure 10a (mass versus age; R = 0.91) and Figure 10b (CSA versus age; R = 0.71). The latter figure includes data (marked nominally at age 16 years) in relation to the range of mean values of CSA (head) observed for the samples of adults undergoing head CT at the different CT centres in the survey; the vertical bar indicates the minimum and maximum mean values, together with the mean for this distribution. It is evident that, beyond a few months of age, CSA values for the present sample of paediatric heads fall largely in the range typically observed for the heads of adult patients.

Correlations between size and dose for individual paediatric patients undergoing head CT are illustrated in Figures 11 and 12 in relation to $CTDI_{vol}$ and total DLP, respectively. The strongest relationships (as indicated by the largest correlation coefficients) are apparent in relation to mass (Figures 11c and 12c), although all these trends remain relatively weak. Once again, the figures illustrating information concerning age include data (marked nominally at age 16 years) in relation to the range of mean values of $CTDI_{vol}$ (Figure 11a) and DLP (Figure 12a) observed for the samples of adults undergoing head CT at the different CT centres in the survey; the vertical bar indicates the minimum and maximum mean values, together with the mean for this distribution. It is evident that the dose indicators recorded for many of the children in the survey, even those of younger age, are similar to the values of $CTDI_{vol}$ or DLP typically used for examinations on adults. Indeed, subsequent review by some participating centres of their paediatric data submitted to the survey unfortunately identified the local use of protocols that were similar to those used for examinations of the adult head. Such analyses highlight the urgent need for these centres in particular to implement specific protocols that are optimised for imaging paediatric patients of different ages and size.

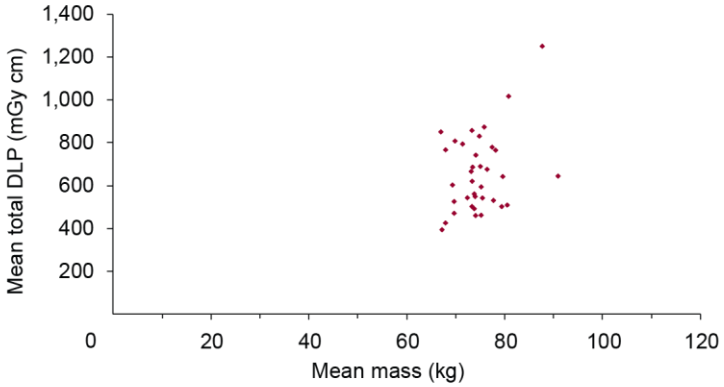
The optimisation of protection for all patients requires recourse to a range of protocols that have been specifically developed for each disparate patient group (with due account of size) in order to meet the particular imaging tasks for each type of examination (and associated clinical indication) for the lowest possible levels of dose.



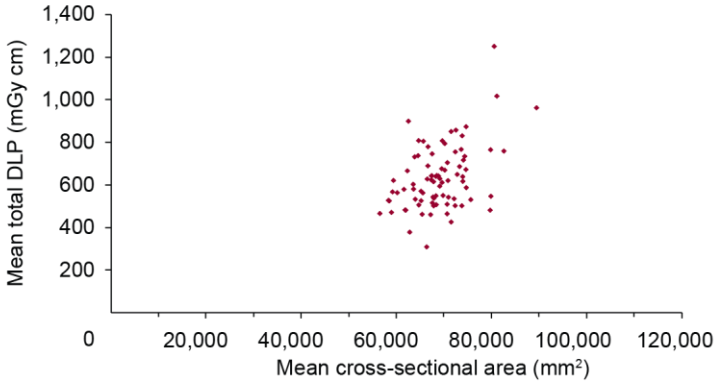
(a) Mean $CTDI_{vol}$ versus mean mass (correlation coefficient R = 0.42)



(b) Mean $CTDI_{vol}$ versus mean cross-sectional area (correlation coefficient R = 0.42)

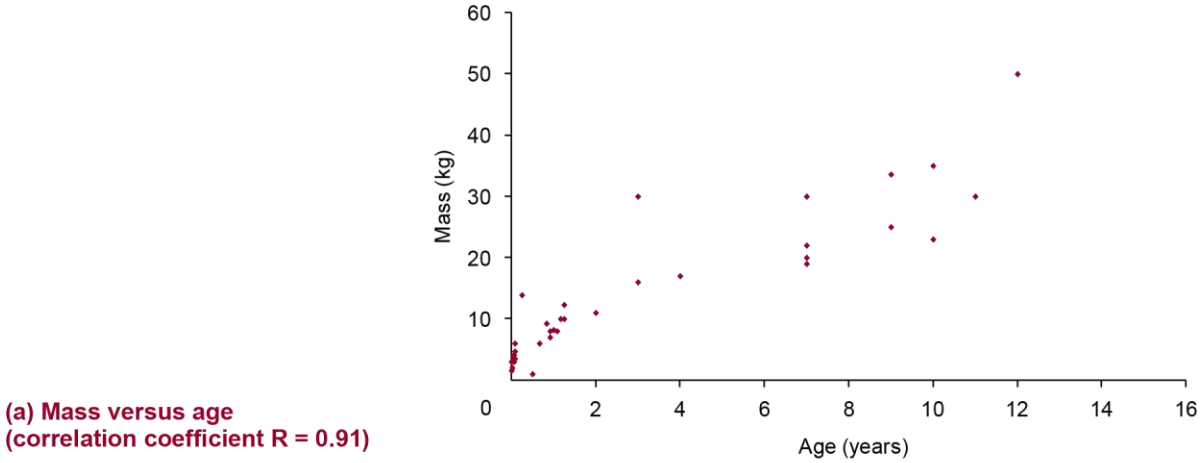


(c) Mean total DLP versus mean mass (correlation coefficient R = 0.34)

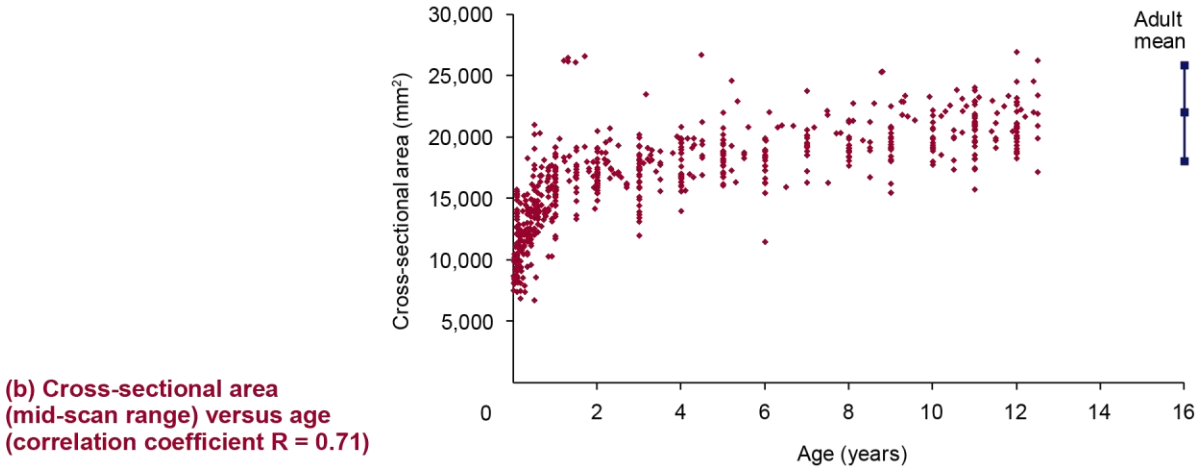


(d) Mean total DLP versus mean cross-sectional area (correlation coefficient R = 0.45)

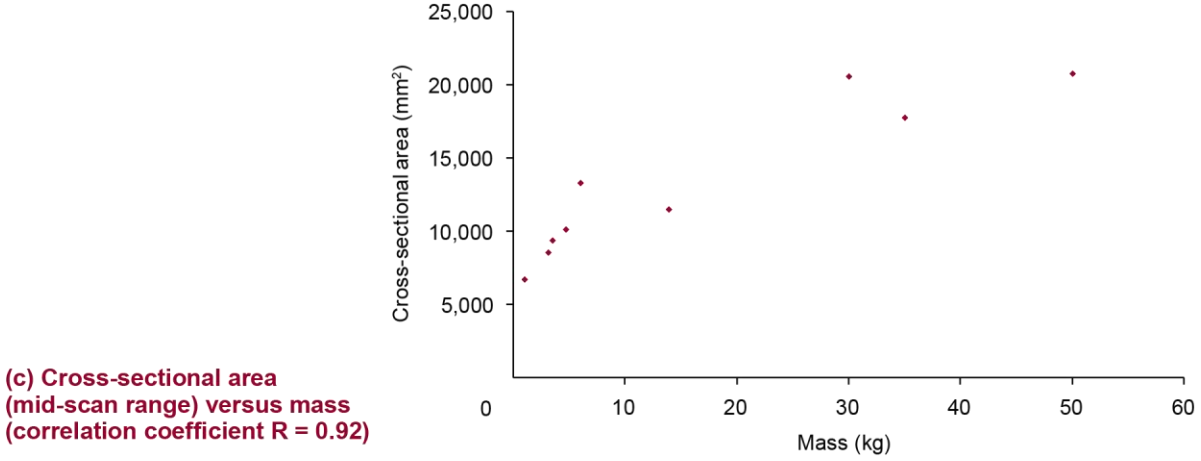
FIGURE 9 Correlations between mean dose ($CTDI_{vol}$ and total DLP) and mean values of mass and cross-sectional area for samples of patients (n > 4) undergoing CT examinations of the abdomen and pelvis (abscess)



(a) Mass versus age (correlation coefficient R = 0.91)

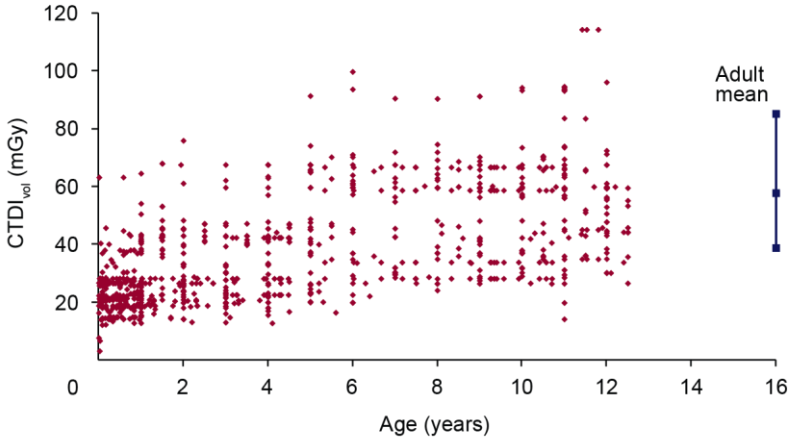


(b) Cross-sectional area (mid-scan range) versus age (correlation coefficient R = 0.71)

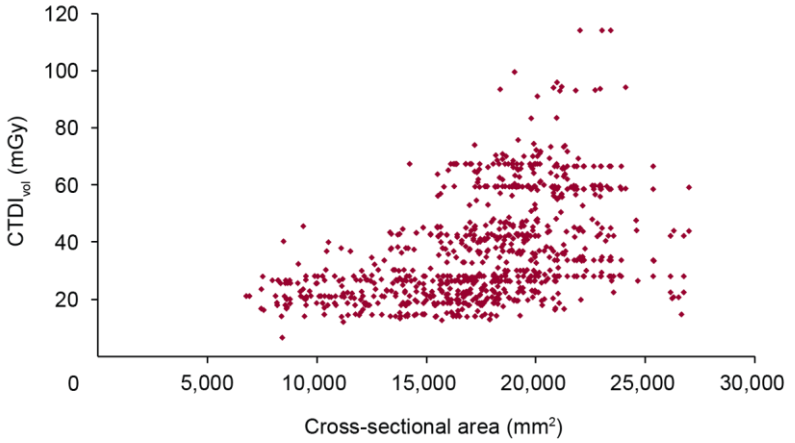


(c) Cross-sectional area (mid-scan range) versus mass (correlation coefficient R = 0.92)

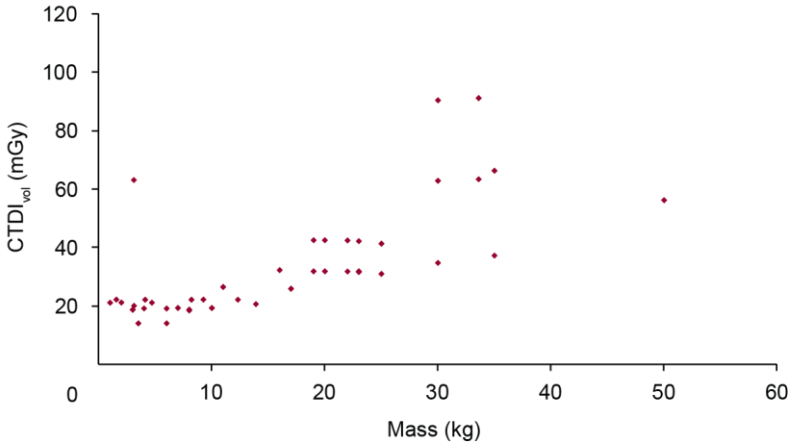
FIGURE 10 Correlations between age, mass and cross-sectional area for individual paediatric patients undergoing CT examinations of the head (trauma)



(a) $CTDI_{vol}$ versus age (correlation coefficient R = 0.62)

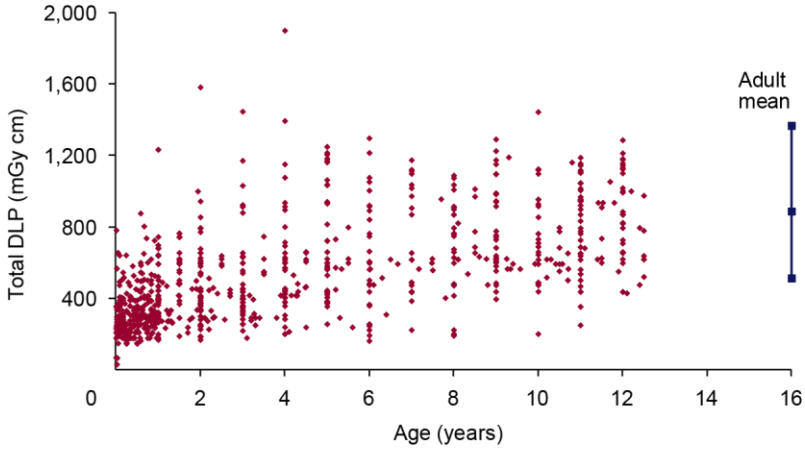


(b) $CTDI_{vol}$ versus cross-sectional area (correlation coefficient R = 0.46)

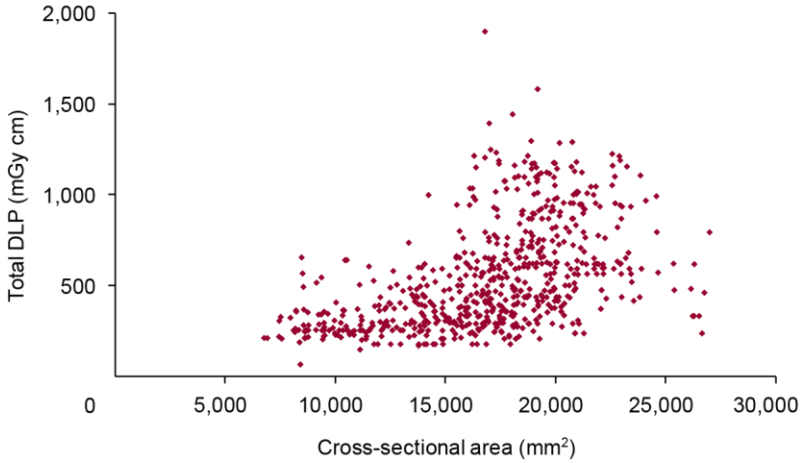


(c) $CTDI_{vol}$ versus mass (correlation coefficient R = 0.72)

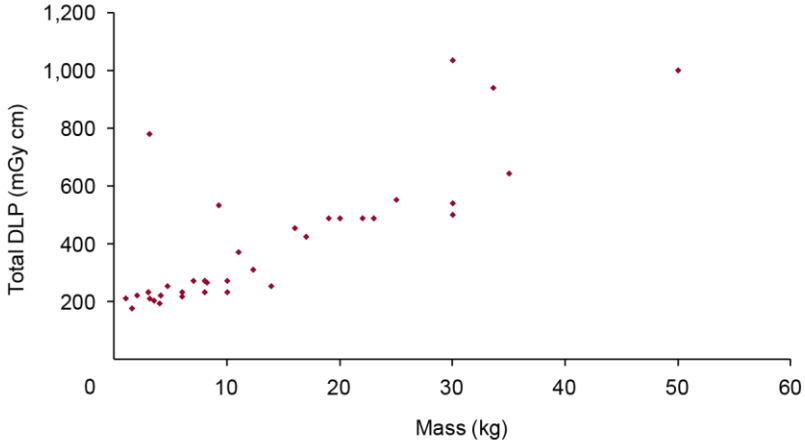
FIGURE 11 Correlations between $CTDI_{vol}$ and age, mass and cross-sectional area for individual paediatric patients undergoing CT examinations of the head (trauma)



(a) Total DLP versus age (correlation coefficient R = 0.62)



(b) Total DLP versus cross-sectional area (correlation coefficient R = 0.49)



(c) Total DLP versus mass (correlation coefficient R = 0.81)

FIGURE 12 Correlations between total DLP and age, mass and cross-sectional area for individual paediatric patients undergoing CT examinations of the head (trauma)

3.5 Special Analyses

3.5.1 Examinations of the head

Ongoing changes in technology require the review and appropriate adaptation of scanning techniques in order to ensure the continuing effective and efficient use of CT with optimised patient protection. One type of examination for which significant variations in scanning technique were apparent between centres was CT of the head for adult patients. Analysis of the present survey data revealed centres using axial or helical sequences exclusively, and with single or multiple sequences per examination, but also sometimes a mixture of scan modes (axial and helical). Helical-only examinations, for example, were very largely conducted as a single sequence of the whole brain, whereas the axial-only technique was split broadly between centres using a single sequence of the 'brain' or two separate sequences of the 'posterior fossa' and 'cerebrum'. The introduction of broad sequence labels to facilitate a more detailed analysis of survey data was discussed in Section 3.3 and dose information concerning the sequence labels 'brain', cerebrum' and 'posterior fossa' has already been summarised in Tables C4.1 to C4.3 (Appendix C).

In order to ensure robust comparisons of typical practice between CT centres, data samples relating to CT of the adult head were once again filtered to exclude those where sample sizes

TABLE 8 Analysis by technique of the distributions of mean doses[a,b] observed for examinations of the adult head

		$CTDI_{vol}$ per sequence (mGy)				DLP per examination (mGy cm)			
Scan mode	Technique	No. of data sets	Mean	Median	3rd quartile	No. of data sets	Mean	Median	3rd quartile
Axial	1 seq[c]	26	57	57	60	27	842	836	913
	>1 seq[d]	31	63	62	68	33	869	890	957
	All[e]	60	59	58	65	62	851	862	924
Helical	1 seq[c]	53	56	56	61	54	904	896	972
	>1 seq[d]	2	(62[f])	–	–	2	(841[f])	–	–
	All[e]	60	56	56	61	61	920	914	1000
All	1 seq[c]	76	56	56	61	78	887	895	954
	>1 seq[d]	114	58	57	63	127	905	907	988
	All[e]	114	58	57	63	152	888	895	973

Notes

(a) Doses refer to measurements in the 16 cm standard CT dosimetry phantom.

(b) Mean doses for sample sizes of $n > 4$ in relation to $CTDI_{vol}$ or DLP.

(c) Sequence label 'whole brain'.

(d) Sequence label not 'whole brain'.

(e) Includes all sequence labels for imaging. Totals for 'All' differ from the sums of figures for the single and multiple sequence categories owing to operation of the selection criterion for $n > 4$ under differing circumstances.

(f) Small sample size of only two sets of data.

for $CTDI_{vol}$ or total DLP were less than five, prior to the calculation of local mean values. The resulting distributions of mean doses are summarised (in terms of the number of sets of data and mean, median and third quartile values) by scan mode (axial or helical) and broad technique (single or multiple sequences) in Table 8.

In this summary table, the smallest mean values of mean $CTDI_{vol}$ are associated with examinations involving only single scan sequences, whereas the largest mean value is for the category of axial scanning with multiple sequences. This latter observation is consistent with the higher values of mean $CTDI_{vol}$ reported for sequences of the 'posterior fossa' (Table C4.3) compared with those for the cerebrum (Table C4.2) or the whole brain (Table C4.1). In relation to the mean values of mean DLP per examination, the smallest figure is for examinations using a single axial sequence, whereas the largest mean values are associated with helical scanning and examinations involving multiple sequences.

More quantitatively, the mean value of mean $CTDI_{vol}$ observed in the survey for examinations involving single axial sequences (57 mGy) is statistically significantly lower ($p < 0.01$) than that for examinations employing multiple axial sequences (63 mGy). The mean values of DLP per examination for these two particular categories also follow a similar trend, although the difference is not statistically significant. Furthermore, helical scanning (all techniques) is associated with a statistically significantly lower mean value of mean $CTDI_{vol}$ compared with axial scanning (all techniques) (56 mGy versus 59 mGy; $p < 0.05$). Conversely, the mean value of mean DLP for (all) helical scanning is statistically significantly higher than that for (all) axial scanning (920 mGy cm versus 851 mGy cm; $p < 0.05$). All other differences in the mean dose are not statistically significant, including comparisons between axial-only or helical-only and all techniques taken together.

In selecting CT scan technique and setting up imaging protocols, it is important not only to make full use of the technology available, but also to ensure the optimisation of protection for each patient group and type of examination that is consistent with the clinical purpose of the investigation. The observed variations in technique and dose for CT of the head suggest scope for improvement in establishing best practice in relation to the use of axial and/or helical scanning.

3.5.2 High resolution examinations of the chest

High resolution examination of the adult chest (in relation to interstitial lung disease) is another procedure for which significant differences in technique are apparent between CT centres in the survey. Dose information for this examination has already been summarised in relation to the use of axial-only scanning (Table C3.5, Appendix C), helical-only scanning (Table C3.6) and all techniques taken together (Table C3.4). Data associated with the specific sequence labels 'axial' and 'helical' is shown in Tables C4.6 and Table C4.7.

A comparison of the typical levels of dose by broad technique (axial- or helical-only scanning and all types together) is presented in Table 9. This is based on analyses of the distributions of mean doses (in terms of the number of sets of data and the mean, median and third quartile values) for each category, following once again the pre-filtering of data samples to exclude those where sample sizes for $CTDI_{vol}$ or total DLP were less than five, prior to the calculation of local mean values. Both axial-only and helical-only scanning techniques were in widespread use at CT centres in the survey, together also with a mixture of scan modes (axial and helical) for some patients.

TABLE 9 Analysis by technique of the distributions of mean doses[a,b] observed for high resolution examinations of the adult chest

	$CTDI_{vol}$ per sequence (mGy)				DLP per examination (mGy cm)			
Technique	No. of data sets	Mean	Median	3rd quartile	No. of data sets	Mean	Median	3rd quartile
Axial-only scanning	53	3.1	2.3	3.9	54	111	75	139
Helical-only scanning	34	11	9.1	12	33	361	296	350
All[c]	82	6.1	4.6	8.5	110	226	150	299

Notes

(a) Doses refer to measurements in the 32 cm standard CT dosimetry phantom.

(b) Mean doses for sample sizes of $n > 4$ in relation to $CTDI_{vol}$ or DLP.

(c) Analysis over all data together per centre, including axial, helical or unknown modes of scanning. Totals for 'All' differ from the sums of figures shown for the axial-only and helical-only categories owing to some centres using both these techniques, and others (including 'group' data) using unknown technique.

The mean values of typical dose (mean $CTDI_{vol}$ and mean DLP) for axial-only scanning (levels of 3.1 mGy and 111 mGy cm, respectively) are statistically ($p < 0.0001$) significantly lower by factors of more than three compared with those for helical-only scanning (11 mGy and 361 mGy cm, respectively). Furthermore, doses for both axial-only and helical-only examinations are statistically ($p < 0.005$) significantly different from those for all techniques taken together. These observations underpin the need to take account of the specific technique when setting national reference doses for the effective promotion of improvements in protection for patients undergoing high resolution examination of the chest, as presented in the next section.

3.6 PHE National Reference Doses

A key purpose of the present survey is to provide updated national reference doses for CT in order to facilitate continuing review and improvement in local practice in the pursuit of optimisation of patient protection (Wall, 2004). 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 the first UK CT survey (Shrimpton et al, 1991b) was subsequently used when establishing reference doses as part of European guidelines on quality criteria for CT (European Commission, 1999). National reference doses for the UK were revised following the second national CT survey for 2003 (Shrimpton et al, 2005).

Third quartile doses for a selection of CT examinations from the present (third) national survey for 2011 are summarised in Tables 10 and 11 in relation to $CTDI_{vol}$ per sequence and DLP per complete examination, respectively.

The third quartile data reported in Tables 10 and 11 for the present (2011) survey is based on the distributions of typical doses (pre-filtered to exclude sample sizes for $CTDI_{vol}$ or total DLP of less than five prior to the calculation of local mean values) that are summarised in Appendix C, Sections C3 and C4. Similar data (where available) is also included in these tables from the previous national review for 2003 (Shrimpton et al, 2005), with doses shown separately in relation to practice for single-slice CT (SSCT) and multi-detector-row CT (MDCT), whereas the present data refers solely to the latter technology.

TABLE 10 Comparison by examination type of values of $CTDI_{vol}$ (mGy) from the 2003 and 2011 national CT surveys: third quartile values for distributions of typical practice (mean doses per CT scanner) and recommended national reference doses

		Third quartile values for $CTDI_{vol}$ per sequence (mGy)			National reference doses for $CTDI_{vol}$ per sequence (mGy)		
		2003		2011[a]	2003		2011
Examination (clinical indication)	Scan region/ technique	SSCT	MDCT	MDCT	SSCT	MDCT	MDCT
Head[b] (acute stroke)	Post fossa	64	103	80 (30)	65	100	**80**
	Cerebrum	56	63	58 (30)	55	65	**60**
	Brain (whole)	–	–	61 (85)	–	–	**60**
	All sequences	59	80	63 (114)	–	–	**–**
Cervical spine[b] (fracture)	All sequences	–	–	28 (37)	–	–	**28**
Chest[c] (lung cancer)	Lung	10	13	–	10	13	**–**
	Liver	11	14	–	11	14	
	All sequences	11	13	12 (99)	–	–	**12**
Chest – high resolution[c] (interstitial lung disease)	Axial	–	–	4 (53)	–	–	**4**
	Helical	–	–	12 (34)	–	–	**12**
	All sequences	3	7	9 (82)	3	7	**–**
CTA[c] (abdominal aorta/blood vessels)	All sequences	–	–	15 (43)	–	–	**15**
CTPA[c] (pulmonary embolism)	All sequences	–	–	13 (80)	–	–	**13**
Abdomen[c] (liver metastases)	All sequences	13	14	14 (48)	13	14	**14**
Abdomen and pelvis[c] (abscess)	All sequences	13	14	15 (95)	13	14	**15**
Virtual colonoscopy[c] (polyps/tumour)	All sequences	–	–	11 (51)	–	–	**11**
Enteroclysis[c] (Crohn's disease)	All sequences	–	–	12 (6)	–	–	**–**
Kidney-ureters-bladder[c] (stones/colic)	All sequences	–	–	10 (92)	–	–	**10**
Urogram[c] (tumour/stones/colic)	All sequences	–	–	13 (63)	–	–	**13**

TABLE 10 *(continued)* Comparison by examination type of values of $CTDI_{vol}$ (mGy) from the 2003 and 2011 national CT surveys: third quartile values for distributions of typical practice (mean doses per CT scanner) and recommended national reference doses

		Third quartile values for $CTDI_{vol}$ per sequence (mGy)			National reference doses for $CTDI_{vol}$ per sequence (mGy)		
		2003		2011[a]	2003		2011
Examination (clinical indication)	Scan region/ technique	SSCT	MDCT	MDCT	SSCT	MDCT	MDCT
Chest-abdomen-pelvis[c] (cancer)	Lung	10	12	–	10	12	–
	Abdo/pelvis	12	14	–	12	14	–
	All sequences	12	13	13 (11)	–	–	–
Paediatric head: 0–1 y[b] (trauma)	Post fossa	34[d]	34[d]	–	35[d]	35[d]	–
	Cerebrum	28[d]	28[d]	–	30[d]	30[d]	–
	All sequences	28[d]	28[d]	26 (17)	–	–	**25**
Paediatric head: >1–5 y[b] (trauma)	Post fossa	49[d]	49[d]	–	50[d]	50[d]	–
	Cerebrum	42[d]	42[d]	–	45[d]	45[d]	–
	All sequences	43[d]	43[d]	43 (18)	–	–	**40**
Paediatric head: >5 y[b] (trauma)	Post fossa	65[d]	65[d]	–	65[d]	65[d]	–
	Cerebrum	46[d]	46[d]	–	50[d]	50[d]	–
	All sequences	51[d]	51[d]	61 (15)	–	–	**60**

Notes

(a) Figures in parentheses refer to sample sizes in relation to third quartile values.

(b) Doses refer to measurements in the 16 cm standard CT dosimetry phantom.

(c) Doses refer to measurements in the 32 cm standard CT dosimetry phantom.

(d) Analysis over all practice – single-slice CT (SSCT) and multi-detector CT (MDCT) scanners together.

Dose data is presently shown in relation to an increased number of types of examination for adults compared with the previous survey for 2003, with the addition of cervical spine, CTA, CTPA, virtual colonoscopy, enteroclysis, KUB and urogram. In contrast, results for paediatric CT are this time limited to examination of the head, as being of key importance, and three ranges of patient age (without the previously included examination of the chest). In view of observed differences in technique and associated dose already discussed in Section 3.5, values of $CTDI_{vol}$ are shown separately in relation to sequences broadly covering the scan regions of posterior fossa, cerebrum and whole brain in relation to CT of the adult head, and the techniques of axial-only and helical-only scanning for high resolution examinations of the chest. Separate values of DLP per examination are also shown for these latter two cases. The doses shown for all the other examinations relate to all scan techniques.

TABLE 11 Comparison by examination type of values of DLP (mGy cm) from the 2003 and 2011 national CT surveys: third quartile values for distributions of typical practice (mean doses per CT scanner) and recommended national reference doses

		Third quartile values for DLP per complete examination (mGy cm)			National reference doses for DLP per complete examination (mGy cm)		
		2003		2011[a]	2003		2011
Examination (clinical indication)		SSCT	MDCT	MDCT	SSCT	MDCT	MDCT
Head[b] (acute stroke)		760	931	973 (152)	760	930	**970**
Cervical spine[b] (fracture)		–	–	606 (54)	–	–	**600**
Chest[c] (lung cancer)		427	575	614 (130)	430	580	**610**
Chest – high resolution[c] (interstitial lung disease)	Any technique	77	174	299 (110)	80	170	**–**
	Axial only	–	–	139 (54)	–	–	**140 axial**
	Helical only	–	–	350 (33)	–	–	**350 helical**
CTA[c] (abdominal aorta/blood vessels)		–	–	1042 (47)	–	–	**1040**
CTPA[c] (pulmonary embolism)		–	–	441 (89)	–	–	**440**
Abdomen[c] (liver metastases)		455	472	909 (54)	460	470	**910**
Abdomen and pelvis[c] (abscess)		508	559	745 (120)	510	560	**745**
Virtual colonoscopy[c] (polyps/tumour)		–	–	947 (68)	–	–	**950**
Enteroclysis[c] (Crohn's disease)		–	–	646 (7)	–	–	**–**
Kidney-ureters-bladder[c] (stones/colic)		–	–	458 (100)	–	–	**460**
Urogram[c] (tumour/stones/colic)		–	–	1148 (74)	–	–	**1150**
Chest-abdomen-pelvis[c] (cancer)		762	937	1003 (39)	760	940	**1000**
Paediatric head: 0–1 y[b] (trauma)		270[d]	270[d]	353 (19)	270[d]	270[d]	**350**
Paediatric head: >1–5 y[b] (trauma)		465[d]	465[d]	649 (18)	470[d]	470[d]	**650**
Paediatric head: >5 y[b] (trauma)		619[d]	737[d]	863 (17)	620[d]	620[d]	**860**

Notes

(a) Figures in parentheses refer to sample sizes in relation to the third quartile values.

(b) Doses refer to measurements in the 16 cm standard CT dosimetry phantom.

(c) Doses refer to measurements in the 32 cm standard CT dosimetry phantom.

(d) Analysis over all practice – single-slice CT (SSCT) and multi-detector CT (MDCT) scanners together.

With due rounding, these third quartile data provide the foundation for the updated PHE national reference doses for CT on adult and paediatric patients in the UK that are also shown in Tables 10 and 11 in relation to $CTDI_{vol}$ per sequence and DLP per complete examination, respectively. For comparison, the tables include corresponding recommendations on dose from the 2003 review (Shrimpton et al, 2005).

Unfortunately, insufficient data was collected for enteroclysis examinations in the present survey in order to be able to set any reliable national reference doses, although the limited data from the small sample size of only seven centres is summarised for broad guidance in Table C3.12 (Appendix C). A reference value for $CTDI_{vol}$ has similarly not been recommended for CAP examinations owing to a lack of underlying data (as summarised in Table C3.15). Whereas sample sizes were also relatively small in relation to examinations of the paediatric head, indicative values of national reference doses have been included.

4 DISCUSSION

4.1 Survey Sample

UK practice in CT has continued to evolve in relation to improvements in technology (Table 3) and increased numbers of both scanners (Table 2) and examinations (Figure 1) since the previous 2003 review. It is important, of course, to ensure that scanning techniques are adapted appropriately for continuing effectiveness and efficiency following ongoing changes in CT technology. The present survey for 2011 includes data from a robust sample of some 30% of all UK scanners that is widely distributed in terms of both scanner model and geography. Information has also been collected in relation to 13 (Table 1) rather than the previous six common types of CT examination for adult patients in 2003. Accordingly, results from the study are assumed to provide an updated snapshot of CT practice that is nationally representative for the UK.

In contrast to the 2003 review, which mainly included (in pursuit of minimising data collection) information in relation to the performance of standard CT protocols (Shrimpton et al, 2005), the 2011 study has focused on exposure data from samples of individual patients for each type of examination at participating centres. Small amounts of such data were also included in the 2003 review and mean results from these patient groups were then in reasonable agreement (mostly within 10%) with comparable data for each standard protocol (with the exception of scans of the abdomen in relation to liver metastases, where doses from patient data were significantly higher). Data from individual patients (with sample sizes per centre of five or more in order to allow reliable estimates of mean values) were therefore thought to provide more robust indications of typical practice for the 2011 review.

4.2 Trends in Levels of Dose for the UK

The 2003 national review reported doses separately for the SSCT and MDCT technology then in use, with levels of exposure being slightly higher for the latter type of scanner (Shrimpton et al, 2005). Results from the latest study, where practice is now exclusively MDCT, confirm that there are still wide variations in technique and typical (sample mean) doses between CT centres for similar examinations, as evident from the distributions summarised in Tables C3.1

to C3.18 (Appendix C) and Figures D2.1 to D2.18 (Appendix D). In general terms, typical levels of exposure for examinations of the head and chest (with the exception of high resolution scans of the chest, as discussed separately below) are broadly lower or similar (within ±10%) to corresponding values for MDCT in 2003. In contrast, however, typical levels of total DLP for examinations of the lower trunk are presently higher than previously for MDCT by some tens of per cent, although corresponding levels of $CTDI_{vol}$ are in general quite similar (within ±10%).

One useful way of comparing results between surveys is in terms of third quartile values for the observed distributions of typical (mean) dose, as a simple way of characterising survey data that is also of relevance to national reference doses. Such third quartile values of $CTDI_{vol}$ per sequence for adult patients (Table 10) are presently lower for examinations of the head (by 10–20%) and the chest (by 10%), similar for scans of the abdomen (liver metastases) and higher for examinations of the abdomen and pelvis (by 10%). Third quartile values of the total DLP (Table 11) are presently slightly higher (but only by less than 10%) in relation to examinations of the head, chest and CAP, whereas data for scans of the lower trunk is significantly higher than previously (by 30% for the abdomen and pelvis, and by 90% for the abdomen).

The relative constancy of typical values of $CTDI_{vol}$ over the eight-year period between surveys will have occurred against a background of significant changes in both CT practice and technology, including continuing developments in MDCT (Table 3) and TCM (Table 6). Innovations between national reviews in relation to scanning speed, image quality and dose efficiency, for example, have helped support improvements in clinical imaging and patient protection and hence the effectiveness of contemporary CT as an ever more powerful diagnostic tool, although the present national dose surveys do not, of course, provide detailed analyses of imaging performance.

The observed increase in values of total DLP (yet similar levels of $CTDI_{vol}$) for examinations of the lower trunk between surveys could be a consequence of the present use of increased scan lengths and/or number of sequences (particularly in relation to imaging for different phases in the distribution of contrast medium). Unfortunately, since the main purpose of the national reviews is in relation to the setting of national reference doses rather than the optimisation of scanning technique, the surveys are able only to collect quite limited information in relation to the parameters necessary to support these suggestions. However, comparison of the data available for 2003 (see Table C3, Shrimpton et al, 2005) and 2011 (see the tables in Appendix C, Sections C3 and C4, in this report) provide some broad evidence for the proposed trends; for example, the mean number of sequences for examination of the abdomen (in relation to liver metastases) has risen from 1.4 to 1.7 and the mean length of scan (for sequence label ‘abdomen/pelvis’) has increased from 254 to 431 mm. It is important, of course, to limit the complexity and extent of all CT scans to that necessary to provide the information required to meet the clinical purpose of each examination.

Increased levels of dose in CT can, of course, be appropriate if accompanied by commensurate increases in benefit in relation to clinical efficacy. The optimisation of patient protection is concerned not merely with dose reduction, but rather with systematic improvement in the balance between benefit and risk from X-ray exposures (ICRP, 2007b).

One particular procedure for which patterns of practice have changed significantly between national reviews is high resolution examinations of the chest (in relation to interstitial lung disease), as already discussed in Section 3.5.2. In the previous review for 2003, significant differences in practice for this examination were observed between broad classes of scanner technology, leading to the recommendation of separate national reference doses for SSCT (used in about three-fifths of the survey sample) and MDCT (one-third of the sample), with levels for the latter being over twice those for the former (Shrimpton et al, 2005). Axial scanning was overall the predominant (96% of all sequences) mode of scanning. In contrast, MDCT is the sole modality used for this examination in the 2011 review, with axial scanning now accounting for only three-fifths of sequences (Table 6). Third quartile values for the present distributions of typical dose in relation to axial-only scanning (4 mGy for $CTDI_{vol}$ and 139 mGy cm for DLP; see Tables 9, 10 and 11) are less than the corresponding MDCT data for 2003 by 40% and 20%, respectively. However, similar data in relation to helical-only scanning (12 mGy for $CTDI_{vol}$ and 350 mGy cm for DLP; see Tables 9, 10 and 11) is presently higher by 70% and 100%, respectively, compared with previous practice for MDCT. The present levels for helical-only scanning are 150–200% higher than for axial-only scanning. Both sets of data for 2011 are considerably higher than those for SSCT (3 mGy for $CTDI_{vol}$ and 77 mGy cm for DLP) in the 2003 review. These analyses underpin the recommendation for separate and significantly different national reference doses for axial- and helical-only scanning techniques. Knowledge of typical levels of dose should inform the critical review by CT centres of local scanning technique in pursuit of the optimisation of patient protection in relation to the clinical purpose of each type of examination.

Differences in technique were also observed in relation to CT examinations of the adult head (acute stroke), as already discussed in Section 3.5.1, with the use of axial (as single or multiple sequences) or helical scanning both being in common use. Mean values of (mean) $CTDI_{vol}$ and DLP were significantly ($p < 0.05$) different between these techniques (Table 8), with lower values of $CTDI_{vol}$ reported for helical scanning and lower values of the total DLP in relation to axial scanning. However, differences in corresponding values amounted in each case to less than 10% and so were not thought at present to be sufficiently significant so as to warrant the recommendation of separate national reference doses. However, the analysis does highlight the need for increased attention to the improved selection of scanning technique in order to ensure the optimisation of patient protection in relation to clinical task for this particular common examination. Protocol selection in head CT in relation to ongoing changes in technology is a topic that would merit further detailed attention in future surveys and the revision of national reference doses.

The 2011 review includes two examinations of the urinary system, KUB and urogram, that have become relatively commonly performed since the previous national survey for 2003. Whereas there is partial overlap in the clinical indications for these procedures (Table 1 and Appendix A), their complexity of technique (Appendix A) and typical doses (Tables C3.13 and C3.14, Appendix C) are quite different. The national reference dose for DLP, for example, suggested for the more detailed urogram (1150 mGy cm) is more than twice that (460 mGy cm) for the simpler KUB procedure (Table 11). Accordingly, it is important to ensure clear judgement in referral of patients for CT KUB or urogram.

In addition to presenting information for 13 common types of CT examination for adults, the present survey has collected individual patient data in relation to head examinations on children (trauma). The previous review of standard protocols for 2003 (Shrimpton et al, 2005)

also included paediatric chest examinations, although these were no longer thought to be common enough in general CT centres so as to provide sufficient patient data for the 2011 survey. A more detailed review of paediatric CT is, however, being undertaken as part of a separate ongoing collaborative dose survey involving PHE (Owens CM, Great Ormond Street Hospital for Children, personal communication, 2010).

Notwithstanding the relatively small number of CT centres providing paediatric data for the 2011 review, the reported mean values of DLP are presently somewhat higher than the previous data, although there are slight differences in the three ranges of patient age between surveys. In 2003, standard protocols were collected in relation to patients aged 0–1 year, 5 years and 10 years, whereas the present patient data from each CT centre has been banded into the ranges 0–1 years, >1 to 5 years and >5 years, although the mean values (over all centres) of mean patient ages for these groups (0.4 year, 3 years and 9 years, respectively) are quite similar to the previous classifications. Third quartiles values for the distributions of the mean DLP are 20–40% higher than for the three corresponding age ranges in the 2003 review (Table 11). Third quartile values for mean $CDTI_{vol}$ (all sequences) are presently lower (by –10%) for the youngest age band, similar for the middle age band and higher (by +20%) for the oldest age band (Table 10). These changes in $CTDI_{vol}$ do not alone account for the observed increases in levels of DLP and so other influences, such as increased use of helical rather than axial scanning and longer scan lengths, are probably contributing factors. Comparison of data concerning technique that is available for 2003 (see Tables 7 and C3, Shrimpton et al, 2005) and 2011 (see Table 6 and Tables C4.1 to C4.19 in this report) provide some broad evidence for these suggested trends.

Other analyses of trends between dose and patient size (age, mass or cross-sectional area in the middle of the scan range) were inconclusive owing to numerous confounding factors. However, there is a fundamental need for the development and application of specific protocols that are tailored for the characteristics of each patient group, including in particular paediatric patients, in order to ensure optimisation of patient protection in relation to each type of examination and clinical indication.

4.3 Trends in National Reference Doses for the UK

Trends in recommended values of national reference doses for CT, set on the basis of third quartile data from the periodic national surveys, are summarised in Tables 12 and 13 for adult and paediatric patients, respectively.

Reference doses for adults that were published in 1999 by the European Commission (European Commission, 1999) were derived for particular key CT examinations on the basis of survey data from the UK for 1991 (Shrimpton et al, 1991b). The figures (in parentheses) shown in Table 12 under $CTDI_{vol}$ for 1999 relate to values of $CTDI_{w}$ (that exclude the influence of pitch), although values for these two dose quantities will be very similar in the case of scans of the head. The pairs of doses shown for 2003 refer to data for SSCT and MDCT, respectively. In relation to national reference doses for $CTDI_{vol}$, values have fallen (for MDCT) between 2003 and 2011 for specific scan sequences used in head CT (although they presently remain similar to comparable data for 1999); doses have also fallen for chest CT (lung cancer), whereas they are similar for abdomen (liver metastases) and higher for abdomen and pelvis (abscess) examinations, although none of these changes is large (all being within ±10%). In contrast, national reference doses for total DLP have all increased

TABLE 12 Trends in national reference doses for common CT examinations on adults

Examination (clinical indication)	Region/ technique	National reference doses for the UK					
		$CTDI_{vol}$ per sequence (mGy)			DLP per exam (mGy cm)		
		1999[a]	2003[b]	2011[c]	1999[a]	2003[b]	2011[c]
Head[d] (acute stroke)	Post fossa	–	65/100	80	–	–	–
	Cerebrum	–	55/65	60	–	–	–
	Brain (whole)	–	–	60	–	–	–
	Whole exam	(60[e,f])	–	–	1050[f]	760/930	970
Chest[g] (lung cancer)	Lung	(30[e,f])	10/13	–	–	–	–
	Liver	(35[e,h])	11/14	–	–	–	–
	Whole exam	–	–	12	650[f]	430/580	610
Chest – high resolution[g] (interstitial lung disease)	Axial only	–	–	4	–	–	140
	Helical only	–	–	12	–	–	350
	Whole exam	(35[e,h])	3/7	–	280[h]	80/170	–
Abdomen[g] (liver metastases)	Whole exam	(35[e,h])	13/14	14	900[h]	460/470	910
Abdomen and pelvis[g] (abscess)	Whole exam	(35[e,f])	13/14	15	780[f]	510/560	745
Chest-abdomen-pelvis[g] (cancer)	Whole exam	–	12/14	–	–	760/940	1000

Notes

(a) European Commission (1999) using some data from the first UK CT survey (Shrimpton et al, 1991b).
(b) Shrimpton et al (2005). Data shown separately for SSCT/MDCT.
(c) Present work.
(d) Doses refer to measurements in the 16 cm standard CT dosimetry phantom.
(e) Data refers to values of $CTDI_w$ rather than $CTDI_{vol}$.
(f) Based on data from the first UK CT survey (Shrimpton et al, 1991b).
(g) Doses refer to measurements in the 32 cm standard CT dosimetry phantom.
(h) Based on data from European pilot study (Jurik et al, 2000).

between 2003 and 2011; by less than 10% each for the head, chest and CAP, 30% for the abdomen and pelvis, and 90% for the abdomen. These changes reverse the previous trend for lower doses and, as a consequence, the updated values of DLP for 2011 (Table 12) are now quite similar to the levels for 1999 (on the assumption of comparable examinations and clinical indications).

As an exception to the above analysis, national reference doses for high resolution chest examinations (interstitial lung disease) are presently recommended, on the basis of the significantly different doses observed, for two specific techniques: axial-only and helical-only

scanning. This strategy is in order to promote effectively practical improvement in specific performance. The new national reference dose levels for this examination are quite different to the previous single values for $CTDI_{vol}$ and DLP for MDCT in 2003 (Table 12): the present doses for axial scanning are lower by 40% and 20%, respectively, whereas the doses for helical scanning are higher by 70% and 100%, respectively.

National reference doses for paediatric CT were first set in 2000 (Shrimpton and Wall, 2000) on the basis of a wide-scale survey of practice in a range of European countries, including the UK. The 2003 UK review included both paediatric head and chest examinations, with only the former now included in the 2011 survey as being sufficiently commonly performed in general CT centres. Trends in national reference doses for this particular examination in the UK are summarised in Table 13. Whereas the 2003 review included values of $CTDI_{vol}$ in relation to specific scan sequences for the head, this approach was not practical for either the 2000 European or 2011 UK surveys. For the youngest two age ranges, national reference dose values for $CTDI_{vol}$ have continued to fall since 2003 and are over 30% lower than the reference levels recommended for 2000. The reference value of $CTDI_{vol}$ for the oldest age band (>5 years) is lower (by 10%) relative to the 2003 level for scans of the posterior fossa, but higher (by 20%) than previously for scans of the cerebrum, although the 2011 dose is 15% lower than that for 2000. The pattern in relation to reference dose values for DLP is quite different, however. The previously observed trend for lower dose levels has been reversed, with relative increases since 2003 by between 30% and 40%, such that the 2011 data is now larger by 15–20% than the corresponding values for 2000.

Following this latest rise in national reference doses for head examinations on patients aged over 5 years, the present level (of 60 mGy) for $CTDI_{vol}$ is the same as that for adults (cerebrum

TABLE 13 Trends in national reference doses for common CT examinations on children

		National reference doses for the UK[a]					
		$CTDI_{vol}$ per sequence (mGy)			DLP per exam (mGy cm)		
Examination (clinical indication)	Region/ technique	2000[b]	2003[c]	2011[d]	2000[b]	2003[c]	2011[d]
Paediatric head: 0–1 y[e] (trauma)	Post fossa	–	35	–	–	–	–
	Cerebrum	–	30	–	–	–	–
	Whole exam	40	–	25	300	270	350
Paediatric head: >1–5 y[e] (trauma)	Post fossa	–	50	–	–	–	–
	Cerebrum	–	45	–	–	–	–
	Whole exam	60	–	40	600	470	650
Paediatric head: >5 y[e] (trauma)	Post fossa	–	65	–	–	–	–
	Cerebrum	–	50	–	–	–	–
	Whole exam	70	–	60	750	620	860

Notes

(a) Doses refer to measurements in the 16 cm standard CT dosimetry phantom.

(b Data from the 2000 European survey including the UK (Shrimpton and Wall, 2000).

(c) Shrimpton et al (2005).

(d) Present work.

(e) Slight differences in age banding between surveys underlying the three sets of reference doses.

or whole brain), and the corresponding figure (of 860 mGy cm) for the DLP is approaching the value of 970 mGy cm for adult patients. Notwithstanding the apparent similarity in cross-sectional area between the heads of older children and adults (Figure 10b, as discussed in Section 3.4), it is important to ensure the use of specific scanning protocols for optimised patient protection in paediatric CT, in view of an assumed increase in radiation risk per unit dose with decreasing age at exposure (Wall et al, 2011).

The updated national reference doses from this review for the UK refer to the mix in practice pertaining in 2011 and, notwithstanding continuing evolution in CT, are suitable for general application in patient protection over the next few years. Whereas levels are recommended in relation to only 14 specific types of examination for particular clinical indications, these reference doses can also help inform improvements in practice for other procedures with similar technical requirements for imaging. The doses are intended to support an initial step towards optimisation of patient protection by providing broad guidance to local CT centres on (potentially) unusually high doses during review of practice. The mean levels of dose determined locally for groups of patients undergoing each type of examination should be compared against the relevant national reference dose (IPEM, 2004). The present national reference doses are likely to underpin any national DRLs subsequently set by the Department of Health (2007). 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.

The present national reference doses for the UK are in general similar to national DRLs published for other countries, such as those in continental Europe (Dose Datamed 2, 2013). However, such comparisons should always be approached with caution in relation to the degree of compatibility between results from different countries for apparently similar types of examination, particularly in the absence of their specified clinical indication.

4.4 Typical Doses from CT in the UK

Typical doses from common CT examinations in the UK are summarised in Table 14 in terms of the dose monitoring quantities $CTDI_{vol}$ and DLP. The data represents the mean values for the distributions of the typical (mean) doses observed for the samples of patients from each centre participating in the survey. Typical levels of effective dose (*E*) have also been derived from these mean values of DLP and will be published with due detailed discussion elsewhere (Shrimpton et al: Updated estimates of typical effective doses for common CT examinations in the UK following the 2011 national review; *in preparation*), since this particular topic is not the prime focus of the present report.

The typical doses for examinations on adults are presently higher than the previous results from the 2003 review determined for standard protocols in relation to overall national practice (including both SSCT and MDCT) (see Table 13, Shrimpton et al, 2005). Increases for typical levels of $CTDI_{vol}$ are within 10% in relation to examinations of the head, chest (lung cancer) and abdomen (liver metastases), but they rise to 20% for the abdomen and pelvis (abscess) and, when including all types of technique, 90% for high resolution examinations of the chest (interstitial lung disease). Typical levels of DLP are presently 30–40% higher in relation to examinations of the head, chest, and abdomen and pelvis, whereas the increases are more substantial in relation to the abdomen (90%) and high resolution chest (all techniques) (160%).

TABLE 14 Typical doses[a] from CT in the UK for 2011

Examination (indication)		$CTDI_{vol}$ (mGy)[b]	DLP (mGy cm)[b]
Head (acute stroke)		58	890
Cervical spine (fracture)		24	525
Chest (lung cancer)		11	500
Chest – high resolution (interstitial lung disease)	All techniques	6.1	230
	Axial-only	3.1	110
	Helical-only	11	360
CTA (abdominal aorta/blood vessels)		13	800
CTPA (pulmonary embolism)		11	360
Abdomen (liver metastases)		13	670
Abdomen and pelvis (abscess)		13	645
Virtual colonoscopy (polyps/tumour)		8.5	780
Enteroclysis (Crohn's disease)		10	580
Kidney-ureters-bladder (stones/colic)		8.3	355
Urogram (tumour/stones/colic)		11	960
Chest-abdomen-pelvis (cancer)		10	900
Paediatric head: 0–1 y (trauma)		23	315
Paediatric head: >1–5 y (trauma)		35	530
Paediatric head: >5 y (trauma)		52	750

Notes

(a) Doses represent the mean values of the distributions of typical (mean) doses from the sample of CT centres (Appendix C).

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

For head examinations on children, typical values of the dose descriptors $CTDI_{vol}$ and DLP decrease with decreasing age (and size). The present data is based on practice for samples of patients rather than (as previously) standard protocols and there are slight differences in the three age bands used between the surveys. Typical values of $CTDI_{vol}$ are 10% lower than previously for the youngest group (0–1 year) and 20% higher for the oldest group (>5 years), whereas the values of DLP are all higher by 40–50%.

It is important, of course, to limit the complexity and extent of all CT scans to that necessary to provide the information required to meet the clinical purpose of each examination following due justification. Since children are potentially more susceptible to radiation effects (Wall et al,

2011), special efforts should be made in clinical practice to reduce their doses by the use of size-specific scan protocols for optimised CT imaging (Goske, 2014).

4.5 Future National Reviews for the UK

Dose data from the present survey will provide a new baseline to support further improvements in the optimisation of patient protection in CT and will inform, in due course, the revision of national DRLs by the Department of Health (2007). In view of the continuing evolution in technology and clinical application of CT, including in particular cardiac CT, there is a particular need for further close monitoring of such developments and their impact on national practice. Local surveys of dose in CT should already be a routine part of periodic performance testing in X-ray departments (IPEM, 2005) in support of the setting and review of local DRLs (IPEM, 2004). Coordination of such local dose information, as presently undertaken by PHE (and previously by the HPA and NRPB), provides the essential added value of national overview to monitor trends and to underpin the timely revision of national DRLs. All CT centres are strongly encouraged to continue to participate actively in this important process by the regular submission of new survey data.

However, in conducting further such national surveys, there is presently a timely opportunity to improve methods for the streamlined collection of data in order to exploit fully the increasing availability of information in electronic form from picture archiving and communication systems (PACS) and radiology information systems (RIS) used by healthcare providers. This process should also facilitate the systematic collection and collation of data to meet evolving requirements for monitoring national doses from diagnostic and interventional radiology. There is therefore a need to review national imperatives and to develop a new strategy for the efficient and effective performance of future surveys to provide timely dose information. PHE intends to work collaboratively with healthcare professionals and others in the development of such a new approach for the improved automation of national dose surveys.

In addition, in order to supplement the limited data for children included in the present review, there is a need for a more detailed study on paediatric CT, as presently underway (Owens CM, Great Ormond Street Hospital for Children, personal communication, 2010), that includes practice in both specialised and general centres so as to support improvements in patient protection.

5 CONCLUSIONS

The present review includes data from a robust sample of nearly a third of all CT scanners in the UK and provides a substantial snapshot of CT practice (now all MDCT) for 2011 in relation to 13 common types of examination on adults and also head examinations for children (collated into three age bands). Whereas the previous two national reviews (Shrimpton et al, 1991b, 2005) focused on standard CT protocols and necessarily included SSCT, this survey collected information on technique, not least the established dose indicators $CTDI_{vol}$ and DLP, for 47,000 individual patients, representing some 900 examination protocol/scanner combinations and 24,000 separate scan sequences. Typical practice at each CT centre has been characterised by the mean values of dose determined for each sample of patients.

Wide variations are still apparent in typical practice between CT centres for similar procedures. This observation highlights the need for continuing review of scanning techniques following advances in CT technology in order to ensure patient protection remains optimised in relation to each type of examination and clinical indication. Typical doses for examinations on adults are presently higher than the previous results from the 2003 review in relation to overall national practice (that included both SSCT and MDCT). In general, increases for typical levels of $CTDI_{vol}$ are within 20% and those for DLP within 40%, although more significant changes are observed in relation to high resolution scans of the chest, where two quite different techniques are presently used; typical doses for axial-only scanning are significantly lower by factors of more than three compared with those for helical-only scanning. Notwithstanding slight differences in the three age bands for children used between the surveys, relative changes in typical values of $CTDI_{vol}$ for examinations of the head are between –10% and +20%, whereas those for DLP are between +40% and +50%, with the smallest changes for the youngest age band (0–1 year) and the largest for the oldest age band (>5 years).

The review provides essential data to facilitate further initiatives in the optimisation of patient protection in CT. In particular, the report includes updated national reference dose values (derived as rounded third quartiles for the distributions of typical (mean) $CTDI_{vol}$ per sequence and DLP per examination) as simple yardsticks to help identify centres where levels of dose are unusually high. Values are recommended for more examinations than previously and, relative to corresponding MDCT data from 2003 for adults, levels for $CTDI_{vol}$ are within ±10%, whereas those for DLP are 5–90% higher, with the largest increases occurring for examinations of the lower trunk. These changes reverse the previous trend for lower reference doses and, as a consequence, the updated DLP values for 2011 are now quite similar to the levels for 1999 (European Commission, 1999). Similar trends are apparent in relation to the national reference doses for head examinations on children, with values for DLP now being larger by 15–20% than the corresponding values for 2000 (Shrimpton and Wall, 2000).

Results from the survey will also inform the subsequent setting of national diagnostic reference levels (DRLs) by the Department of Health (2007) in accordance with the Ionising Radiation (Medical Exposure) Regulations 2000 (Department of Health, 2000). The updated PREDICT database represents a useful and sustainable national resource for monitoring continuing developments in CT practice through the ongoing collation of further survey data, although there is presently a timely opportunity to improve methods for the streamlined collection of data in order to exploit fully the increasing availability from healthcare providers of information in electronic form. Periodic review of such further data will allow timely analyses of trends and the updating of national reference doses for CT.

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APPENDIX A Data Acquisition Form and Guidance Notes for the Third National CT Survey

A1 Acquisition Form

CT dose survey data acquisition form

3rd UK CT Survey

Accreditation by cpd now the College of Radiographers

Health Protection Agency

CT Protocol		page 2 ☐
☐ CT Head (acute stroke)	☐ C-spine (fracture)	
☐ Chest (lung cancer)	☐ Chest High-Res. (interstitial lung disease)	
☐ CTA (blood vessels)	☐ CTPA (PE)	
☐ Abdomen (liver metastases)	☐ Abdomen and pelvis (abscess)	
☐ Virtual Colonoscopy (polyps/tumour)	☐ Enteroclysis (Crohn's disease)	
☐ CT KUB (stones/colic)	☐ CT Urogram (tumour or stones/colic)	
☐ Paediatric head (trauma)	☐ < 1 yr ☐ 1 – 4 yrs ☐ 5 – 12 yrs	

Exam Accession Number		Sample Number	/20
Health Care Facility		Scanner ID	
Age at time of scan (years)	Gender ☐ M ☐ F	Body Mass	☐ kg ☐ st
Scanner Make	☐ GE ☐ Philips ☐ Siemens ☐ Toshiba ☐ Other		
Number of Detector Rows	☐ 16 ☐ 64 ☐ 128 ☐ Other		

Parameters	Sequence 1	Sequence 2	Sequence 3
Tube Voltage (kV)			
Fixed mA or Auto mA's available range			
Tube Current Modulation brand used			
Auto mA quality factor			
IV contrast used	☐	☐	☐
Beam collimation (mm)			
Scan field of View (mm)			
Patient transverse width (mm)			
Patient anteroposterior (AP) width (mm)			
Axial (A) or Helical (H) scan	☐ A ☐ H	☐ A ☐ H	☐ A ☐ H
No. of slices or pitch			
Scan length (mm)			
$CTDI_{vol}$ (mGy)			
DLP (mGy.cm)			
DLP for total examination (mGy.cm)			
☐ mean mAs/slice or mean mA (if given) ☐ total mAs (if given)			

A2 Guidance Notes – Page 1

Bulleted instructions for using form

3rd UK CT Survey

Accreditation by cpd now the College of Radiographers

Health Protection Agency

CT Protocol A		page 2 B
☐ CT Head (acute stroke)	☐ C-spine (fracture)	
☐ Chest (lung cancer)	☐ Chest High-Res. (interstitial lung disease)	
☐ CTA (blood vessels)	☐ CTPA (PE)	
☐ Abdomen (liver metastases)	☐ Abdomen and pelvis (abscess)	
☐ Virtual Colonoscopy (polyps/tumour)	☐ Enteroclysis (Crohn's disease)	
☐ CT KUB (stones/colic)	☐ CT Urogram (tumour or stones/colic)	
☐ Paediatric head (trauma) ☐ < 1 yr ☐ 1 – 4 yrs ☐ 5 – 12 yrs		

Exam Accession Number C		Sample Number C	
Health Care Facility		Scanner ID	
Age at time of scan (years) D	Gender ☐ M ☐ F	Body Mass E	☐ kg ☐ st
Scanner Make	☐ GE ☐ Philips ☐ Siemens ☐ Toshiba ☐ Other		
Number of Detector Rows	☐ 16 ☐ 64 ☐ 128 ☐ Other		

Parameters	Sequence 1	Sequence 2	Sequence 3
Tube Voltage (kV)			
Fixed mA or Auto mA's available range	F		
Tube Current Modulation brand used			
Auto mA quality factor			
IV contrast used	☐	☐	☐
Beam collimation (mm)	G		
Scan field of View (mm)			
Transverse width (mm)	H		
Anteroposterior (AP) width (mm)			
Axial (A) or Helical (H) scan	☐ A ☐ H	☐ A ☐ H	☐ A ☐ H
No. of slices or pitch			
Scan length (mm)			
$CTDI_{vol}$ (mGy)			
DLP (mGy.cm)			
DLP for total examination (mGy.cm)			
☐ mean mAs/slice or mean mA (if given) ☐ total mAs (if given)			

A3 Guidance Notes – Page 2

Bulleted instructions:

Form Note	Description
A	CT protocols are listed along with their key clinical indications in parenthesis. Further details are included below, including keywords and generic search strings for RIS searches. Examples of typical CT protocols are also included below, including referral notes, anatomical markers and showing regions under investigation. Details of typical contrast use and number of sequences/phases are also given. However, please provide data on your equivalent protocols that are in use at your centre.
B	Indicate here if this is the second sheet for the same patient and scanner attendance, required if more than three image sequences were employed.
C	Accession number is used as an anonymous scan ID reference, held locally only, that can be used to find examinations on RIS and PACS. Accession number is linked to sample number on this form, to facilitate help with any further queries after data have been submitted. The target for data collection is 20 different patients per CT protocol (tick sheet included at the end of the document), on a single scanner. Sample number out of 20 must be recorded here. Only sample number will be added to the spreadsheet later.
D	Please supply age at the time of scan in years. NB. For paediatric scans record the age to the nearest half year. However, for paediatric patients under 1-year of age, please supply age in months (traceable from CT protocol selection).
E	If available please supply body mass to the nearest half kilogram or stone.
F	Many scanners are now in use with automatic tube current modulation. To help to assess how these systems are being used please record the range of mA that the automatic system can select between. (This is the range for the protocol not for each patient.) Please also record the auto mA brand (e.g. "Smart mA", "CareDose") and the actual quality factor (e.g. "noise index" of x, "quality reference mAs", "mAs/slice") used.
G	Please supply the collimation product for multi-slice systems, e.g. 64x0.5mm.
H	To get a measure of patient size, other than body mass and that can be calculated retrospectively, cross-sectional area is being used. To estimate this, using the middle image in the main scan sequence, measure the major (transverse) and minor (anteroposterior (AP)) patient widths using your PACS viewer (shown graphically below). These will be used to estimate the cross-sectional area, approximating the patient to be an ellipse. These measurements are only needed from one image sequence per patient.

A4 Guidance Notes – Page 3

Data acquisition:

1. Field work will be a collaboration between radiographers and medical physicists
2. We need a straightforward system that can be operated at any centre across the UK
3. We envisage the survey will be performed retrospectively at many centres
4. Prospective data acquisition has the advantage of being able to ask patients how much they weigh, with body mass (kg) then being used as an indicator of patient size
    - This is in addition to the major and minor axis widths measured from images recovered from PACS
    - Body mass is not recoverable retrospectively from some centres
5. For prospective data acquisition the accession number and body mass will need to be linked with CT protocol and sample number, for later collection of remaining data
6. Radiographers will be asked to perform RIS searches, identify relevant patients and to perform some of the data acquisition
7. Clinical professionals (radiographers and/or physicists) with access to PACS will complete data acquisition
8. Data managers (physicists or radiographer as appropriate) will verify data before transferring it to the survey spreadsheet
9. Final results should be returned to the HPA by e-mail

NB.

- Existing recent survey results can be used and added to as appropriate
- Where existing local electronic data searches are in operation these can be used to query and simplify data acquisition

Any queries please contact me using: stuart.meeson @ hpa.org.uk

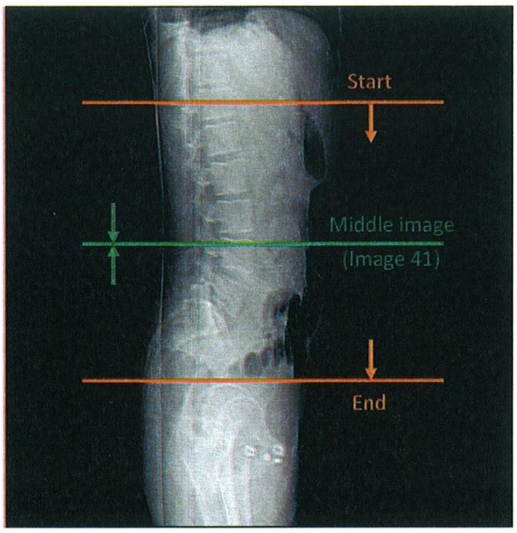
Continuing Professional Development:

The College of Radiographers has endorsed the survey via CPD Now. Participation will enable practitioners to develop their knowledge and expertise in a range of data collection and dose optimisation techniques.

IPEM members participating can include any activities in their personal CPD record.

A5 Guidance Notes – Page 4

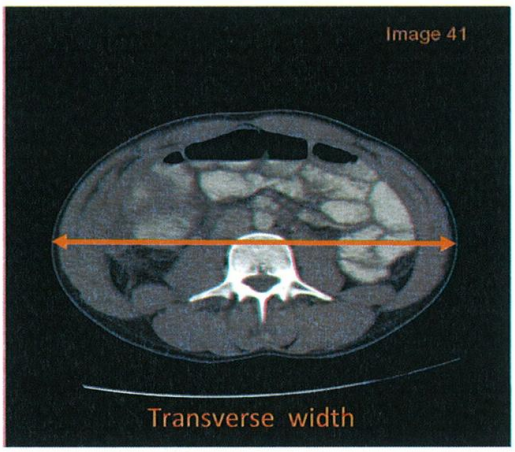
Transverse and Anteroposterior (AP) patient width measurements:



Schematic showing a scout scan used to identify the middle image in the sequence.

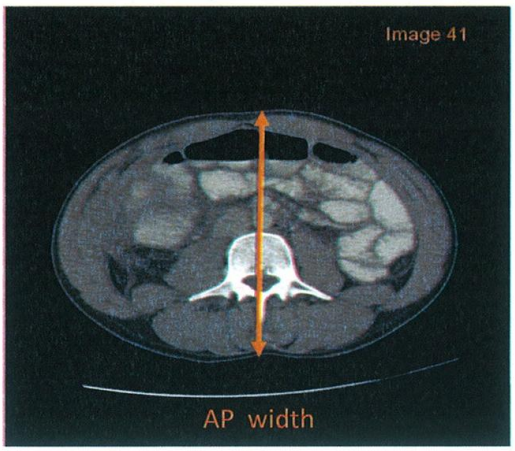
NB. For C-spine examinations, select an image close to the middle of the sequence that avoids the shoulders.

One set of width measurements per patient.



Transverse width (mm) measured using the image from the middle of the sequence.

NB. If axial images do not show the full extent of the patient, try other image views.



Anteroposterior (AP) width (mm) measured using the image from the middle of the sequence.

A6 Guidance Notes – Page 5

Clinical indications and keywords:

CT Protocol	Clinical indications	Keywords for electronic searches
Head	Acute stroke	Stroke, CVA, haemorrhage
C-spine	Fracture	Fracture, #, dislocation, trauma
Chest	Lung cancer query	Lung: cancer, metastases, malignancy, tumour, neoplasm
Chest High-Resolution	Interstitial lung disease	Emphysema, pulmonary fibrosis, bronchiectasis
CTA	Abdominal aorta	AAA, aorta, peripheral vessels, aneurysm, atherosclerosis, stent, ischaemia, leak
CTPA	PE	Pulmonary embolism, PE
Abdomen	Liver metastases	Liver: cancer, metastases, malignancy, tumour, neoplasm
Abdomen and pelvis	Abscess	Abscess, infection, infected fluid
Virtual Colonoscopy	Polyps/tumour	Polyp, cancer, malignancy, tumour, neoplasm
Enteroclysis	Crohn's disease	Crohn's, small bowel inflammation
KUB	Stones/colic	Renal, kidney, ureter, stones, colic, haematuria, calculi
Urogram	Stones/colic or tumour	Renal, kidney, ureter, stones, colic, haematuria, calculi, cancer, malignancy, tumour, neoplasm
Paediatric Head (x3)	Trauma	Trauma, injury, NAI, haemorrhage, fracture

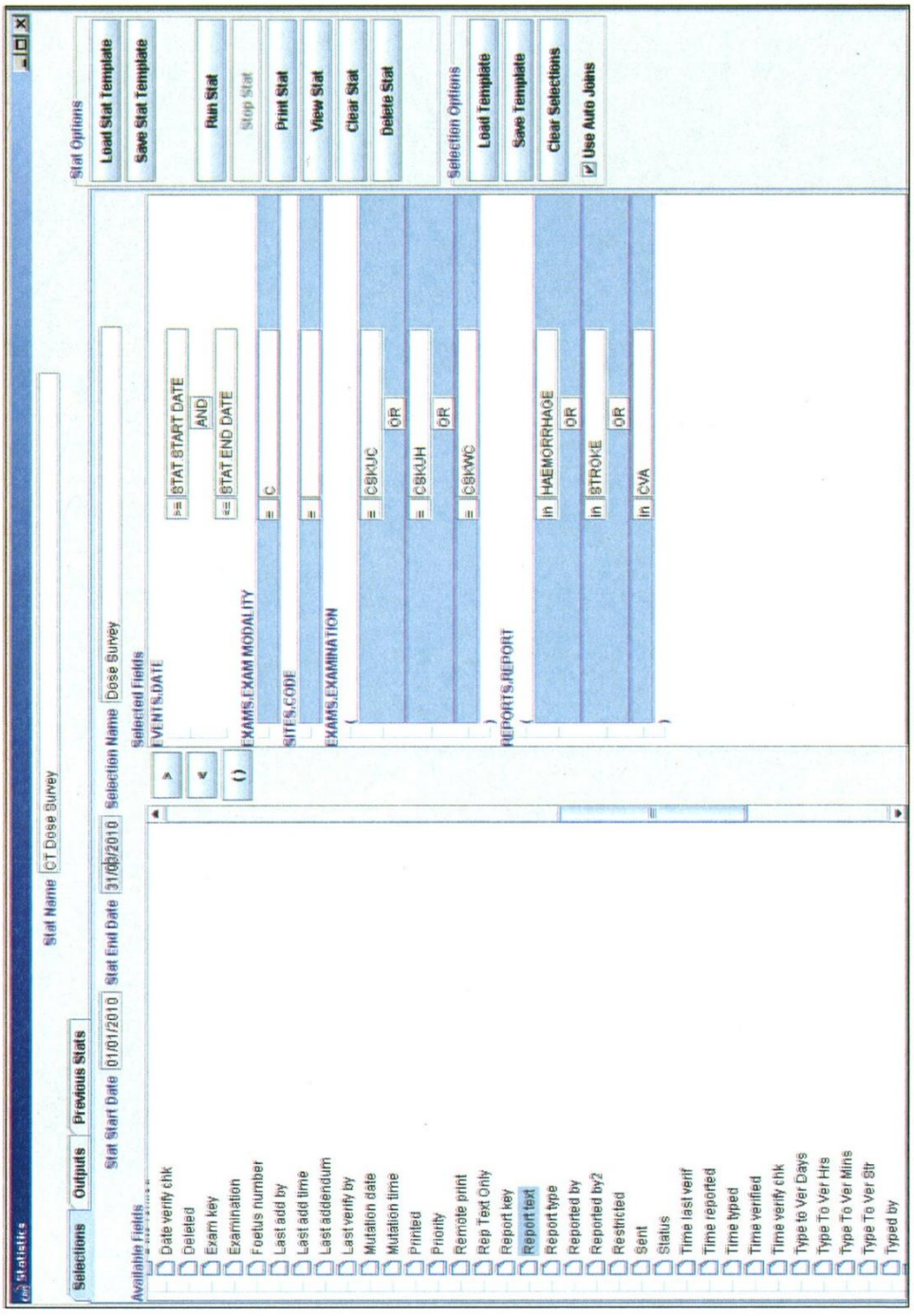
Generic RIS search examples for retrospective data collection:

The screenshots included below provide examples of searches that may be undertaken on RIS to locate suitable CT examinations as required for the HPA CT dose survey.

In Screenshot 1 the Selections screen includes fields that may be used to refine a search of the RIS. These include:

- date range – typically a 3 month window, but longer for low frequency examinations and up to 1-year retrospectively
- modality
- site
- examinations – multiple exam code may be used to include examinations of a body part with and without contrast
- text found in a report – multiple key words may be used in a single search

A7 Guidance Notes – Page 6



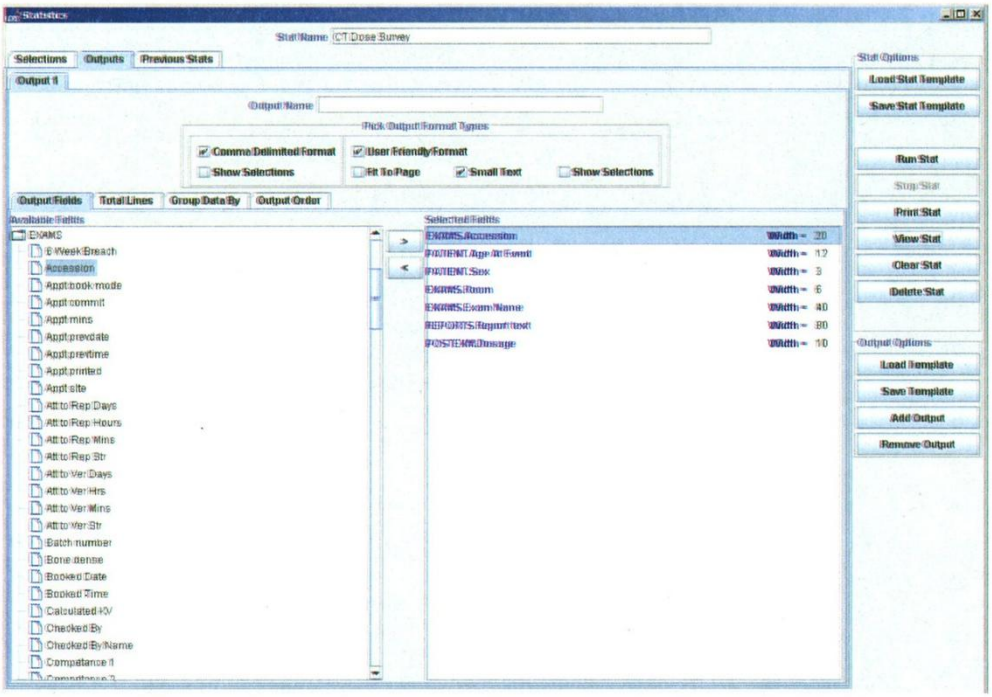
Screenshot 1: example of a RIS Selections screen

A8 Guidance Notes – Page 7

From this search Screenshot 2 shows some of the outputs that may be displayed:

- exam accession number
- age at the time of scan
- patient sex
- room – this will identify which scanner was used if more than one at a site
- exam name
- report – by being able to view the report the reason for the scan may be determined
- dose

This list is not exhaustive and it may be that more fields will be used as appropriate.

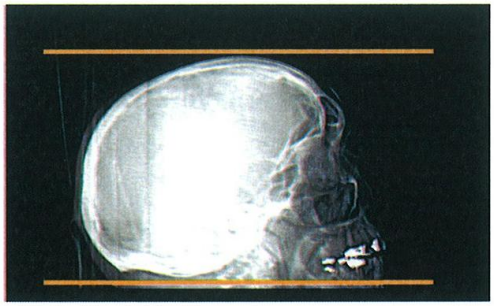


Screenshot 2: example of a RIS Outputs screen

Once examinations that meet the criteria have been identified, the accession number may be used to locate the images on PACS. From these images other required information as laid out on the data acquisition form can be recorded.

A9 Guidance Notes – Page 8

CT Head – typical protocol



Clinical indication: acute stroke

Typical scan justification: query stroke/CVA/haemorrhage

Could include: *head trauma. Onset of headaches or facial pain. Visual disturbances, aura/migraine, atypical seizure. Confusion, vomiting, slurred speech, limb weakness/worsening mobility. Existing aneurysm. Previous surgery: CVA, evacuation of haematoma, biopsy.*

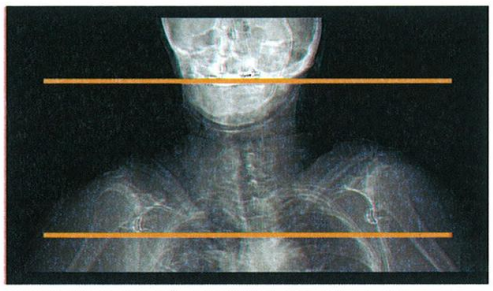
Scan from: base of skull

Ending at: top of skull

Sequences/Phases for examination: 1

Contrast used: Y or N

C-spine – typical protocol



Clinical indication: fracture

Typical scan justification: trauma, query fracture/dislocation

Could include: *head and neck injury. Fall/trauma/polytrauma. Previous vertebral tension. Neck pain or tenderness.*

RTC

Contact sports neck related injury.

Scan from: base of skull

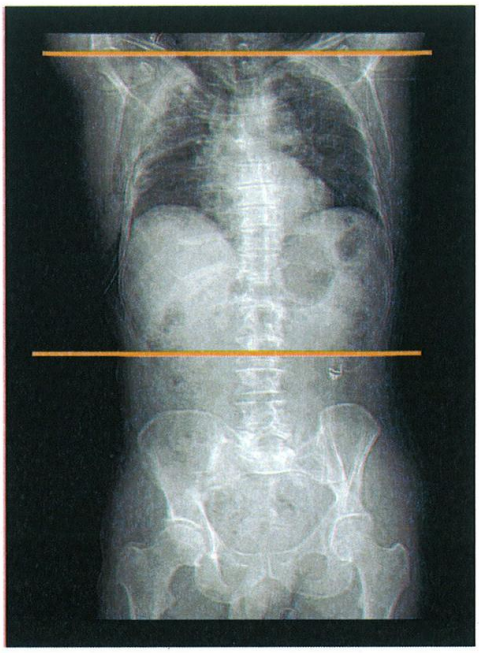
Ending at: T2

Sequences/Phases for examination: 1

Contrast used: Y or N

A10 Guidance Notes – Page 9

Chest – typical protocol



Clinical indication: query lung cancer

Typical scan justification: query lung cancer/metastases/malignancy/ tumour/neoplasm

Could include: *query cause of shadowing. Query lymphadenopathy. Previous lymph node enlargement. Bulky hilum (that persist on plain film).*

Scan from: top of the lungs

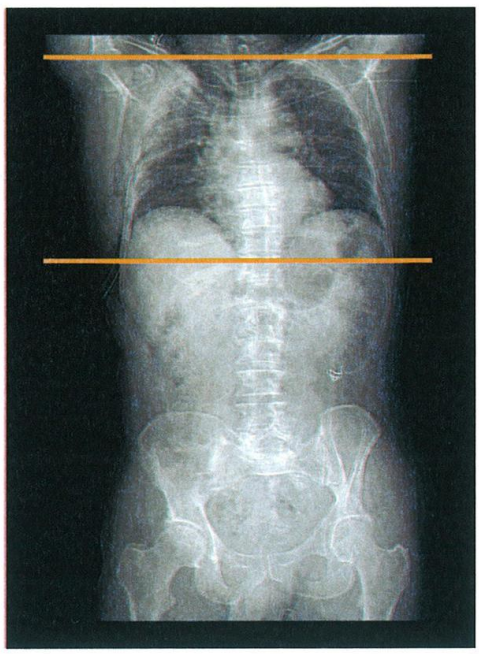
Ending at: below liver

Sequences/Phases for examination: 2

Contrast used: Y or N

Breath held: Y or N

Chest High-Resolution – typical protocol



Clinical indication: interstitial lung disease

Typical scan justification: query emphysema/pulmonary fibrosis/ bronchiectasis

Could include: *patient < 45-years old. Severe breathlessness, hypoxia, query parenchymal involvement. Subpleural ground-glass opacity.*

Scan from: top of the lungs

Ending at: below diaphragm

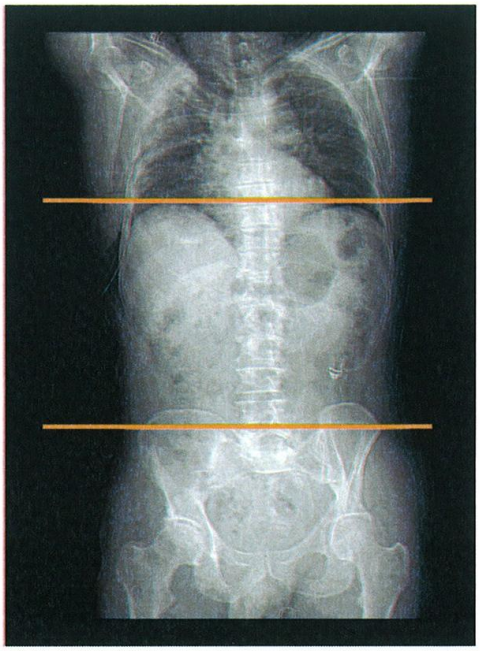
Sequences/Phases for examination: 2

Contrast used: Y or N

Breath held: Y or N

A11 Guidance Notes – Page 10

CTA – typical protocol, AAA only



Clinical indication: blood vessels, AAA

Typical scan justification: query AAA. Check appearance of aorta and peripheral vessels. Query atherosclerosis/ischaemia/leak/stent properties.

Could include: *sudden onset of abdominal pain (that may radiate to back). Review of existing AAA, bifurcation and suitability for EVAR (post ultrasound).*

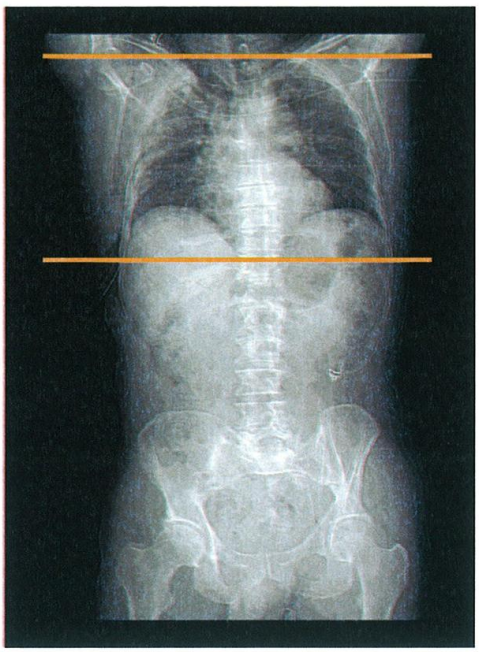
Scan: For AAA – abdomen

Sequences/Phases for examination: 2

Contrast used: Y or N

Breath held: Y or N

CTPA – typical protocol



Clinical indication: PE

Typical scan justification: query PE

Could include: *Pleuritic chest pain, decreased saturations, breathlessness. Sudden onset SOB.*

Previous surgery/PE.

Scan from: top of the lungs

Ending at: below diaphragm

Sequences/Phases for examination: 2

Contrast used: Y or N

Breath held: Y or N

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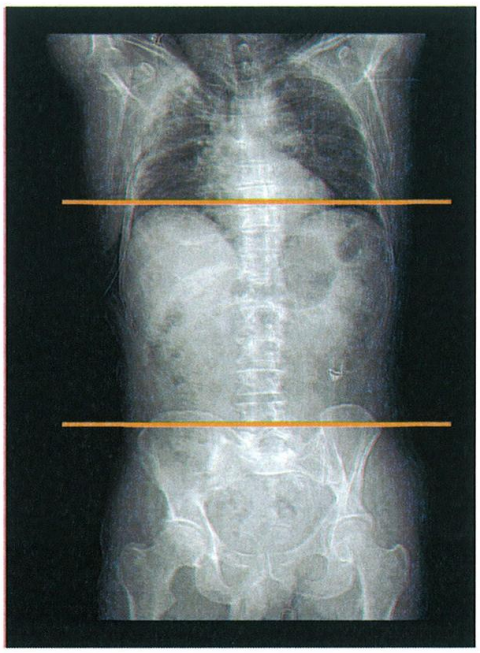
Abdomen – typical protocol



Clinical indication: liver metastases

Typical scan justification: query liver cancer/metastases/malignancy/ tumour/neoplasm

Could include: *abdominal pain, jaundice, abnormal liver lesions on ultrasound for further assessment, liver enlarged on ultrasound.*

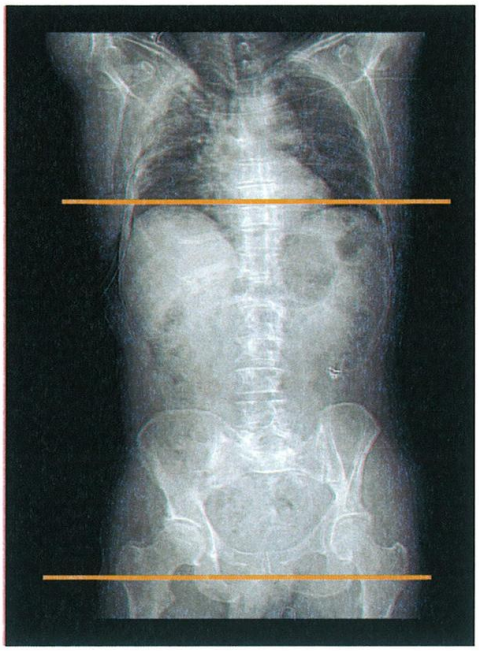
Other existing/treated sites of malignancy.

Scan: abdomen

Sequences/Phases for examination: 3

Contrast used: Y or N

Abdomen and pelvis – typical protocol



Clinical indication: abscess

Typical scan justification: query abscess/infection/infected fluid

Could include: *abdominal distension, tenderness/pain/guarding, sepsis. Fever, leukocytosis and surgery in the last four weeks.*

Scan: abdomen and pelvis

Sequences/Phases for examination: 1

Contrast used: Y or N

Breath held: Y or N

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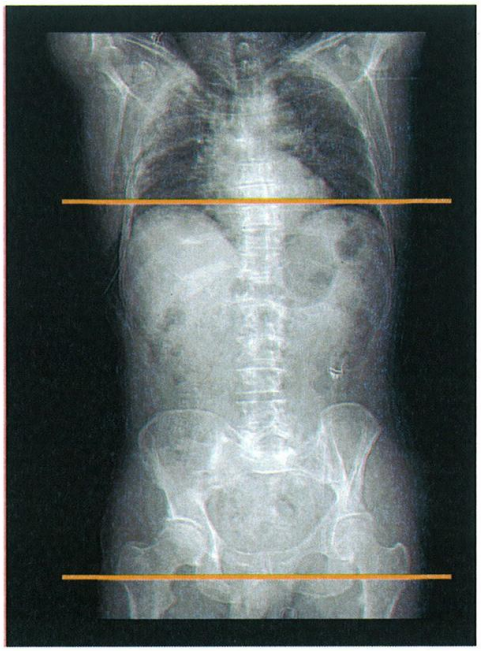
Virtual Colonoscopy – typical protocol



Clinical indication: polyps/tumour

Typical scan justification: query polys/tumour

Could include: *diarrhoea/constipation, rectal bleeding, change in bowel habit, anaemia, abdominal pain.*

Incomplete colonoscopy.

Scan from: diaphragm

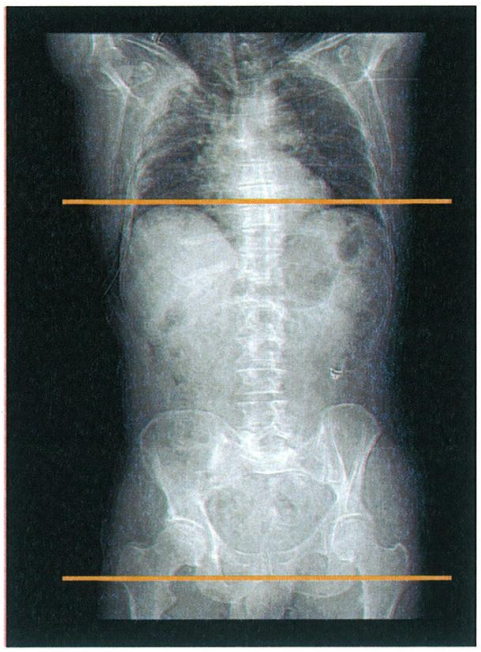
Ending at: symphysis pubis

Sequences/Phases for examination: 2

Contrast used: Y or N

Breath held: Y or N

Enteroclysis – typical protocol



Clinical indication: Crohn's disease

Typical scan justification: query Crohn's disease/small bowel

Could include: *attacks of vomiting, pain and diarrhoea.*

Recent diagnosis of coeliac disease. Existing condition. Findings from colonoscopy – such as small bowel mesenteric nodes.

Scan from: diaphragm

Ending at: symphysis pubis

Sequences/Phases for examination: 1

Contrast used: Y or N

Breath held: Y or N

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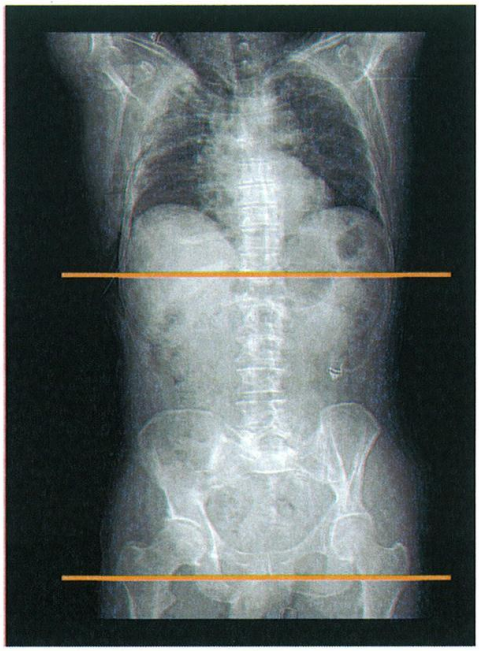
CT KUB – typical protocol



Clinical indication: stones/colic

Typical scan justification: query stones/renal colic

Could include: *colicky pain, vomiting, previous calculus, heamaturia.*

Scan from: above kidneys

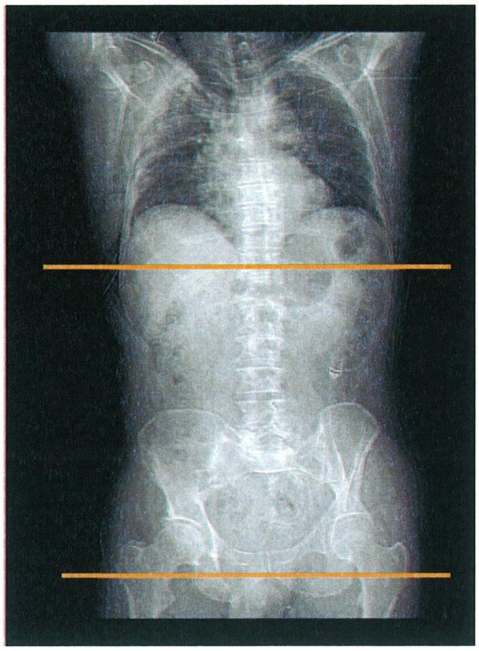
Ending at: below bladder

Sequences/Phases for examination: 1

Contrast used: Y or N

Breath held: Y or N

CT Urogram – typical protocol



Clinical indication: tumour or stones/colic

Typical scan justification: query tumour or stones/renal colic

Could include: *query urological malignancy/ tumour/neoplasm. Query urological injury.*

Colicky pain, vomiting, previous calculus, heamaturia.

Scan from: above kidneys

Ending at: below bladder

Sequences/Phases for examination: 3

Contrast used: Y or N

Breath held: Y or N

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CT Protocol	PROSPECTIVE DATA COLLECTION - Progress tick-sheet for samples of 20 patients																			
CT Head (acute stroke)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
C-spine (fracture)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Chest (lung cancer)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Chest Hi-Res (l. lung disease)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
CTA (blood vessels)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
CTPA (PE)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Abdomen (liver metastases)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Abdomen (abscess)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
V. Colonoscopy (polys/tumour)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Enteroclysis (Crohn's disease)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
CT KUB (stones/colic)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Urogram (tumour or stones)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Paediatric Head < 1 yr	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Paediatric Head 1 – 4 yrs	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Paediatric Head 5 – 12 yrs	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

APPENDIX B Participating CT Centres

B1 England

Barnsley Hospital
Bedford Hospital
BMI The Chaucer Hospital, Canterbury
BMI The London Independent Hospital
Bristol Haematology and Oncology Centre
Bristol Royal Infirmary
Burnley General Hospital
Castle Hill Hospital, Cottingham
Chelsea and Westminster Hospital, London
Cheltenham General Hospital
Churchill Hospital, Oxford
City Hospital, Birmingham
Clatterbridge Centre for Oncology, Bebington
Colchester Hospital
Croydon University Hospital
Cumberland Infirmary, Carlisle
Derriford Hospital, Plymouth
Freeman General Hospital, Newcastle upon Tyne
Frenchay Hospital, Bristol
Friarage Hospital, Northallerton
Furness General Hospital, Barrow-in-Furness
Gloucestershire Royal Hospital, Gloucester
Guy's Hospital, London
Halton General Hospital, Runcorn
Harefield Hospital, Middlesex
Hemel Hempstead Hospital
Hexham General Hospital
Hinchingbrooke Hospital, Huntingdon
Hospital of St Cross, Rugby
Hull Royal Infirmary
Hurstwood Park Neurological Centre, Haywards Heath
James Paget University Hospitals, Great Yarmouth
John Radcliffe Hospital, Oxford
Kent & Canterbury Hospital, Canterbury
Kettering General Hospital
Kidderminster Hospital and Treatment Centre
Leeds General Infirmary
Luton & Dunstable Hospital, Luton
Macclesfield District General
Mount Vernon Cancer Centre, Northwood
Norfolk and Norwich University Hospitals, Norwich
North Tyneside General Hospital, North Shields
Ormskirk & District General Hospital, Ormskirk
Papworth Hospital, Cambridge
Peterborough City Hospital
Poole Hospital
Princess Alexandra Hospital, Harlow
Princess Royal Hospital, Bromley

Princess Royal Hospital, Telford
Queen Alexandra Hospital, Portsmouth
Queen Elizabeth Hospital, Gateshead
Queen Elizabeth II Hospital, Welwyn Garden City
Queen Elizabeth The Queen Mother Hospital, Margate
Queens Hospital, Burton upon Trent
Robert Jones & Agnes Hunt Orthopaedic Hospital, Oswestry
Rochdale Infirmary
Royal Albert Edward Infirmary, Wigan
Royal Blackburn Hospital
Royal Bournemouth Hospital
Royal Devon and Exeter Hospital, Exeter
Royal Free Hospital, London
Royal Preston Hospital
Royal Shrewsbury Hospital
Royal Sussex County Hospital, Brighton
Royal United Hospital Bath
Royal Victoria Infirmary, Newcastle upon Tyne
Russells Hall Hospital, Dudley
Southmead Hospital, Bristol
Southport & Formby District General Hospital, Southport
Spire Bristol Hospital
Spire Little Aston Hospital, Sutton Coldfield
Spire Parkway Hospital, Solihull
St Bartholomew's Hospital, London
St Helens Hospital
St James' University Hospital, Leeds
St Thomas' Hospital, London
Stafford Hospital
The Christie, Manchester
The Ipswich Hospital
The Lister Hospital, Stevenage
The London Chest Hospital
The Royal London Hospital
The Royal Marsden Hospital, London
The York Hospital
University Hospital Aintree, Liverpool
University Hospital of Hartlepool
University Hospital of James Cook, Middlesbrough
University Hospital of North Durham, Durham
University Hospital of North Staffordshire, Stoke-on-Trent
University Hospital of North Tees, Stockton on Tees
University Hospitals Coventry
Wansbeck General Hospital, Ashington
Warrington Hospital
Watford General Hospital
West Cumberland Hospital, Whitehaven
Weston General Hospital, Weston-super-Mare
Whipps Cross University Hospital, London
Whiston Hospital, Prescot
William Harvey Hospital, Ashford

B2 Northern Ireland

Antrim Area Hospital, Antrim
Downe Hospital, Downpatrick
Lagan Valley Hospital, Lisburn
Mid-Ulster Hospital, Magherafelt
Ulster Hospital, Belfast

B3 Scotland

Belford Hospital, Fort William
Caithness General Hospital, Wick
Ninewells Hospital, Dundee
Perth Royal Infirmary
Queen Margaret Hospital, Dunfermline
Raigmore Hospital, Inverness
Royal Infirmary of Edinburgh
Spire Murrayfield Hospital, Edinburgh
St.John's Hospital, Livingston
Stracathro Hospital, Brechin
Vale of Leven Hospital, Alexandria
Victoria Hospital, Kirkcaldy
Western General Hospital, Edinburgh
Western Isles Hospital, Stornoway

B4 Wales

Glan Clwyd Hospital, Bodelwyddan
Nevill Hall Hospital, Abergavenny
Prince Charles Hospital, Merthyr Tydfil
Royal Gwent Hospital, Newport
Spire Cardiff Hospital
The Royal Glamorgan Hospital, Llantrisant
University Hospital Llandough
University Hospital of Wales, Cardiff
Velindre Hospital, Cardiff

APPENDIX C Tables of Detailed Results from Analyses of Survey Data

C1 Key to Abbreviations Used in Tables

Trans	patient width measured along major (transverse) axis in middle image of main scan sequence (unit of mm)
AP	patient width measured along minor (antero-posterior) axis in middle image of main scan sequence (unit of mm)
CSA	cross-sectional area for patient estimated from measurements of width as CSA = (π x Transverse/2 x AP/2) (unit of mm^2)
Applied Pot	applied potential (unit of kV)
CTDI	volume-weighted CT dose index (unit of mGy); data presented for head and neck examinations is assumed to refer to the 16 cm diameter standard CT dosimetry phantom, whereas that for the other examinations refers to the 32 cm diameter standard CT dosimetry phantom
DLP	dose-length product (unit of mGy cm); data presented for head and neck examinations is assumed to refer to the 16 cm diameter standard CT dosimetry phantom, whereas that for the other examinations refers to the 32 cm diameter standard CT dosimetry phantom
Total DLP	dose-length product for complete examination (unit of mGy cm)
No	number
Sample size (DLP)	number of values of DLP contributing towards each mean value
Sample size (CTDI)	number of values of $CTDI_{vol}$ contributing towards each mean value
Pitch (helical)	value of pitch used for helical scan sequence
Collimation	width of X-ray beam used during data acquisition for a scan sequence
Scan length	as recorded on survey questionnaires
Std Dev	standard deviation
%CV	coefficient of variation expressed as (100 x Std Dev/Mean)
Min	minimum value of a distribution
P05	5th percentile of a distribution
P10	10th percentile of a distribution
P25	25th percentile (first quartile) of a distribution
P50	50th percentile (median) of a distribution
P75	75th percentile (third quartile) of a distribution
P90	90th percentile of a distribution
P95	95th percentile of a distribution
Max	maximum value of a distribution

C2 Distributions of Data for Individual Patients (Note: data for applied potential and $CTDI_{vol}$ refers to individual sequences)

TABLE C2.1 Head (acute stroke): individual patients

	Age (Years)	Mass (kg)	Trans (mm)	AP (mm)	CSA (mm2)	Applied Pot (kV)	CTDI (mGy)	Total DLP (mGy cm)	No of Sequences
Mean	65.7	73.8	149	188	22074	122	58.6	943	1.4
Count	2018	487	1607	1606	1606	3211	3029	3151	2245
Std Dev	19	17	8.6	10	2263	6.5	14	239	0.6
%CV	29	23	5.8	5.6	10	5.3	25	25	44
Min	14	32.5	120	141	13950	100	5.7	116	1.0
P05	27	50.9	136	171	18538	120	38.4	639	1.0
P10	36	54.1	139	175	19320	120	42.7	691	1.0
P25	53	60.7	143	181	20524	120	50.1	796	1.0
P50	70	70.0	149	188	21995	120	57.6	916	1.0
P75	81	83.0	155	195	23603	120	64.5	1044	2.0
P90	87	95.5	160	201	25120	140	71.7	1212	2.0
P95	89	108	164	205	25917	140	86.5	1287	3.0
Max	98	156	190	220	31341	140	118	2608	4.0

TABLE C2.2 Cervical spine (fracture): individual patients

	Age (Years)	Mass (kg)	Trans (mm)	AP (mm)	CSA (mm2)	Applied Pot (kV)	CTDI (mGy)	Total DLP (mGy cm)	No of Sequences
Mean	52.8	73.2	144	149	17498	123	23.6	552	1.0
Count	647	71	562	562	562	668	635	792	672
Std Dev	22	20	58	27	11304	7.4	13	329	0.2
%CV	41	27	41	18	65	6.0	54	60	15
Min	13	11.5	76.9	88.2	8000	100	3.7	42.0	1.0
P05	19	50.9	105	111	9721	120	8.1	153	1.0
P10	23	57.0	110	117	10641	120	10.6	203	1.0
P25	35	60.5	118	130	12406	120	14.9	326	1.0
P50	52	70.0	129	145	14585	120	21.0	489	1.0
P75	71	79.3	144	164	17886	120	28.3	671	1.0
P90	83	100	172	184	23396	140	39.9	1028	1.0
P95	87	103	225	198	34304	140	52.5	1202	1.0
Max	99	153	483	273	103361	140	100	2336	2.0

TABLE C2.3 Chest (lung cancer): individual patients

	Age (Years)	Mass (kg)	Trans (mm)	AP (mm)	CSA (mm2)	Applied Pot (kV)	CTDI (mGy)	Total DLP (mGy cm)	No of Sequences
Mean	66.5	74.8	345	250	68344	120	10.8	501	1.5
Count	1715	499	1579	1579	1579	2832	2618	2077	1866
Std Dev	14	17	43	35	16069	3.5	6.9	283	0.6
%CV	21	23	13	14	24	2.9	64	56	37
Min	14	34.0	227	130	25937	80	2.1	52.0	1.0
P05	42	50.9	278	197	44804	120	4.4	172	1.0
P10	49	54.9	292	206	48695	120	5.2	206	1.0
P25	59	63.5	315	226	56953	120	7.0	295	1.0
P50	68	74.0	342	248	66981	120	9.6	438	1.0
P75	77	85.0	372	272	78647	120	12.7	646	2.0
P90	83	95.0	400	295	88638	120	17.2	865	2.0
P95	86	103	415	308	98171	120	21.0	1029	2.0
Max	98	152	570	383	134321	140	79.8	2492	3.0

TABLE C2.4 Chest – high resolution (interstitial lung disease) – individual patients

	Age (Years)	Mass (kg)	Trans (mm)	AP (mm)	CSA (mm2)	Applied Pot (kV)	CTDI (mGy)	Total DLP (mGy cm)	No of Sequences
Mean	62.5	76.3	347	253	69460	122	5.9	248.5	1.4
Count	1303	261	1199	1199	1199	1900	1759	1573	1414
Std Dev	16	18	41	34	15059	6.5	5.9	268	0.7
%CV	25	23	12	13	22	5.3	99	108	53
Min	13	40.0	236	127	26935	120	0.2	17.0	1.0
P05	31	50.3	284	201	47177	120	0.7	35.0	1.0
P10	40	55.4	296	211	50867	120	1.0	43.2	1.0
P25	54	63.6	320	230	58064	120	1.7	65.0	1.0
P50	65	74.8	347	252	68809	120	4.3	163	1.0
P75	74	89.0	370	275	79154	120	7.9	305	1.0
P90	81	100	399	294	88678	140	14.0	616	2.0
P95	84	106	414	307	94923	140	17.9	785	3.0
Max	96	138	530	389	126097	140	39.4	2310	5.0

TABLE C2.5 CT angiography (CTA) (blood vessels) – individual patients

	Age (Years)	Mass (kg)	Trans (mm)	AP (mm)	CSA (mm2)	Applied Pot (kV)	CTDI (mGy)	Total DLP (mGy cm)	No of Sequences
Mean	69.9	80.6	346	258	70975	119	14.1	765	1.9
Count	757	152	721	721	721	1415	1352	766	766
Std Dev	14	17	42	42	18675	3.3	12	557	1.1
%CV	20	21	12	16	26	2.7	88	73	60
Min	17	44.5	229	142	26101	100	0.9	69.0	1.0
P05	42	56.7	284	193	42641	120	2.6	191	1.0
P10	50	60.5	294	205	47676	120	3.2	254	1.0
P25	64	69.7	319	230	57922	120	6.8	406	1.0
P50	73	80.0	344	255	69789	120	10.9	624	1.0
P75	79	90.0	370	286	82324	120	16.7	930	3.0
P90	85	102	398	313	95735	120	27.9	1420	4.0
P95	88	110	417	333	105520	120	36.4	1729	4.0
Max	101	127	503	396	140909	140	111	5778	5.0

TABLE C2.6 CT pulmonary angiography (CTPA) (pulmonary embolism) – individual patients

	Age (Years)	Mass (kg)	Trans (mm)	AP (mm)	CSA (mm2)	Applied Pot (kV)	CTDI (mGy)	Total DLP (mGy cm)	No of Sequences
Mean	65.6	78.1	353	246	68764	116	9.6	362	1.7
Count	1567	317	1440	1440	1440	2757	2581	1681	1681
Std Dev	17	21	45	32	15476	9.3	7.5	202	0.9
%CV	26	27	13	13	23	8.0	78	56	56
Min	17	33.7	220	131	34930	80	0.2	48.0	1.0
P05	33	51.0	284	197	46811	100	1.7	132	1.0
P10	42	54.1	299	207	50359	100	2.7	154	1.0
P25	55	63.6	322	225	58256	120	4.5	214	1.0
P50	68	76.0	350	243	67323	120	7.9	310	1.0
P75	78	89.0	379	266	77278	120	12.5	464	3.0
P90	85	105	409	287	88115	120	19.4	624	3.0
P95	88	119	430	300	95822	120	22.8	724	3.0
Max	99	154	555	365	149886	140	99.8	1958	6.0

TABLE C2.7 Abdomen (liver metastases) – individual patients

	Age (Years)	Mass (kg)	Trans (mm)	AP (mm)	CSA (mm2)	Applied Pot (kV)	CTDI (mGy)	Total DLP (mGy cm)	No of Sequences
Mean	63.2	75.3	334	251	67140	120	13.1	718	1.7
Count	804	133	803	803	803	1432	1373	844	835
Std Dev	15	15	44	43	19605	1.5	6.6	530	0.9
%CV	24	19	13	17	29	1.2	51	74	53
Min	16	38.0	236	153	28734	100	3.3	83.0	1.0
P05	36	51.6	265	184	39611	120	5.9	183	1.0
P10	43	58.5	280	197	44498	120	7.0	238	1.0
P25	53	65.0	305	221	53163	120	8.8	349	1.0
P50	64	74.0	330	248	64545	120	11.6	564	1.0
P75	75	84.6	359	280	78555	120	15.5	927	3.0
P90	83	95.0	390	311	92454	120	21.7	1422	3.0
P95	86	98.9	406	328	102903	120	26.0	1779	3.0
Max	96	116	526	383	153173	140	62.9	4256	4.0

TABLE C2.8 Abdomen and pelvis (abscess) – individual patients

	Age (Years)	Mass (kg)	Trans (mm)	AP (mm)	CSA (mm2)	Applied Pot (kV)	CTDI (mGy)	Total DLP (mGy cm)	No of Sequences
Mean	61.8	74.2	344	250	69002	120	13.0	676	1.1
Count	1648	572	1566	1566	1566	1970	1852	2495	1822
Std Dev	17	17	47	45	20653	1.9	7.0	375	0.4
%CV	28	22	14	18	30	1.6	54	55	34
Min	16	32.0	197	134	23676	80	2.1	96.5	1.0
P05	29	50.0	273	182	40316	120	4.1	265	1.0
P10	39	55.4	289	195	45076	120	6.2	317	1.0
P25	50	63.6	311	219	54286	120	8.5	421	1.0
P50	64	72.0	341	248	66564	120	11.9	591	1.0
P75	75	85.3	372	280	80538	120	15.3	818	1.0
P90	82	95.0	406	308	97314	120	21.4	1168	1.0
P95	86	102	426	327	105299	120	25.6	1412	2.0
Max	102	170	544	426	182120	140	73.8	3546	3.0

TABLE C2.9 Virtual colonoscopy (polyps/tumour) – individual patients

	Age (Years)	Mass (kg)	Trans (mm)	AP (mm)	CSA (mm2)	Applied Pot (kV)	CTDI (mGy)	Total DLP (mGy cm)	No of Sequences
Mean	68.3	73.4	338	264	71194	120	8.5	796	2.0
Count	903	222	832	833	832	1842	1739	1005	913
Std Dev	13	17	42	43	19493	0.5	5.3	427	0.2
%CV	19	24	12	16	27	0.4	62	54	8.9
Min	25	37.0	232	165	34625	100	1.0	79.4	1.0
P05	45	50.0	274	197	44262	120	2.3	275	2.0
P10	50	52.0	286	213	48801	120	3.0	358	2.0
P25	60	60.0	310	233	57634	120	4.6	491	2.0
P50	70	72.0	334	261	68048	120	7.4	724	2.0
P75	78	83.3	363	292	82141	120	11.1	996	2.0
P90	84	96.0	395	321	97058	120	16.0	1309	2.0
P95	86	105	412	340	104777	120	18.6	1703	2.0
Max	95	149	499	470	177209	120	33.5	2962	4.0

TABLE C2.10 Enteroclysis (Crohn's disease) – individual patients

	Age (Years)	Mass (kg)	Trans (mm)	AP (mm)	CSA (mm2)	Applied Pot (kV)	CTDI (mGy)	Total DLP (mGy cm)	No of Sequences
Mean	50.5	72.9	322	233	60177	117	10.7	597	1.2
Count	98	5	95	95	95	114	114	111	99
Std Dev	19	14	44	45	19683	7.0	4.0	303	0.4
%CV	37	19	14	19	33	6.0	37	51	31
Min	18	60.5	247	156	32473	100	4.1	209	1.0
P05	21	61.6	264	170	36522	100	4.5	235	1.0
P10	25	62.7	272	180	37899	100	5.0	278	1.0
P25	35	66.0	285	195	43353	120	8.0	373	1.0
P50	51	70.0	316	229	55378	120	10.4	566	1.0
P75	64	72.0	357	263	73612	120	12.5	694	1.0
P90	76	86.4	386	298	92022	120	15.6	1035	2.0
P95	79	91.2	396	314	94870	120	15.8	1173	2.0
Max	94	96.0	429	334	108616	120	25.9	1703	2.0

TABLE C2.11 Kidney-ureters-bladder (KUB) (stones/colic) – individual patients

	Age (Years)	Mass (kg)	Trans (mm)	AP (mm)	CSA (mm2)	Applied Pot (kV)	CTDI (mGy)	Total DLP (mGy cm)	No of Sequences
Mean	49.0	80.5	345	241	66573	119	8.2	352	1.0
Count	1538	308	1479	1479	1479	1654	1614	1637	1637
Std Dev	16	20	46	44	20134	4.4	5.0	220	0.1
%CV	34	24	13	18	30	3.6	62	63	13
Min	16	40.8	209	119	22153	100	1.3	48.0	1.0
P05	23	52.8	278	177	40453	120	2.8	117	1.0
P10	27	57.2	291	190	44772	120	3.6	146	1.0
P25	37	66.6	312	211	52705	120	5.0	210	1.0
P50	48	79.1	341	238	63300	120	7.1	302	1.0
P75	61	90.8	371	267	76915	120	9.7	427	1.0
P90	71	106	406	297	92374	120	13.6	615	1.0
P95	78	114	428	318	102998	120	17.7	790	1.0
Max	95	175	533	423	162958	140	37.6	1839	2.0

TABLE C2.12 Urogram (stones/colic or tumour) – individual patients

	Age (Years)	Mass (kg)	Trans (mm)	AP (mm)	CSA (mm2)	Applied Pot (kV)	CTDI (mGy)	Total DLP (mGy cm)	No of Sequences
Mean	61.7	80.6	348	250	69570	120	11.3	1007	2.1
Count	1027	245	959	959	959	2230	2137	1074	1071
Std Dev	16	18	44	45	20555	1.8	6.4	599	0.7
%CV	26	23	13	18	30	1.5	56	59	33
Min	16	44.0	230	148	29777	100	1.5	127	1.0
P05	33	55.0	281	183	41445	120	4.2	251	1.0
P10	40	57.6	296	197	46723	120	5.0	436	1.0
P25	51	67.0	318	218	55570	120	7.0	635	2.0
P50	64	80.0	344	246	66178	120	9.9	894	2.0
P75	74	90.0	373	278	80649	120	13.9	1235	3.0
P90	81	102	403	308	95210	120	19.4	1700	3.0
P95	84	111	424	327	107372	120	23.7	2007	3.0
Max	98	147	500	441	164154	140	76.6	6577	4.0

TABLE C2.13 Chest-abdomen-pelvis (CAP) (cancer) – individual patients

	Age (Years)	Mass (kg)	Trans (mm)	AP (mm)	CSA (mm2)	Applied Pot (kV)	CTDI (mGy)	Total DLP (mGy cm)	No of Sequences
Mean	60.1	57.4	335	241	64017	121	9.9	1047	1.5
Count	143	118	36	36	36	326	326	761	224
Std Dev	13	16	36	37	15710	3.2	4.2	611	0.5
%CV	22	27	11	15	25	2.7	43	58	35
Min	18	39.0	277	158	42818	120	2.6	125	1.0
P05	36	45.0	280	187	44233	120	4.5	370	1.0
P10	41	46.0	292	197	45377	120	5.4	427	1.0
P25	54	51.0	310	213	50882	120	6.5	615	1.0
P50	62	55.0	335	235	61533	120	9.1	891	1.0
P75	69	57.0	352	271	76395	120	12.6	1310	2.0
P90	76	71.0	377	293	83283	130	15.0	1883	2.0
P95	77	83.2	390	299	89851	130	17.0	2252	2.0
Max	89	170	450	301	105689	130	28.2	4246	3.0

TABLE C2.14 Paediatric head: age 0–1 y (trauma) – individual patients

	Age (Years)	Mass (kg)	Trans (mm)	AP (mm)	CSA (mm2)	Applied Pot (kV)	CTDI (mGy)	Total DLP (mGy cm)	No of Sequences
Mean	0.4	5.1	119	138	13043	118	23.9	333	1.1
Count	305	18	240	239	239	348	302	305	305
Std Dev	0.3	3.2	15	19	3096	6.4	8.6	145	0.3
%CV	76	64	12	14	24	5.4	36	44	31
Min	0.003	1.0	83.0	99.0	6744	80	3.1	30.7	1.0
P05	0.02	1.5	95.1	108	8303	100	14.2	179	1.0
P10	0.1	1.9	97.9	115	8627	120	14.9	192	1.0
P25	0.1	3.0	106	125	10485	120	18.8	238	1.0
P50	0.4	4.1	121	139	13344	120	22.0	297	1.0
P75	0.8	6.8	128	151	15311	120	26.9	389	1.0
P90	1.0	8.5	136	162	17258	120	36.9	520	2.0
P95	1.0	9.9	142	169	17750	120	40.8	635	2.0
Max	1.0	13.9	149	220	21042	140	64.6	1234	2.0

TABLE C2.15 Paediatric head: age >1–5 y (trauma) – individual patients

	Age (Years)	Mass (kg)	Trans (mm)	AP (mm)	CSA (mm2)	Applied Pot (kV)	CTDI (mGy)	Total DLP (mGy cm)	No of Sequences
Mean	3.0	14.3	137	166	17833	120	34.2	518	1.4
Count	264	8	201	201	201	353	295	264	261
Std Dev	1.2	7.1	10	11	2272	7.6	15	267	0.6
%CV	40	49	7.5	6.7	13	6.4	43	52	42
Min	1.0	8.0	104	133	12019	100	12.7	168	1.0
P05	1.3	8.7	123	149	14827	100	16.9	235	1.0
P10	1.5	9.4	126	153	15683	120	18.8	264	1.0
P25	2.0	10.0	131	158	16640	120	22.5	333	1.0
P50	3.0	11.7	136	165	17493	120	28.2	442	1.0
P75	4.0	16.3	142	172	18872	120	42.8	617	2.0
P90	5.0	20.9	148	179	19932	120	58.6	909	2.0
P95	5.0	25.5	152	183	20777	140	67.5	1059	2.0
Max	5.0	30.0	182	203	26734	140	91.4	1901	3.0

TABLE C2.16 Paediatric head: age >5 y (trauma) – individual patients

	Age (Years)	Mass (kg)	Trans (mm)	AP (mm)	CSA (mm2)	Applied Pot (kV)	CTDI (mGy)	Total DLP (mGy cm)	No of Sequences
Mean	9.2	28.8	146	176	20187	122	51.0	731	1.5
Count	269	10	219	219	219	363	348	269	247
Std Dev	2.1	9.3	10	10	2180	7.8	18	264	0.8
%CV	23	32	6.6	5.8	11	6.4	36	36	57
Min	5.2	19.0	110	133	11504	100	14.2	162	1.0
P05	6.0	19.5	131	160	16359	120	26.6	271	1.0
P10	6.0	19.9	134	163	17653	120	28.2	437	1.0
P25	7.5	22.3	139	170	18879	120	34.8	562	1.0
P50	9.0	27.5	145	177	20046	120	54.9	684	1.0
P75	11.0	32.7	152	183	21496	120	62.9	942	2.0
P90	12.0	36.5	157	188	22943	140	69.3	1105	2.0
P95	12.0	43.3	160	193	23476	140	83.6	1160	4.0
Max	12.5	50.0	177	203	26972	140	114	1445	4.0

C3 Distributions of Mean Data from Patient Samples (*n* > 4) at CT Centres by Examination Type

TABLE C3.1 Head (acute stroke): mean data for patient samples (*n* > 4)

	Age (Years)	Mass (kg)	Trans (mm)	AP (mm)	CSA (mm2)	CTDI (mGy)	Total DLP (mGy cm)	Sample Size (DLP)	No of Sequences
Mean	65.9	72.3	149	188	22059	57.8	888	106	1.4
Count	106	35	90	90	90	114	152	152	117
Std Dev	7.0	7.6	4.4	5.5	1233	8.4	147	456	0.6
%CV	11	10	3.0	2.9	5.6	15	17	429	43
Min	47.4	48.0	138	164	18075	38.8	513	5	1.0
P05	53.7	63.1	140	179	19750	44.3	652	9	1.0
P10	56.8	66.4	143	180	20444	47.4	703	13	1.0
P25	61.4	68.3	147	185	21518	53.2	797	20	1.0
P50	65.9	71.3	150	188	22171	57.4	895	20	1.0
P75	70.6	77.0	152	191	22830	62.7	973	20	2.0
P90	75.0	79.3	154	193	23474	68.2	1075	78	2.1
P95	76.3	81.4	156	194	23775	70.3	1101	99	3.0
Max	82.0	92.5	160	206	25876	85.2	1368	3227	3.0

TABLE C3.2 Cervical spine (fracture): mean data for patient samples (*n* > 4)

	Age (Years)	Mass (kg)	Trans (mm)	AP (mm)	CSA (mm2)	CTDI (mGy)	Total DLP (mGy cm)	Sample Size (DLP)	No of Sequences
Mean	53.3	73.1	142	149	17333	23.9	526	26	1.0
Count	37	13	34	34	34	37	54	54	38
Std Dev	8.1	7.9	47	16	8971	11	220	34	0.2
%CV	15	11	33	11	52	46	42	133	17
Min	39.0	57.3	95.5	129	10593	7.3	137	5	1.0
P05	43.0	61.8	120	130	12484	11.2	288	6	1.0
P10	44.2	64.9	123	133	13206	13.3	299	7	1.0
P25	46.5	67.4	126	141	14353	16.4	377	15	1.0
P50	51.9	74.0	132	146	15171	21.5	482	20	1.0
P75	59.7	80.0	140	152	17707	27.8	606	20	1.0
P90	63.2	81.6	162	166	18933	39.2	811	36	1.0
P95	69.1	82.3	173	175	23907	46.1	922	73	1.1
Max	70.2	82.9	394	209	65348	55.4	1214	234	2.0

TABLE C3.3 Chest (lung cancer): mean data for patient samples (*n* > 4)

	Age (Years)	Mass (kg)	Trans (mm)	AP (mm)	CSA (mm2)	CTDI (mGy)	Total DLP (mGy cm)	Sample Size (DLP)	No of Sequences
Mean	66.2	74.4	345	250	68353	10.7	503	18.5	1.5
Count	93	34	88	88	88	99	130	130	102
Std Dev	4.5	5.5	18	14	5468	4.2	171	7.2	0.6
%CV	6.8	7.4	5.3	5.4	8.0	39	34	39	36
Min	51.0	64.9	311	212	54374	5.5	175	5	1.0
P05	59.5	65.9	319	226	59783	7.2	250	8	1.0
P10	61.0	66.9	323	234	60662	7.5	301	10	1.0
P25	63.6	71.1	332	243	65366	8.4	368	16	1.0
P50	66.7	74.2	343	251	68480	9.9	502	20	1.5
P75	69.1	77.5	357	258	71638	12.2	614	20	2.0
P90	71.3	80.8	370	266	75695	13.9	739	21	2.0
P95	72.5	82.7	376	272	76923	15.4	803	28	2.2
Max	75.1	90.0	389	288	82922	41.3	1018	63	3.0

TABLE C3.4 Chest – high resolution (interstitial lung disease): mean data for patient samples (*n* > 4) (all techniques)

	Age (Years)	Mass (kg)	Trans (mm)	AP (mm)	CSA (mm2)	CTDI (mGy)	Total DLP (mGy cm)	Sample Size (DLP)	No of Sequences
Mean	62.5	75.3	346	253	69389	6.1	226	23.7	1.4
Count	76	26	70	70	70	82	110	110	82
Std Dev	5.4	9.1	19	13	5886	5.4	214	34	0.7
%CV	8.7	12	5.6	5.1	8.5	88	94	143	50
Min	50.8	52.0	307	216	54159	0.9	25.3	5	1.0
P05	53.1	62.2	314	228	56171	1.2	41.7	6	1.0
P10	54.7	67.8	325	237	62580	1.3	52.5	7	1.0
P25	60.0	71.6	338	246	66570	1.8	69.5	12	1.0
P50	62.7	75.4	346	254	69694	4.6	150	20	1.0
P75	66.3	80.5	356	261	73375	8.5	299	20	1.4
P90	69.2	84.0	368	270	75708	12.0	490	29	2.2
P95	71.1	86.8	379	272	77649	18.7	669	50	3.0
Max	74.8	100	407	278	86894	25.4	1210	245	4.0

TABLE C3.5 Chest – high resolution (interstitial lung disease): mean data for patient samples (*n* > 4) (axial scanning only)

	Age (Years)	Mass (kg)	Trans (mm)	AP (mm)	CSA (mm2)	CTDI (mGy)	Total DLP (mGy cm)	Sample Size (DLP)	No of Sequences
Mean	62.4	74.0	349	252	69770	3.1	111	15.4	1.4
Count	53	17	50	50	50	53	54	54	54
Std Dev	5.1	10	20	14	6693	2.9	94	5.6	0.7
%CV	8.1	14	5.8	5.7	9.6	92	85	36	52
Min	52.6	52.0	312	216	54159	1.0	34.1	5.0	1.0
P05	53.7	58.8	314	226	56171	1.1	39.0	6.0	1.0
P10	55.2	64.6	326	236	61207	1.3	46.2	7.3	1.0
P25	60.3	70.0	338	243	66570	1.6	60.3	11.0	1.0
P50	61.8	73.8	348	253	69879	2.3	75.4	18.0	1.0
P75	66.3	77.8	360	260	74487	3.9	139	20.0	1.5
P90	68.5	81.3	372	270	77871	5.9	194	20.0	2.2
P95	70.5	86.5	385	275	78909	6.7	264	20.0	3.0
Max	74.8	100	407	283	86894	18.9	616	29.0	4.0

TABLE C3.6 Chest – high resolution (interstitial lung disease): mean data for patient samples (*n* > 4) (helical scanning only)

	Age (Years)	Mass (kg)	Trans (mm)	AP (mm)	CSA (mm2)	CTDI (mGy)	Total DLP (mGy cm)	Sample Size (DLP)	No of Sequences
Mean	63.1	76.5	342	256	69418	10.8	361	15.7	1.2
Count	30	12	27	27	27	34	33	33	33
Std Dev	6.3	6.7	15	11	4349	5.2	204	5.6	0.5
%CV	10	8.8	4.4	4.1	6.3	48	56	36	44
Min	50.8	66.8	307	229	56009	0.9	25.3	5.0	1.0
P05	51.4	68.0	313	239	63252	6.1	188	5.6	1.0
P10	53.4	69.1	326	243	64750	6.7	211	7.2	1.0
P25	59.3	71.5	336	251	68249	7.9	249	11.0	1.0
P50	64.0	74.6	344	257	69759	9.1	296	19.0	1.0
P75	66.8	81.8	351	262	71366	12.5	350	20.0	1.0
P90	70.7	84.7	359	268	74508	18.3	671	20.8	2.0
P95	72.6	86.0	362	272	75403	21.0	727	21.8	2.4
Max	74.6	87.5	374	274	77457	27.3	1042	23.0	3.0

TABLE C3.7 CT angiography (CTA) (blood vessels): mean data for patient samples (*n* > 4)

	Age (Years)	Mass (kg)	Trans (mm)	AP (mm)	CSA (mm2)	CTDI (mGy)	Total DLP (mGy cm)	Sample Size (DLP)	No of Sequences
Mean	70.3	86.1	344	257	70556	13.4	802	16.4	1.9
Count	44	16	43	43	43	43	47	47	44
Std Dev	6.4	11	15	13	5716	4.2	372	6.1	1.1
%CV	9.1	13	4.3	5.1	8.1	32	46	37	60
Min	52.3	74.3	315	229	58185	7.7	223	5	1.0
P05	55.1	75.9	319	235	61230	8.4	397	6	1.0
P10	60.8	77.4	328	245	64230	9.0	419	8	1.0
P25	68.3	79.0	335	247	66600	10.6	525	11	1.0
P50	71.2	82.9	346	258	71078	12.5	666	19	1.3
P75	74.1	89.5	351	265	73444	15.2	1042	20	2.9
P90	77.5	94.9	365	274	78715	19.1	1318	20	3.4
P95	78.4	102	367	281	79680	22.6	1552	21	4.0
Max	80.0	120	382	283	83364	25.4	1725	36	5.0

TABLE C3.8 CT pulmonary angiography (CTPA) (pulmonary embolism): mean data for patient samples (*n* > 4)

	Age (Years)	Mass (kg)	Trans (mm)	AP (mm)	CSA (mm2)	CTDI (mGy)	Total DLP (mGy cm)	Sample Size (DLP)	No of Sequences
Mean	65.6	77.7	353	246	68651	10.8	358	18.6	1.7
Count	83	30	80	80	80	80	89	89	89
Std Dev	5.3	9.9	22	12	5854	4.7	143	3.9	1.0
%CV	8.1	13	6.3	4.7	8.5	44	40	21	55
Min	54.2	60.0	295	201	46562	3.8	134	5	1.0
P05	57.4	62.7	321	230	59665	5.1	170	9	1.0
P10	58.8	66.3	329	233	62090	5.8	197	12	1.0
P25	61.7	71.8	342	237	65755	7.8	253	19	1.0
P50	66.2	77.0	352	247	68508	9.7	330	20	1.0
P75	69.3	81.9	365	253	72239	12.9	441	20	3.0
P90	72.2	89.4	372	260	75031	16.5	550	20	3.0
P95	74.6	94.8	388	261	76283	20.0	626	21	3.0
Max	77.2	102	444	267	87827	29.0	864	29	4.7

TABLE C3.9 Abdomen (liver metastases): mean data for patient samples (*n* > 4)

	Age (Years)	Mass (kg)	Trans (mm)	AP (mm)	CSA (mm2)	CTDI (mGy)	Total DLP (mGy cm)	Sample Size (DLP)	No of Sequences
Mean	63.4	76.2	335	251	67117	12.7	670	18.6	1.7
Count	47	16	47	47	47	48	54	54	48
Std Dev	5.0	7.8	15	16	6424	2.6	319	9.1	0.8
%CV	8.0	10	4.5	6.3	9.6	21	48	49	49
Min	53.5	65.5	292	206	48039	8.3	245	5	1.0
P05	56.3	65.6	311	220	54768	9.0	290	6	1.0
P10	58.1	66.2	318	232	60358	9.6	322	8	1.0
P25	59.9	70.0	325	244	63887	10.9	407	15	1.0
P50	62.6	76.4	336	252	68177	12.5	634	20	1.2
P75	66.1	82.2	344	262	71086	13.8	909	20	2.7
P90	69.2	86.1	352	270	74638	15.7	1065	20	3.0
P95	69.8	88.0	356	274	76487	18.0	1273	30	3.0
Max	81.8	90.0	369	277	80612	20.6	1496	60	3.0

TABLE C3.10 Abdomen and pelvis (abscess): mean data for patient samples (*n* > 4)

	Age (Years)	Mass (kg)	Trans (mm)	AP (mm)	CSA (mm2)	CTDI (mGy)	Total DLP (mGy cm)	Sample Size (DLP)	No of Sequences
Mean	61.6	74.6	344	250	68912	13.3	646	43.4	1.1
Count	88	36	83	83	83	95	120	120	98
Std Dev	6.2	5.1	14	13	6012	3.8	162	109	0.3
%CV	10	6.9	4.1	5.1	8.7	29	25	252	30
Min	40.0	66.9	315	222	56465	6.1	310	5	1.0
P05	51.1	67.7	322	231	59156	8.6	427	10	1.0
P10	53.7	68.6	329	235	61803	9.4	482	12	1.0
P25	57.7	72.1	334	242	65139	10.7	527	20	1.0
P50	62.2	73.9	343	250	68337	12.5	624	20	1.0
P75	65.7	76.6	353	259	72404	15.0	745	20	1.0
P90	68.6	80.0	358	265	74628	17.8	854	58	1.1
P95	71.1	82.5	367	270	79810	20.1	917	92	2.0
Max	76.2	90.8	390	293	89411	28.4	1252	873	3.0

TABLE C3.11 Virtual colonoscopy (VC) (polyps/tumour): mean data for patient samples (*n* > 4)

	Age (Years)	Mass (kg)	Trans (mm)	AP (mm)	CSA (mm2)	CTDI (mGy)	Total DLP (mGy cm)	Sample Size (DLP)	No of Sequences
Mean	67.8	74.6	338	264	71025	8.5	783	36.3	2.0
Count	51	22	48	48	48	51	68	68	52
Std Dev	4.6	13	13	18	6443	2.7	286	99	0.08
%CV	6.7	17	3.9	6.9	9.1	32	37	272	4.1
Min	59.6	44.0	306	222	56525	2.6	132	5	1.9
P05	61.1	63.9	310	229	60448	3.9	263	7	2.0
P10	62.2	66.8	321	241	61031	5.4	426	9	2.0
P25	64.5	69.4	329	251	66929	6.7	633	13	2.0
P50	67.4	72.1	339	267	71700	8.1	788	20	2.0
P75	70.7	79.2	346	277	75941	10.6	947	20	2.0
P90	74.2	83.8	354	286	78666	12.4	1146	24	2.1
P95	75.9	93.7	356	288	80078	12.9	1273	117	2.2
Max	78.3	115	359	291	82525	13.7	1471	786	2.4

TABLE C3.12 Enteroclysis (Crohn's disease): mean data for patient samples (*n* > 4)

	Age (Years)	Mass (kg)	Trans (mm)	AP (mm)	CSA (mm2)	CTDI (mGy)	Total DLP (mGy cm)	Sample Size (DLP)	No of Sequences
Mean	48.4	-	320	231	59502	10.2	578	13.4	1.2
Count	6	-	6	6	6	6	7	7	6
Std Dev	8.9	-	11	10	4405	2.0	183	5.4	0.2
%CV	18	-	3.4	4.5	7.4	19	32	40	17
Min	38.4	-	304	224	55696	7.9	437	5	1.0
P05	38.9	-	307	224	55977	8.2	441	6	1.0
P10	39.4	-	310	225	56259	8.5	445	7	1.0
P25	41.9	-	315	225	57079	9.1	450	10	1.0
P50	48.2	-	318	228	58443	9.4	481	14	1.1
P75	51.7	-	324	231	59459	11.7	646	18	1.3
P90	57.5	-	331	242	63806	12.6	772	19	1.4
P95	60.2	-	334	247	65908	12.7	855	19	1.4
Max	62.9	-	337	252	68010	12.8	938	20	1.4

TABLE C3.13 Kidney-ureters-bladder (KUB) (stones/colic): mean data for patient samples (*n* > 4)

	Age (Years)	Mass (kg)	Trans (mm)	AP (mm)	CSA (mm2)	CTDI (mGy)	Total DLP (mGy cm)	Sample Size (DLP)	No of Sequences
Mean	49.3	81.2	345	242	66745	8.3	355	23.3	1.0
Count	87	29	84	84	84	92	100	100	94
Std Dev	6.2	8.8	17	17	7241	3.4	142	35	0.1
%CV	12	11	5.0	7.1	11	41	40	149	14
Min	32.8	67.5	296	213	51965	2.2	101	5	1.0
P05	39.1	68.0	313	218	56122	4.1	171	8	1.0
P10	42.5	72.3	325	222	57751	4.7	195	9	1.0
P25	44.5	75.7	335	232	62522	5.9	255	14	1.0
P50	49.1	80.0	347	239	66079	7.6	323	20	1.0
P75	54.5	85.9	356	248	70433	10.2	458	20	1.0
P90	56.1	89.2	365	268	75682	12.7	558	20	1.0
P95	59.2	95.5	370	272	78910	15.3	644	24	1.1
Max	63.4	109	391	303	91944	18.7	828	294	2.0

TABLE C3.14 Urogram (stones/colic or tumour): mean data for patient samples (*n* > 4)

	Age (Years)	Mass (kg)	Trans (mm)	AP (mm)	CSA (mm2)	CTDI (mGy)	Total DLP (mGy cm)	Sample Size (DLP)	No of Sequences
Mean	61.9	80.9	347	250	69235	11.3	960	29.2	2.1
Count	61	21	57	57	57	63	74	74	63
Std Dev	6.4	9.2	15	16	6483	3.5	363	81	0.7
%CV	10	11	4.2	6.4	9.4	31	38	278	32
Min	45.4	57.3	319	215	57150	4.6	204	5	1.0
P05	49.0	72.0	327	225	59153	5.4	254	6	1.0
P10	53.5	72.6	331	229	61146	7.7	577	7	1.0
P25	57.4	77.0	338	238	64812	9.1	777	10	2.0
P50	62.5	80.2	347	250	69583	11.2	978	20	2.0
P75	66.1	84.0	354	261	74414	12.7	1148	20	2.6
P90	68.0	89.0	366	271	77863	15.5	1373	20	3.0
P95	71.0	90.3	368	274	80741	16.2	1552	39	3.0
Max	79.0	106	388	286	81681	23.7	1973	690	3.1

TABLE C3.15 Chest-abdomen-pelvis (CAP) (cancer): mean data for patient samples (*n* > 4)

	Age (Years)	Mass (kg)	Trans (mm)	AP (mm)	CSA (mm2)	CTDI (mGy)	Total DLP (mGy cm)	Sample Size (DLP)	No of Sequences
Mean	61.1	62.4	335	240	63936	10.4	897	125	1.7
Count	5	3	2	2	2	11	39	39	11
Std Dev	3.2	17	3.9	11	2044	2.8	294	261	0.4
%CV	5.3	27	1.2	4.6	3.2	27	33	209	25
Min	58.3	52.6	332	233	62491	6.3	426	7	1.0
P05	58.5	52.7	333	233	62636	6.7	527	10	1.0
P10	58.8	52.7	333	234	62780	7.1	605	10	1.0
P25	59.5	52.8	334	236	63214	8.3	719	16	1.5
P50	60.0	52.9	335	240	63936	10.9	856	20	2.0
P75	61.3	67.3	336	244	64659	12.5	1003	61	2.0
P90	64.5	75.9	337	247	65092	14.1	1230	481	2.0
P95	65.5	78.7	338	247	65237	14.2	1297	520	2.1
Max	66.6	81.6	338	248	65382	14.2	1931	1398	2.1

TABLE C3.16 Paediatric head (age 0–1 y) (trauma): mean data for patient samples (*n* > 4)

	Age (Years)	Mass (kg)	Trans (mm)	AP (mm)	CSA (mm2)	CTDI (mGy)	Total DLP (mGy cm)	Sample Size (DLP)	No of Sequences
Mean	0.4	4.4	119	138	13010	22.7	313	15.5	1.2
Count	19	4	13	13	13	17	19	19	19
Std Dev	0.1	1.0	6.2	6.3	1181	5.6	96	6.6	0.3
%CV	33	23	5.2	4.6	9.1	25	31	43	24
Min	0.1	2.9	110	129	11351	14.1	179	6	1.0
P05	0.1	3.2	110	130	11564	16.7	192	7	1.0
P10	0.3	3.5	111	131	11808	17.3	211	7	1.0
P25	0.4	4.3	116	132	12262	18.2	250	10	1.0
P50	0.4	4.7	118	137	12891	22.5	297	18	1.0
P75	0.5	4.9	121	143	14009	25.7	353	21	1.2
P90	0.6	5.0	124	146	14187	30.5	421	22	1.5
P95	0.6	5.1	128	147	14787	32.5	450	23	1.7
Max	0.6	5.2	133	149	15624	34.6	569	27	2.0

TABLE C3.17 Paediatric head (age >1–5 y) (trauma): mean data for patient samples (*n* > 4)

	Age (Years)	Mass (kg)	Trans (mm)	AP (mm)	CSA (mm2)	CTDI (mGy)	Total DLP (mGy cm)	Sample Size (DLP)	No of Sequences
Mean	3.0	15.3	137.1	165.3	17836.0	35.4	533	13.7	1.3
Count	18	2	14	14	14	18	18	18	18
Std Dev	0.6	5.8	4.2	5.2	1055	11	184	5.8	0.5
%CV	19	38	3.1	3.1	5.9	31	35	42	36
Min	1.9	11.2	131	157	16090	20.8	292	5	1.0
P05	2.3	11.6	132	159	16572	21.8	312	5	1.0
P10	2.4	12.0	133	160	16862	22.5	317	6	1.0
P25	2.7	13.3	134	162	17213	25.0	381	8	1.0
P50	2.9	15.3	137	165	17553	34.6	505	14	1.1
P75	3.2	17.4	140	168	18399	43.3	649	20	1.3
P90	3.8	18.6	143	171	19003	46.9	825	20	2.0
P95	3.9	19.0	144	174	19442	53.4	838	20	2.1
Max	4.2	19.4	145	176	20166	57.5	843	22	2.6

TABLE C3.18 Paediatric head (age >5 y) (trauma): mean data for patient samples (*n* > 4)

	Age (Years)	Mass (kg)	Trans (mm)	AP (mm)	CSA (mm2)	CTDI (mGy)	Total DLP (mGy cm)	Sample Size (DLP)	No of Sequences
Mean	9.1	34.5	145	176	20022	51.8	751	14.6	1.6
Count	17	3	14	14	14	15	17	17	16
Std Dev	0.7	14	4.5	5.5	1139	14	200	5.3	0.8
%CV	7.6	41	3.1	3.1	5.7	26	27	36	51
Min	8.0	21.8	139	163	18213	31.8	415	5	1.0
P05	8.3	22.8	140	168	18626	35.1	467	5	1.0
P10	8.4	23.8	141	171	18967	36.8	494	7	1.0
P25	8.8	26.8	142	172	19352	40.1	631	10	1.0
P50	9.0	31.8	143	176	19811	52.0	754	16	1.0
P75	9.6	40.9	147	178	20398	60.6	863	19	2.0
P90	10.1	46.4	152	183	21750	69.3	999	20	2.1
P95	10.4	48.2	154	183	22087	73.3	1075	20	2.6
Max	10.5	50.0	155	183	22267	75.8	1086	22	3.9

C4 Distributions of Mean Data from Patient Samples (*n* > 4) by Examination and Sequence Type

TABLE C4.1 Head (acute stroke) – sequence 'brain': mean data (patient samples *n* > 4)

	Applied Pot (kV)	Pitch (Helical)	CTDI (mGy)	Sample Size (CTDI)	Collimation (mm)	Scan Length (mm)	DLP (mGy cm)
Mean	120.2	0.6	55.9	18.3	26.0	148	870
No. of Scanners	84	52	85	85	83	66	85
Std Dev	3.5	0.2	7.9	4.4	34	8.7	139
%CV	2.9	25	14	24	132	5.9	16
Min	100	0.3	38.8	6	0.5	130	325
P05	120	0.4	43.5	7	2.0	137	670
P10	120	0.5	45.4	11	7.6	139	715
P25	120	0.5	49.9	19	12.0	143	782
P50	120	0.6	56.3	20	18.0	148	889
P75	120	0.7	60.8	20	32.0	153	952
P90	120	0.8	66.1	21	40.0	159	1062
P95	120	0.9	68.9	22	40.0	162	1088
Max	140	1.2	76.4	27	300	179	1174

TABLE C4.2 Head (acute stroke) – sequence 'cerebrum': mean data (patient samples *n* > 4)

	Applied Pot (kV)	Pitch (Helical)	CTDI (mGy)	Sample Size (CTDI)	Collimation (mm)	Scan Length (mm)	DLP (mGy cm)
Mean	120.7	1.0	52.8	19.4	15.7	92.3	510
No. of Scanners	30	2	30	30	29	25	30
Std Dev	3.6	0	7.6	4.4	5.9	8.0	85
%CV	3.0	0	14	23	38	8.6	17
Min	120	1.0	37.6	6	0.8	75.8	341
P05	120	1.0	42.4	11	5.0	82.1	378
P10	120	1.0	42.9	15	5.0	82.4	393
P25	120	1.0	46.2	20	13.3	86.3	435
P50	120	1.0	54.3	20	18.0	92.4	525
P75	120	1.0	57.7	20	20.0	100	563
P90	120	1.0	61.1	21	20.0	102	607
P95	121	1.0	63.1	25	22.4	103	622
Max	140	1.0	68.1	31	24.0	105	669

TABLE C4.3 Head (acute stroke) – sequence 'posterior fossa': mean data (patient samples *n* > 4)

	Applied Pot (kV)	Pitch (Helical)	CTDI (mGy)	Sample Size (CTDI)	Collimation (mm)	Scan Length (mm)	DLP (mGy cm)
Mean	128.6	1.0	72.7	19.4	11.4	48.5	366
No. of Scanners	30	2	30	30	30	25	30
Std Dev	10	0	15	4.4	6.1	12	99
%CV	7.8	0	20	23	54	24	27
Min	120	1.0	55.9	6	0.8	33.1	203
P05	120	1.0	56.5	11	2.5	36.1	249
P10	120	1.0	57.5	15	3.9	36.7	265
P25	120	1.0	62.3	20	6.0	39.2	291
P50	120	1.0	67.7	20	10.0	42.5	342
P75	140	1.0	80.3	20	18.0	59.8	417
P90	140	1.0	93.0	21	20.0	64.5	484
P95	140	1.0	98.9	25	20.0	67.3	528
Max	140	1.0	112	31	20.0	69.8	633

TABLE C4.4 Neck (fracture) – sequence 'neck': mean data (patient samples *n* > 4)

	Applied Pot (kV)	Pitch (Helical)	CTDI (mGy)	Sample Size (CTDI)	Collimation (mm)	Scan Length (mm)	DLP (mGy cm)
Mean	123.1	0.8	24.6	16.5	27.0	204	535
No. of Scanners	35	32	36	36	35	33	36
Std Dev	7.1	0.2	11	5.1	20	27	215
%CV	5.8	28	45	31	74	13	40
Min	120	0.3	7.3	5	0.6	147	137
P05	120	0.5	12.0	6	0.9	168	281
P10	120	0.5	14.3	8	1.4	174	322
P25	120	0.7	16.9	15	12.0	185	397
P50	120	0.8	21.7	19	32.0	195	503
P75	120	1.0	27.8	20	40.0	227	606
P90	140	1.0	40.8	20	40.0	242	866
P95	140	1.2	47.2	20	51.0	246	970
Max	140	1.5	55.4	20	76.8	255	1045

TABLE C4.5 Chest (lung cancer) – sequence 'lung/liver': mean data (patient samples *n* > 4)

	Applied Pot (kV)	Pitch (Helical)	CTDI (mGy)	Sample Size (CTDI)	Collimation (mm)	Scan Length (mm)	DLP (mGy cm)
Mean	120.5	1.1	10.3	25.2	31.0	294	328
No. of Scanners	89	78	90	90	85	70	89
Std Dev	2.7	0.2	3.0	11	19	44	85
%CV	2.2	22	30	43	61	15	26
Min	117	0.5	5.7	5	0.6	223	156
P05	120	0.8	7.0	10	1.5	245	235
P10	120	0.8	7.5	14	10.0	250	240
P25	120	0.9	8.1	19	19.2	267	273
P50	120	1.1	9.7	20	28.8	288	311
P75	120	1.4	11.4	38	40.0	312	364
P90	120	1.4	13.9	40	40.0	324	434
P95	120	1.4	15.2	40	76.8	399	462
Max	140	1.5	22.9	48	76.8	468	718

TABLE C4.6 Chest – high resolution (interstitial lung disease) – sequence 'axial': mean data (patient samples *n* > 4)

	Applied Pot (kV)	Pitch (Helical)	CTDI (mGy)	Sample Size (CTDI)	Collimation (mm)	Scan Length (mm)	DLP (mGy cm)
Mean	123.9	-	3.1	18.9	2.2	265	89
No. of Scanners	53	-	53	53	52	41	53
Std Dev	7.8	-	2.9	10.5	2.7	24	92
%CV	6.3	-	92	55	126	9.0	103
Min	120	-	1.0	5	1.0	208	26.6
P05	120	-	1.1	6	1.0	227	30.0
P10	120	-	1.3	8	1.3	232	31.7
P25	120	-	1.6	11	1.3	247	40.1
P50	120	-	2.3	19	1.3	272	60.1
P75	120	-	3.9	20	2.0	280	109
P90	140	-	5.9	39	2.0	289	158
P95	140	-	6.7	40	3.6	293	186
Max	140	-	18.9	41	16.0	315	616

TABLE C4.7 Chest – high resolution (interstitial lung disease) – sequence 'helical': mean data (patient samples *n* > 4)

	Applied Pot (kV)	Pitch (Helical)	CTDI (mGy)	Sample Size (CTDI)	Collimation (mm)	Scan Length (mm)	DLP (mGy cm)
Mean	120.6	1.1	10.6	17.2	25.3	301	322
No. of Scanners	34	27	35	35	33	30	35
Std Dev	3.4	0.2	5.0	7.5	17	16	123
%CV	2.8	22	47	43	67	5.3	38
Min	120	0.6	0.9	5	0.8	279	25.3
P05	120	0.8	6.1	6	1.2	281	191
P10	120	0.8	6.7	9	2.0	283	214
P25	120	0.9	8.0	13	12.0	287	251
P50	120	1.2	9.1	20	28.8	299	305
P75	120	1.4	11.9	20	38.4	312	349
P90	120	1.4	17.8	22	40.0	319	482
P95	120	1.4	21.0	28	40.0	324	549
Max	140	1.5	25.4	40	80.0	346	665

TABLE C4.8 CT angiography (CTA) (blood vessels) – sequence 'abdo/pelvis': mean data (patient samples *n* > 4)

	Applied Pot (kV)	Pitch (Helical)	CTDI (mGy)	Sample Size (CTDI)	Collimation (mm)	Scan Length (mm)	DLP (mGy cm)
Mean	120.0	1.1	13.5	19.4	34.4	416	623
No. of Scanners	41	37	41	41	41	38	41
Std Dev	0.1	0.3	4.3	7.9	21	57	206
%CV	0.1	23	32	41	60	14	33
Min	119	0.6	7.7	6	1.3	253	223
P05	120	0.8	8.4	6	2.0	322	339
P10	120	0.8	8.9	9	4.0	349	396
P25	120	0.9	10.5	14	24.0	382	478
P50	120	1.0	12.5	20	38.4	426	577
P75	120	1.4	15.6	21	40.0	439	758
P90	120	1.4	19.3	27	70.1	483	915
P95	120	1.4	22.8	37	76.8	504	951
Max	120	1.8	25.4	40	80.0	522	1121

TABLE C4.9 CT pulmonary angiography (CTPA) (pulmonary embolism) – sequence 'chest': mean data (patient samples *n* > 4)

	Applied Pot (kV)	Pitch (Helical)	CTDI (mGy)	Sample Size (CTDI)	Collimation (mm)	Scan Length (mm)	DLP (mGy cm)
Mean	116.7	1.0	10.9	18.8	29.3	266	322
No. of Scanners	79	76	80	80	76	64	79
Std Dev	9.4	0.2	4.6	4.0	22	31.90	132
%CV	8.1	23	42	21	75	11.99	41
Min	100	0.5	4.4	5	0.6	173	98
P05	100	0.7	5.6	10	1.0	207	151
P10	100	0.8	6.3	12	3.3	223	181
P25	120	0.9	7.9	19	12.0	255	229
P50	120	1.0	9.8	20	35.2	274	295
P75	120	1.2	13.0	20	40.0	284	381
P90	120	1.4	16.5	20	62.4	294	506
P95	122	1.4	20.0	21	76.8	304	551
Max	140	1.4	29.0	33	79.9	346	746

TABLE C4.10 Abdomen (liver metastases) – sequence 'abdomen': mean data (patient samples *n* > 4)

	Applied Pot (kV)	Pitch (Helical)	CTDI (mGy)	Sample Size (CTDI)	Collimation (mm)	Scan Length (mm)	DLP (mGy cm)
Mean	120.3	1.1	12.9	28.7	31.6	226	351
No. of Scanners	34	31	34	34	33	29	34
Std Dev	1.7	0.3	2.8	15.5	17	26	68
%CV	1.4	25	22	54	54	11	19
Min	119	0.6	8.1	5	0.6	185	189
P05	120	0.7	9.2	11	2.9	190	252
P10	120	0.8	9.5	15	12.4	194	263
P25	120	0.9	11.0	18	24.0	208	322
P50	120	1.1	12.5	22	38.4	225	351
P75	120	1.4	14.6	38	40.0	236	383
P90	120	1.4	15.7	55	40.0	262	456
P95	120	1.4	18.4	58	54.7	271	472
Max	130	1.5	20.3	60	76.8	283	488

TABLE C4.11 Abdomen (liver metastases) – sequence 'abdo/pelvis': mean data (patient samples *n* > 4)

	Applied Pot (kV)	Pitch (Helical)	CTDI (mGy)	Sample Size (CTDI)	Collimation (mm)	Scan Length (mm)	DLP (mGy cm)
Mean	120.0	1.1	11.6	16.3	31.2	431	536
No. of Scanners	20	18	20	20	20	16	20
Std Dev	0	0.3	1.9	6.1	10	32	108
%CV	0	26	17	38	31	7.4	20
Min	120	0.8	7.4	5	10.0	362	329
P05	120	0.8	8.2	6	14.8	379	393
P10	120	0.8	8.8	7	19.5	392	403
P25	120	0.8	10.9	13	24.0	419	428
P50	120	1.0	11.8	19	35.2	430	553
P75	120	1.4	12.8	20	40.0	451	617
P90	120	1.4	13.2	21	40.0	471	656
P95	120	1.4	14.0	24	40.0	475	676
Max	120	1.5	15.7	25	40.0	482	710

TABLE C4.12 Abdomen and pelvis (abscess) – sequence 'abdo/pelvis': mean data (patient samples *n* > 4)

	Applied Pot (kV)	Pitch (Helical)	CTDI (mGy)	Sample Size (CTDI)	Collimation (mm)	Scan Length (mm)	DLP (mGy cm)
Mean	120.2	1.0	13.3	18.3	29.8	438	610
No. of Scanners	94	80	95	95	90	81	95
Std Dev	1.6	0.3	3.8	3.7	19	25	143
%CV	1.3	27	29	20	63	5.6	23
Min	114	0.6	6.1	5	0.6	381	310
P05	120	0.7	8.6	10	1.6	403	409
P10	120	0.8	9.4	11	7.7	414	461
P25	120	0.8	10.7	18	18.3	424	508
P50	120	1.0	12.5	20	28.8	437	596
P75	120	1.4	15.0	20	40.0	449	692
P90	120	1.4	17.8	20	40.0	471	802
P95	120	1.4	20.1	21	76.8	488	854
Max	130	1.5	28.4	23	80.0	513	1025

TABLE C4.13 Virtual colonoscopy (VC) (polyps/tumour) – sequence 'abdo/pelvis': mean data (patient samples *n* > 4)

	Applied Pot (kV)	Pitch (Helical)	CTDI (mGy)	Sample Size (CTDI)	Collimation (mm)	Scan Length (mm)	DLP (mGy cm)
Mean	120.0	1.2	8.5	33.9	29.5	428	391
No. of Scanners	51	46	51	51	50	48	50
Std Dev	0.1	0.3	2.7	10	19	19	124
%CV	0.1	22	32	30	65	4.5	32
Min	120	0.6	2.6	8	0.8	385	117
P05	120	0.8	3.9	12	2.2	398	163
P10	120	0.8	5.4	16	4.9	403	240
P25	120	1.0	6.7	29	12.0	416	331
P50	120	1.2	8.1	40	32.0	429	392
P75	120	1.4	10.6	40	40.0	439	470
P90	120	1.5	12.4	42	40.0	451	544
P95	120	1.5	12.9	43	71.0	456	582
Max	120	1.5	13.7	44	80.0	470	667

TABLE C4.14 Enteroclysis (Crohn's disease) – sequence 'abdo/pelvis': mean data (patient samples *n* > 4)

	Applied Pot (kV)	Pitch (Helical)	CTDI (mGy)	Sample Size (CTDI)	Collimation (mm)	Scan Length (mm)	DLP (mGy cm)
Mean	116.7	1.2	10.1	15.2	28.1	443	488
No. of Scanners	6	6	6	6	4	4	6
Std Dev	8.2	0.2	1.9	4.7	14	25	82
%CV	7.0	16	19	31	50	5.7	17
Min	100	1.0	7.8	9	10.0	411	400
P05	105	1.0	8.1	10	12.1	414	407
P10	110	1.0	8.5	10	14.2	418	414
P25	120	1.1	9.2	12	20.5	429	433
P50	120	1.3	9.4	16	31.2	447	466
P75	120	1.4	11.4	19	38.8	461	531
P90	120	1.4	12.5	20	39.5	465	583
P95	120	1.4	12.7	21	39.8	466	601
Max	120	1.4	12.9	21	40.0	467	619

TABLE C4.15 Kidney-ureters-bladder (KUB) (stones/colic) – sequence 'abdo/pelvis': mean data (patient samples *n* > 4)

	Applied Pot (kV)	Pitch (Helical)	CTDI (mGy)	Sample Size (CTDI)	Collimation (mm)	Scan Length (mm)	DLP (mGy cm)
Mean	119.6	1.1	8.3	17.3	31.1	402	356
No. of Scanners	91	82	92	92	87	76	92
Std Dev	4.3	0.3	3.4	4.6	18	32	143
%CV	3.6	26	41	26	57	7.9	40
Min	100	0.6	2.2	5	0.6	341	101
P05	118	0.8	4.1	9	2.9	360	169
P10	120	0.8	4.7	10	10.0	363	194
P25	120	0.8	5.9	14	22.0	378	255
P50	120	1.0	7.6	20	32.0	401	319
P75	120	1.4	10.2	20	40.0	423	461
P90	120	1.4	12.7	20	40.0	445	524
P95	120	1.4	15.3	20	76.8	452	646
Max	139	1.8	18.7	24	80.0	486	828

TABLE C4.16 Urogram (stones/colic or tumour) – sequence 'abdo/pelv': mean data (patient samples *n* > 4)

	Applied Pot (kV)	Pitch (Helical)	CTDI (mGy)	Sample Size (CTDI)	Collimation (mm)	Scan Length (mm)	DLP (mGy cm)
Mean	120.5	1.1	11.2	30.5	29.6	410	496
No. of Scanners	63	57	63	63	61	56	63
Std Dev	2.1	0.3	3.6	15	17	36	150
%CV	1.7	25	32	48	56	8.7	30
Min	120	0.6	4.6	6	1.0	326	204
P05	120	0.8	5.4	8	1.8	341	240
P10	120	0.8	7.5	11	7.5	364	317
P25	120	0.8	8.6	20	20.0	394	388
P50	120	1.0	10.7	37	32.0	411	497
P75	120	1.4	12.7	40	40.0	433	600
P90	120	1.4	15.5	44	40.0	456	690
P95	120	1.4	16.0	56	40.0	465	761
Max	130	1.5	23.7	60	80.0	480	880

TABLE C4.17 Paediatric head (age 0–1 y) (trauma) – sequence 'brain': mean data (patient samples *n* > 4)

	Applied Pot (kV)	Pitch (Helical)	CTDI (mGy)	Sample Size (CTDI)	Collimation (mm)	Scan Length (mm)	DLP (mGy cm)
Mean	117.4	0.7	22.5	14.9	26.5	126	312
No. of Scanners	16	9	16	16	16	14	16
Std Dev	5.4	0.1	5.8	7.0	17	13	97
%CV	4.6	19	26	47	64	11	31
Min	100	0.5	14.1	6	10.0	108	179
P05	108	0.5	15.8	6	10.0	113	208
P10	112	0.5	16.9	6	10.0	115	226
P25	118	0.6	18.8	8	16.5	118	260
P50	120	0.8	20.6	16	21.0	123	286
P75	120	0.8	25.2	20	38.4	130	331
P90	120	0.8	30.8	22	38.4	136	427
P95	120	0.8	32.6	23	48.0	146	470
Max	120	0.9	34.6	27	76.8	163	569

TABLE C4.18 Paediatric head (age >1–5 y) (trauma) – sequence 'brain': mean data (patient samples *n* > 4)

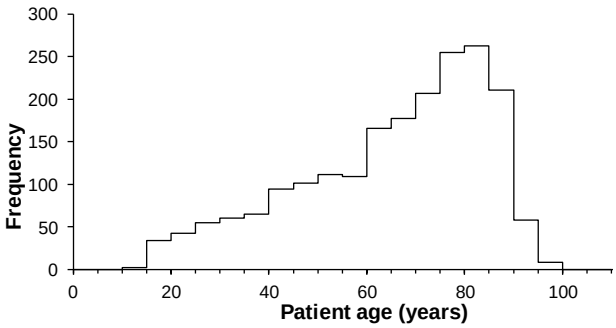
	Applied Pot (kV)	Pitch (Helical)	CTDI (mGy)	Sample Size (CTDI)	Collimation (mm)	Scan Length (mm)	DLP (mGy cm)
Mean	117.7	0.7	32.8	12.4	25.6	149	530
No. of Scanners	13	8	13	13	13	11	13
Std Dev	7.2	0.1	11	6.0	11	10	191
%CV	6.1	21	34	49	44	6.8	36
Min	105	0.5	20.8	5	10.0	139	305
P05	107	0.5	21.5	5	11.2	140	313
P10	108	0.5	22.0	5	12.8	141	328
P25	115	0.5	24.3	8	18.0	142	370
P50	120	0.7	30.8	12	20.0	145	451
P75	120	0.8	40.2	18	38.4	153	649
P90	122	0.8	44.8	20	38.4	164	811
P95	126	0.8	50.0	21	38.5	167	827
Max	132	0.9	57.5	22	38.8	170	838

TABLE C4.19 Paediatric head (age >5 y) (trauma) – sequence 'brain': mean data (patient samples *n* > 4)

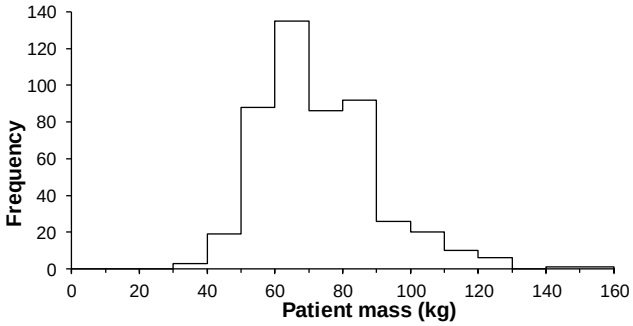
	Applied Pot (kV)	Pitch (Helical)	CTDI (mGy)	Sample Size (CTDI)	Collimation (mm)	Scan Length (mm)	DLP (mGy cm)
Mean	118.7	0.7	46.4	16.9	29.4	159	793
No. of Scanners	8	5	8	8	8	8	8
Std Dev	4.4	0.1	11	3.2	11	14	215
%CV	3.7	22	25	19	36	8.6	27
Min	108	0.5	31.8	10	12.0	141	480
P05	112	0.5	33.7	12	14.8	143	502
P10	116	0.5	35.6	14	17.6	145	523
P25	120	0.6	39.1	16	23.0	151	690
P50	120	0.7	41.9	17	31.2	157	796
P75	120	0.8	57.7	19	38.4	164	899
P90	121	0.8	60.0	20	38.9	172	1067
P95	122	0.8	61.0	20	39.4	178	1076
Max	123	0.9	62.0	20	40.0	185	1086

APPENDIX D Histograms for Distributions of Survey Data

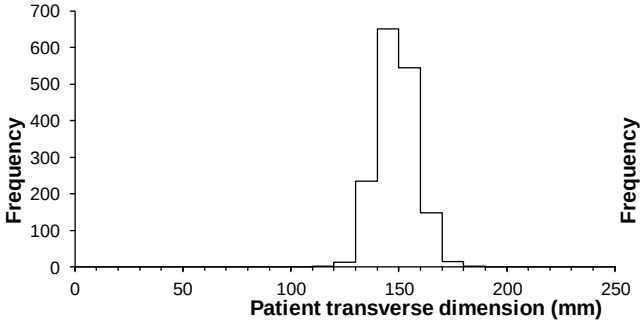
D1 Distributions over Individual Patients (or Sequences) by Examination Type



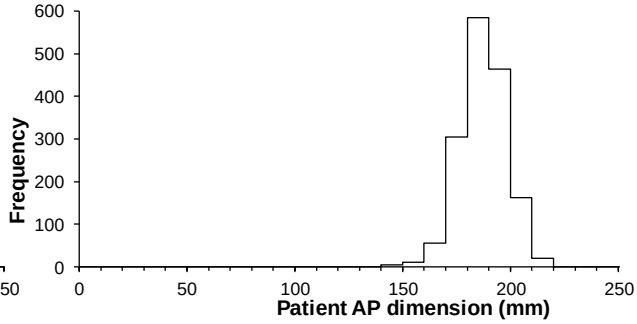
(a) Patient age



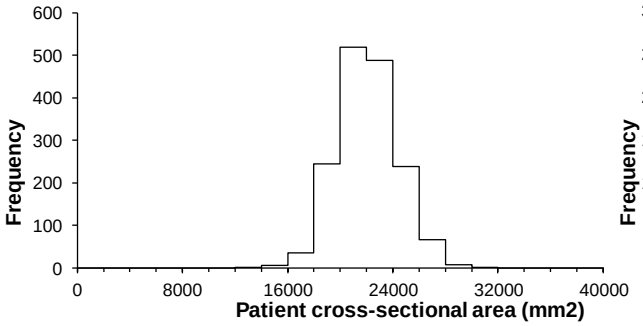
(b) Patient mass



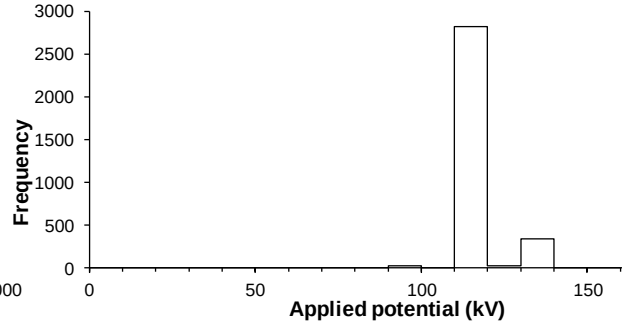
(c) Patient dimension: transverse



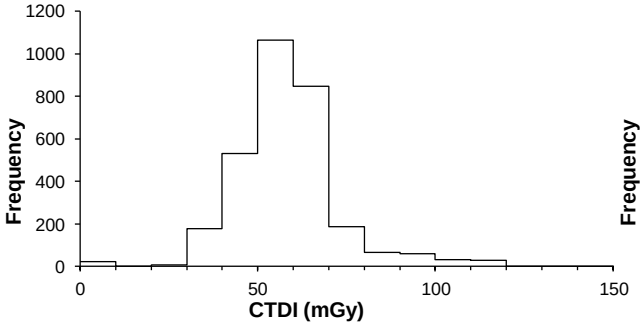
(d) Patient dimension: AP



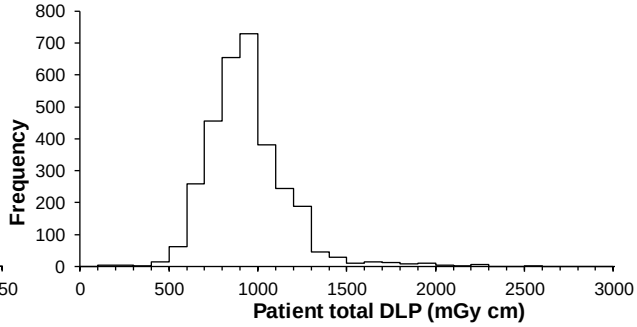
(e) Patient cross-sectional area



(f) Applied potential per individual sequence

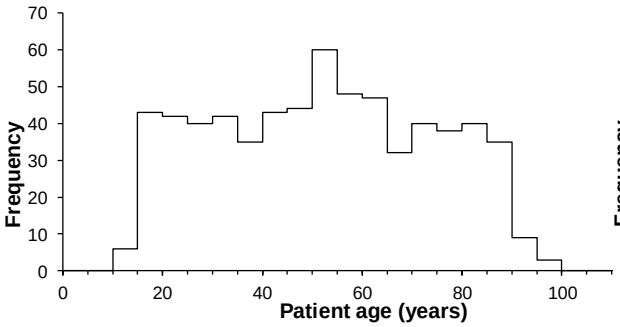


(g) $CTDI_{vol}$ per individual sequence

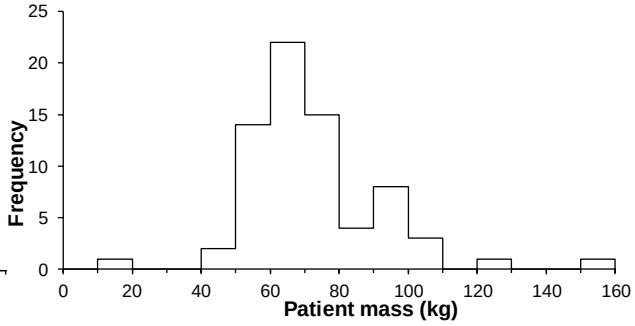


(h) Total DLP per patient

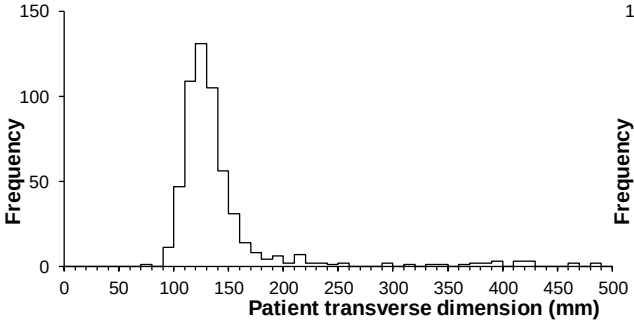
FIGURE D1.1 Head (stroke): distributions over individual patients (or sequences)



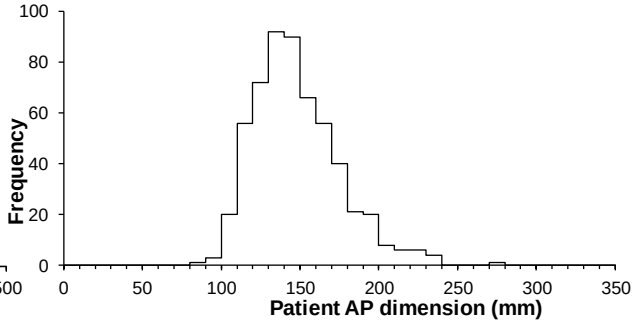
(a) Patient age



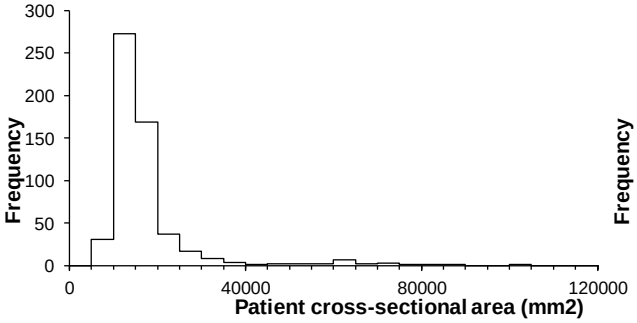
(b) Patient mass



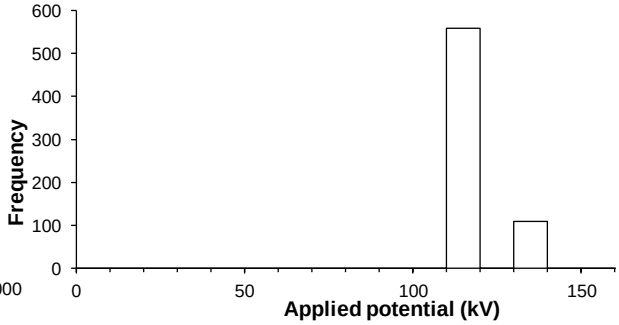
(c) Patient dimension: transverse



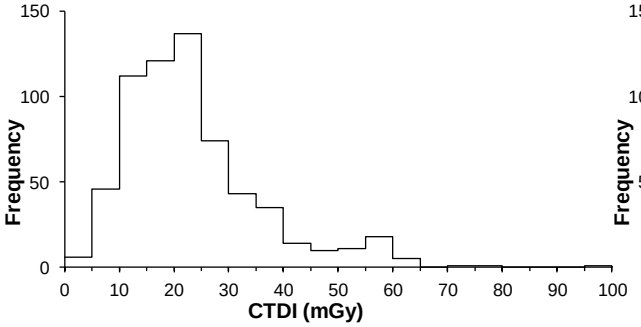
(d) Patient dimension: AP



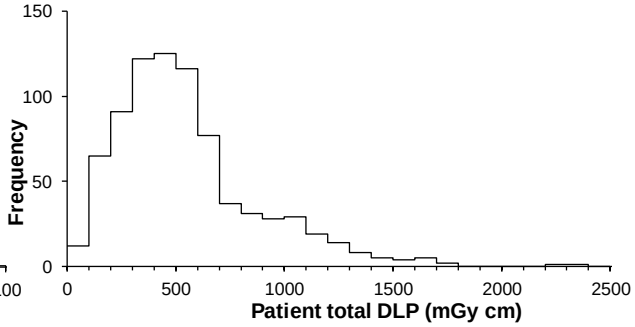
(e) Patient cross-sectional area



(f) Applied potential per individual sequence

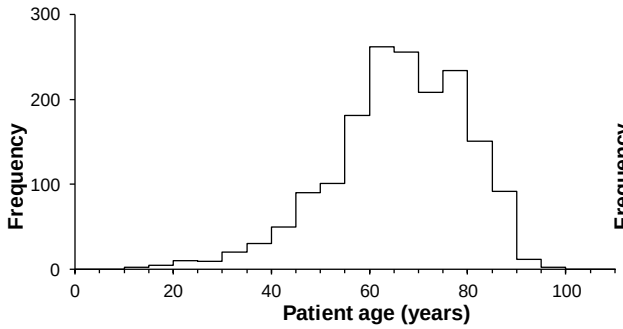


(g) $CTDI_{vol}$ per individual sequence

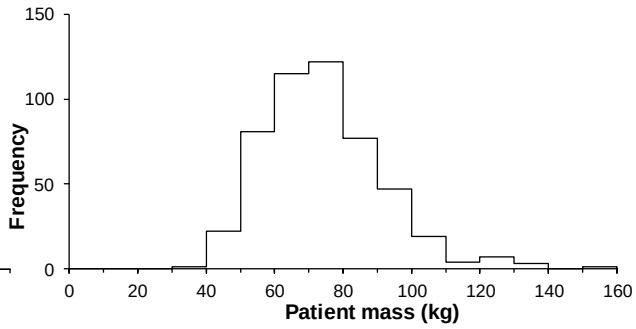


(h) Total DLP per patient

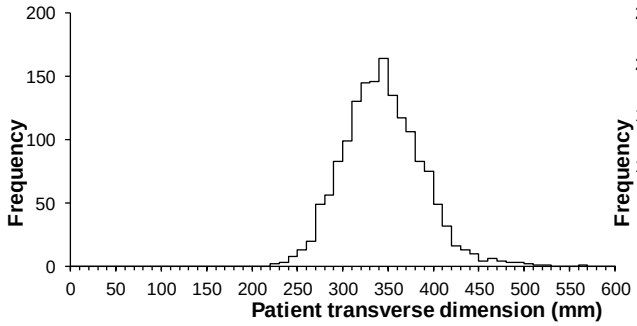
FIGURE D1.2 Cervical spine (fracture): distributions over individual patients (or sequences)



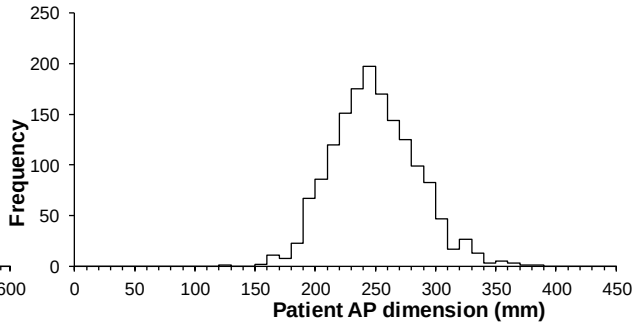
(a) Patient age



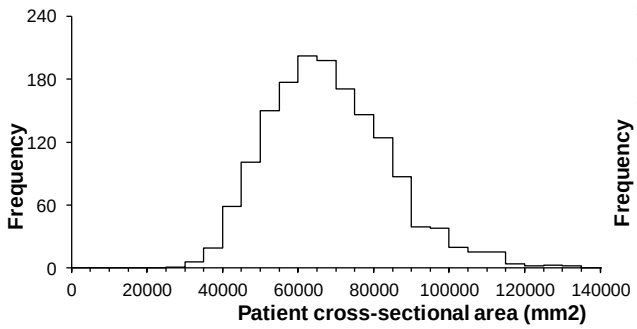
(b) Patient mass



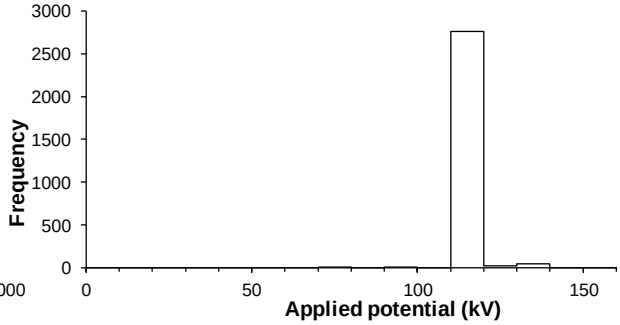
(c) Patient dimension: transverse



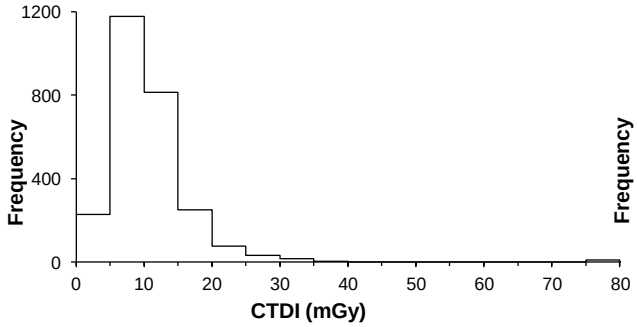
(d) Patient dimension: AP



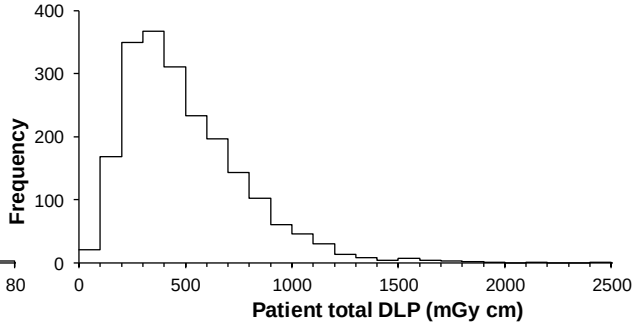
(e) Patient cross-sectional area



(f) Applied potential per individual sequence

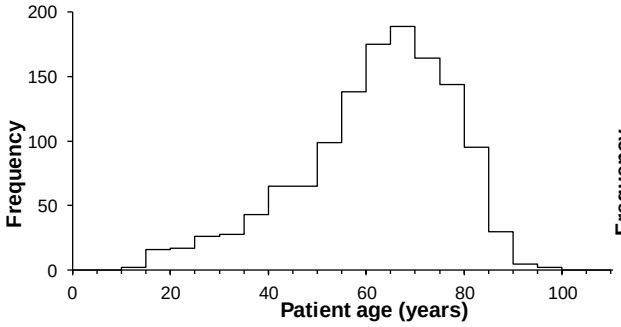


(g) $CTDI_{vol}$ per individual sequence

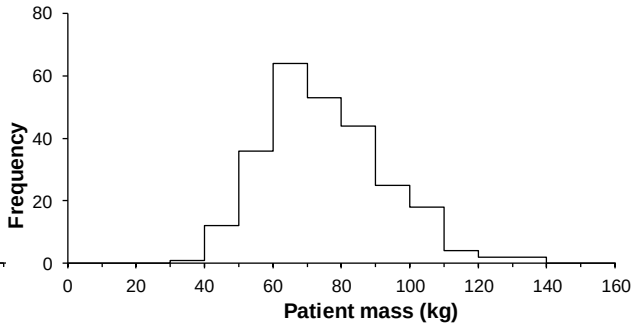


(h) Total DLP per patient

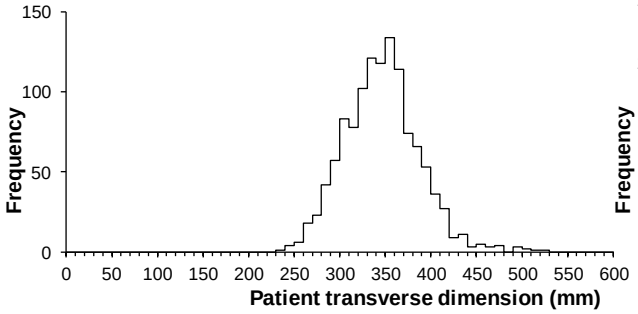
FIGURE D1.3 Chest (lung cancer): distributions over individual patients (or sequences)



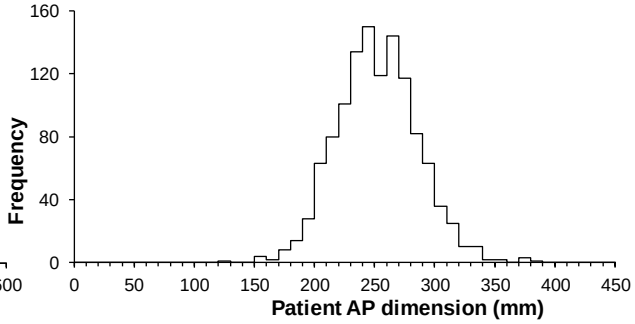
(a) Patient age



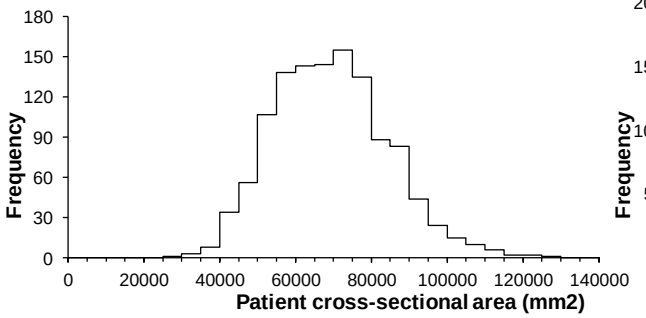
(b) Patient mass



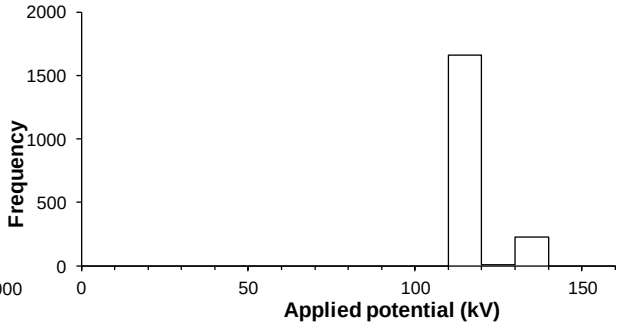
(c) Patient dimension: transverse



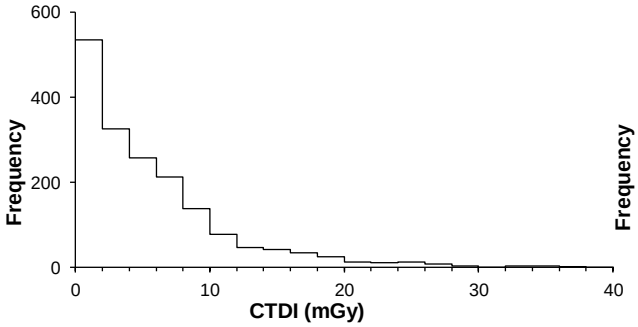
(d) Patient dimension: AP



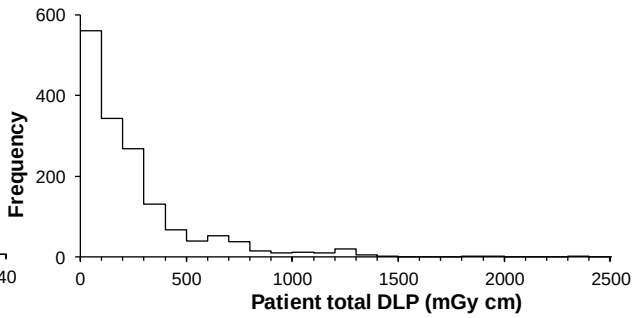
(e) Patient cross-sectional area



(f) Applied potential per individual sequence

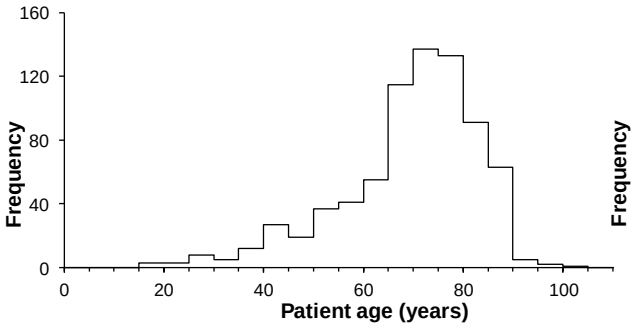


(g) $CTDI_{vol}$ per individual sequence

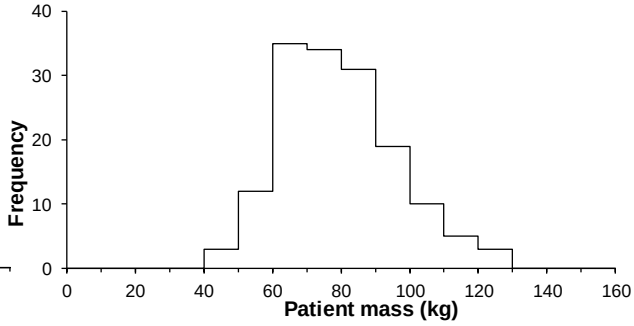


(h) Total DLP per patient

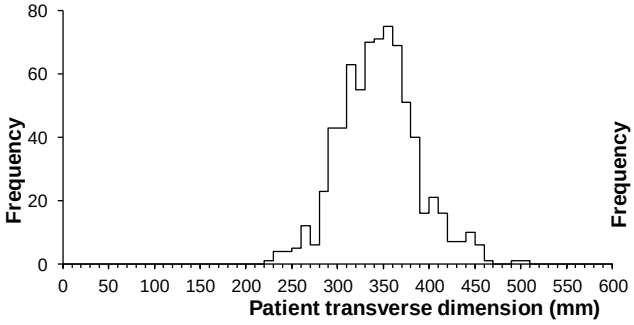
FIGURE D1.4 Chest – high resolution (interstitial lung disease): distributions over individual patients (or sequences)



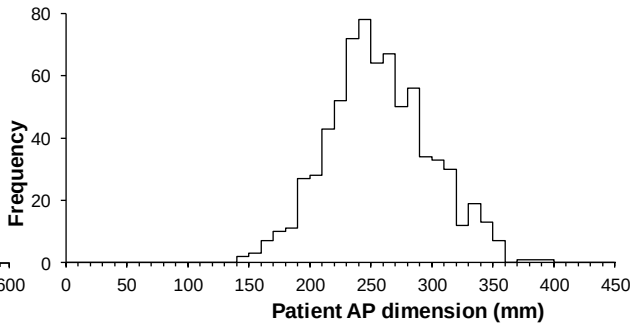
(a) Patient age



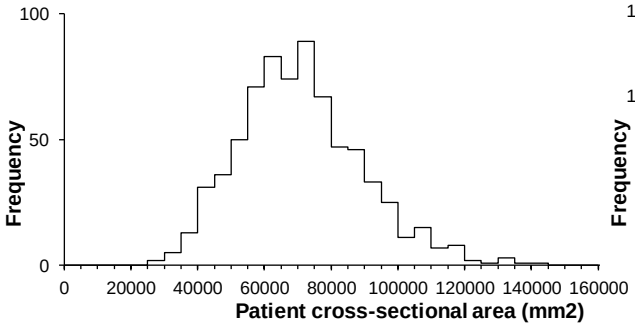
(b) Patient mass



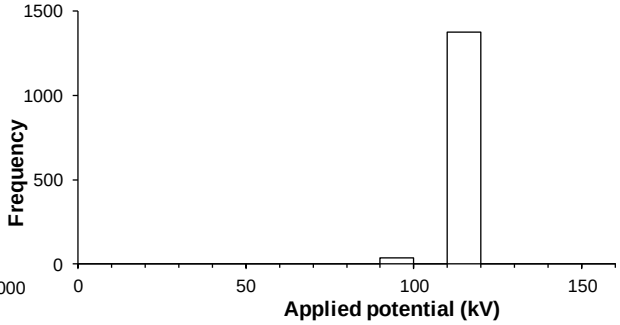
(c) Patient dimension: transverse



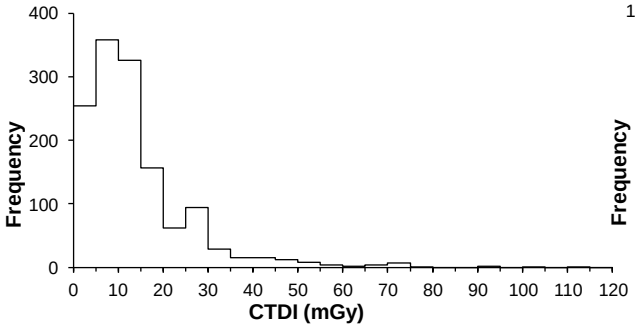
(d) Patient dimension: AP



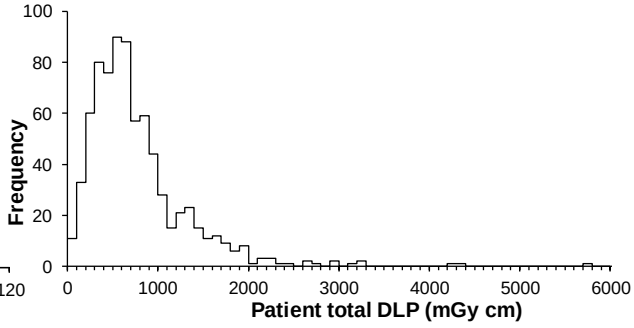
(e) Patient cross-sectional area



(f) Applied potential per individual sequence

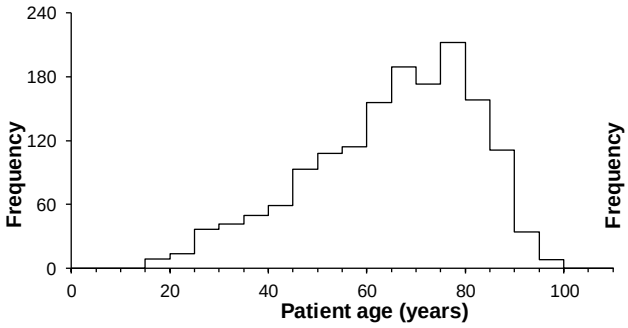


(g) $CTDI_{vol}$ per individual sequence

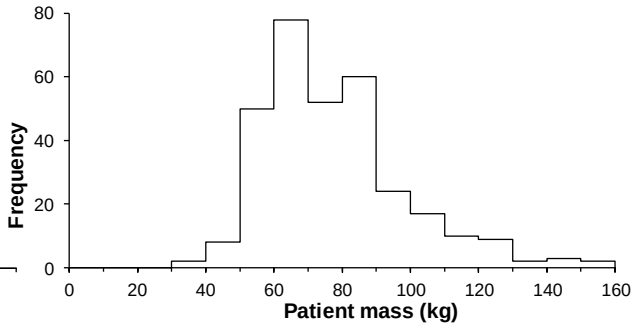


(h) Total DLP per patient

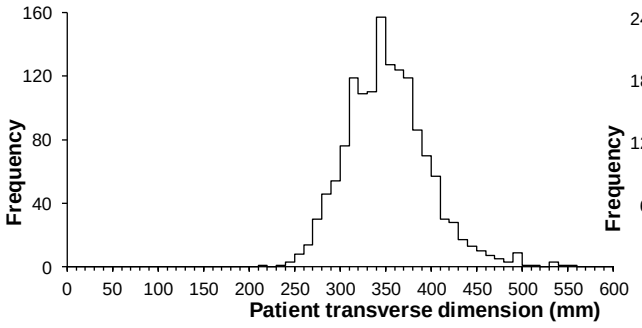
FIGURE D1.5 CT angiography (CTA) (blood vessels): distributions over individual patients (or sequences)



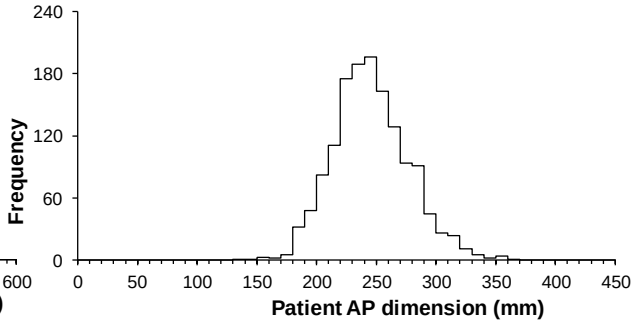
(a) Patient age



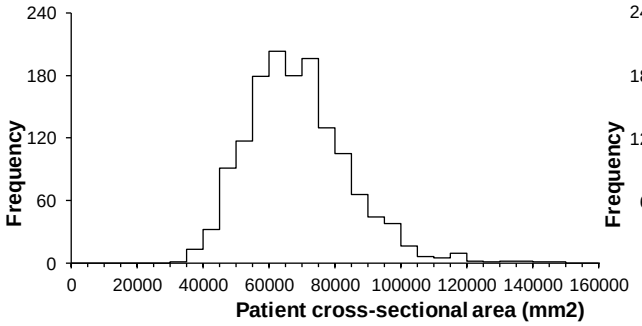
(b) Patient mass



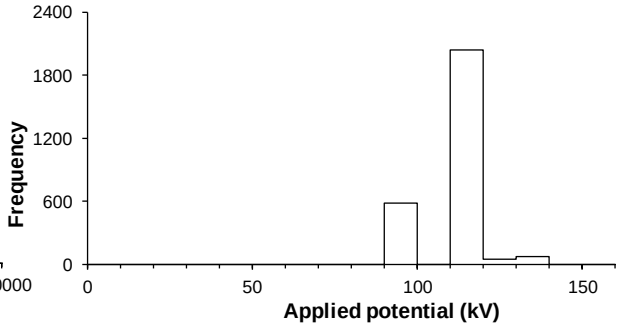
(c) Patient dimension: transverse



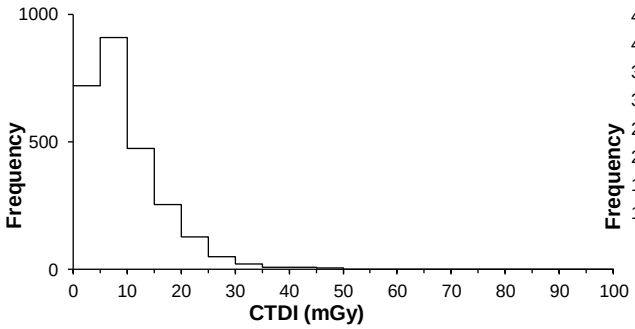
(d) Patient dimension: AP



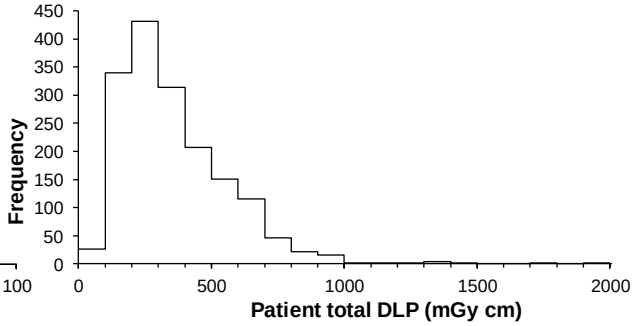
(e) Patient cross-sectional area



(f) Applied potential per individual sequence

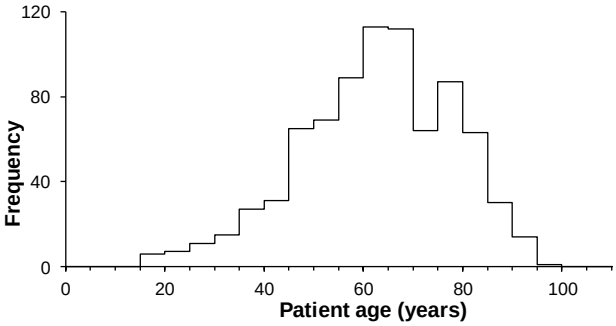


(g) $CTDI_{vol}$ per individual sequence

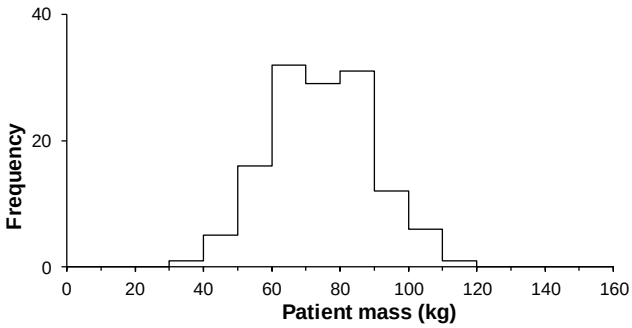


(h) Total DLP per patient

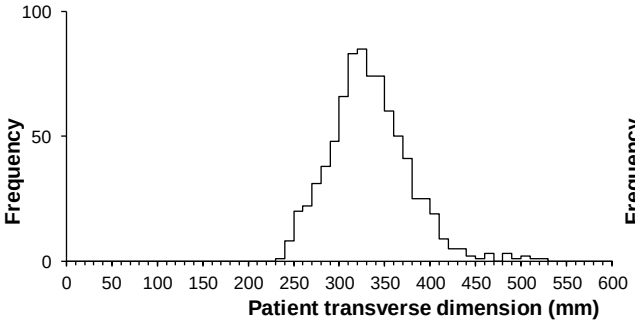
FIGURE D1.6 CT pulmonary angiography (CTPA) (pulmonary embolism): distributions over individual patients (or sequences)



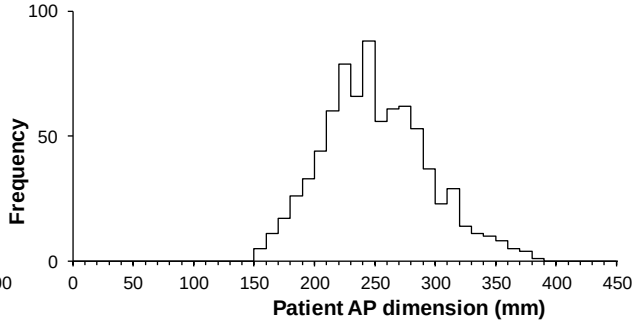
(a) Patient age



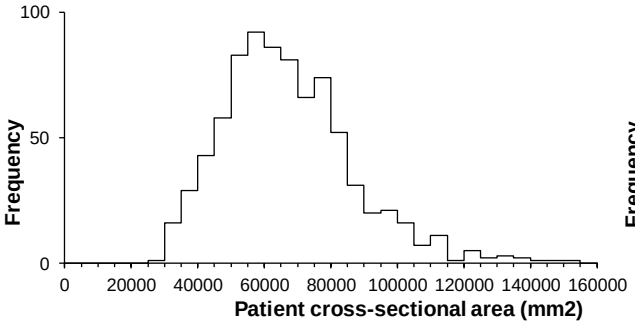
(b) Patient mass



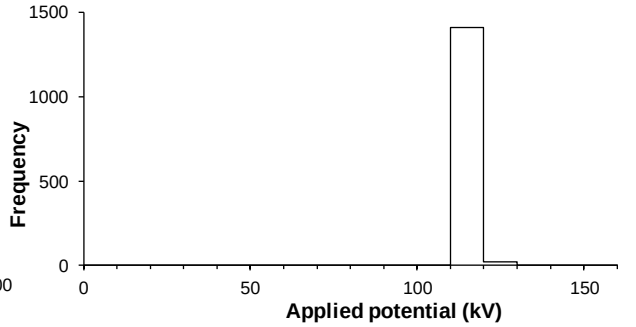
(c) Patient dimension: transverse



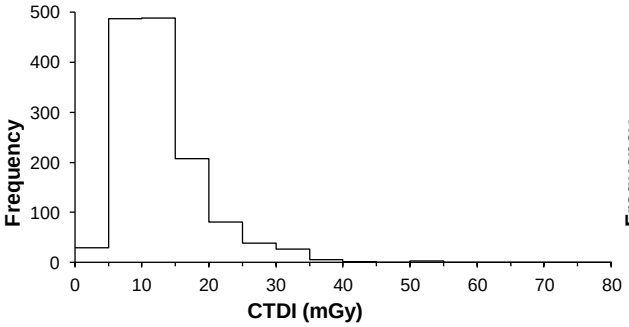
(d) Patient dimension: AP



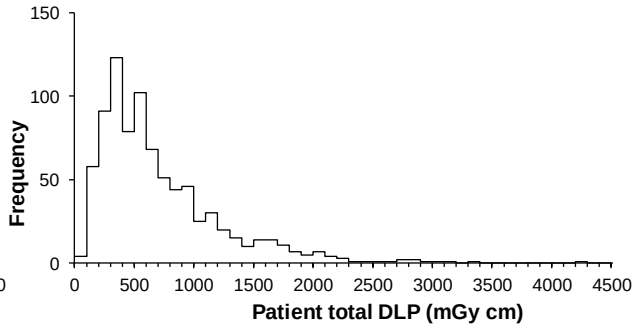
(e) Patient cross-sectional area



(f) Applied potential per individual sequence

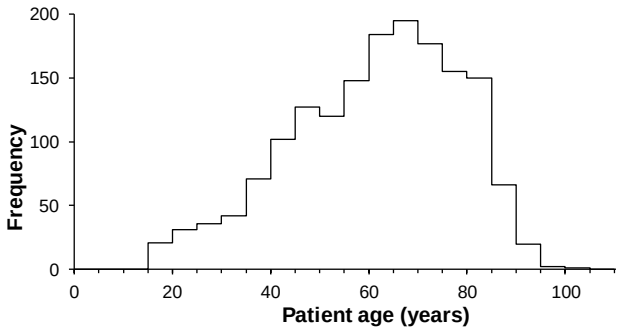


(g) $CTDI_{vol}$ per individual sequence

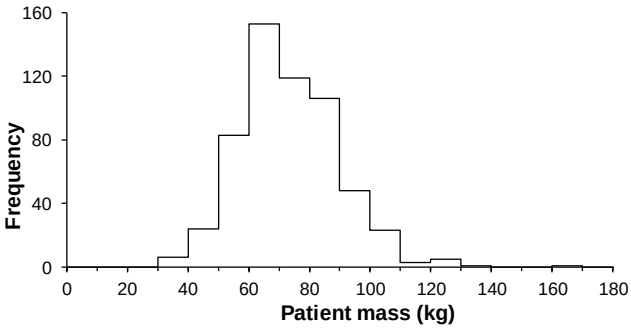


(h) Total DLP per patient

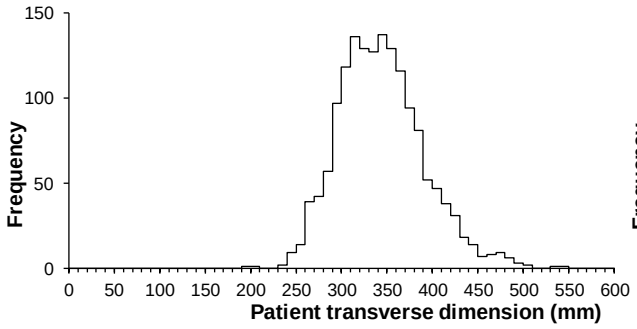
FIGURE D1.7 Abdomen (liver metastases): distributions over individual patients (or sequences)



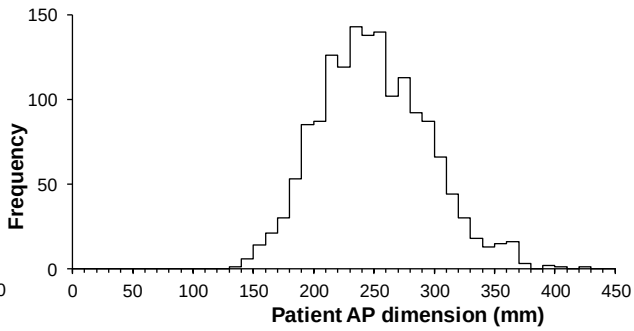
(a) Patient age



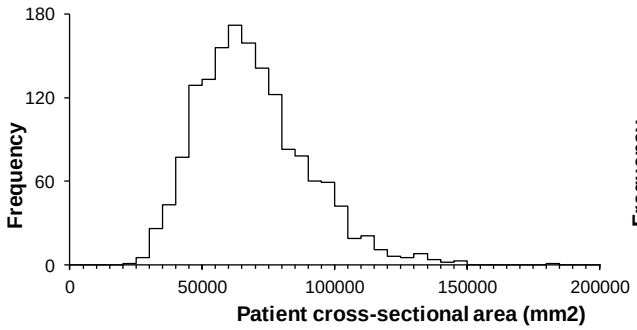
(b) Patient mass



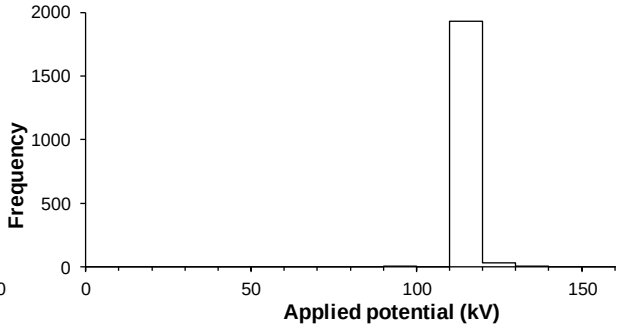
(c) Patient dimension: transverse



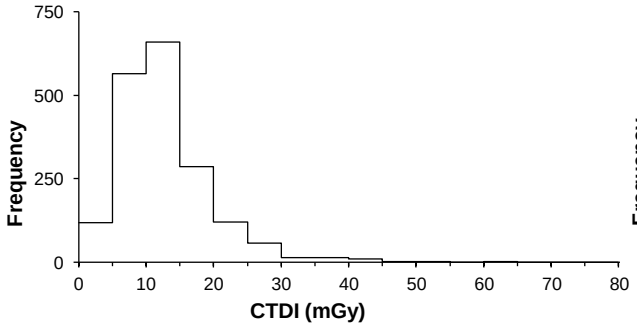
(d) Patient dimension: AP



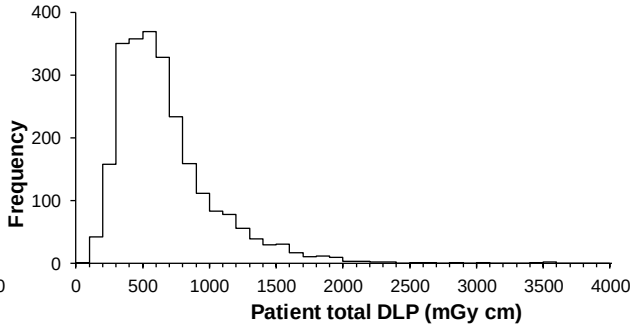
(e) Patient cross-sectional area



(f) Applied potential per individual sequence

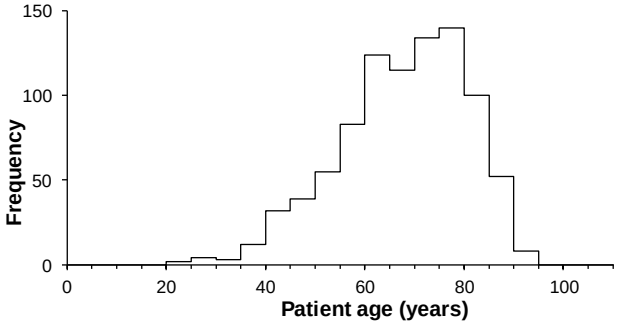


(g) $CTDI_{vol}$ per individual sequence

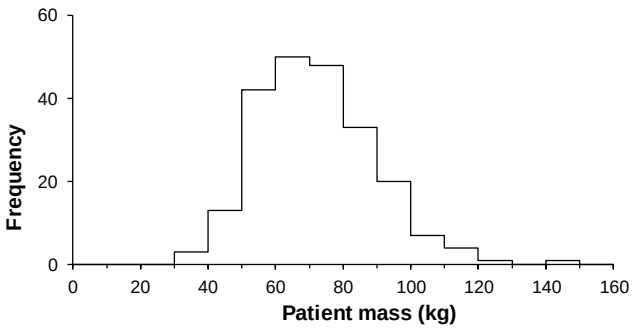


(h) Total DLP per patient

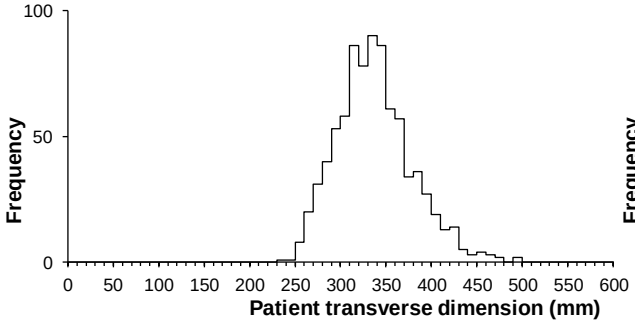
FIGURE D1.8 Abdomen and pelvis (abscess): distributions over individual patients (or sequences)



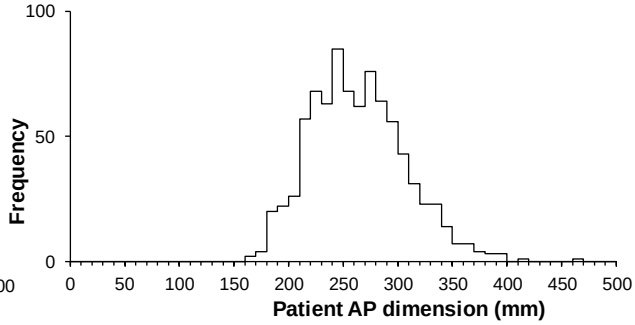
(a) Patient age



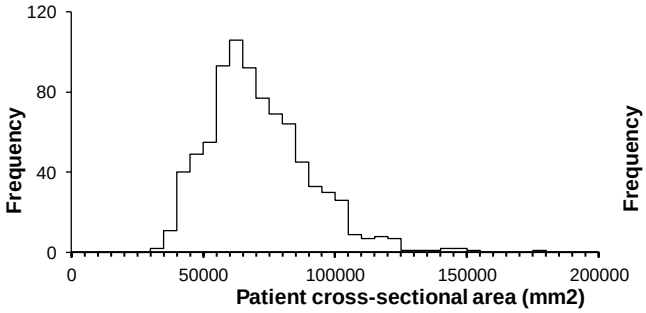
(b) Patient mass



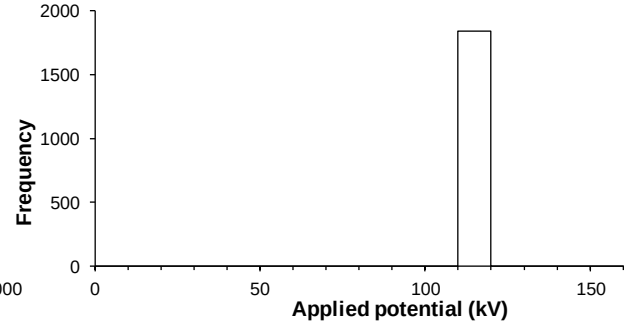
(c) Patient dimension: transverse



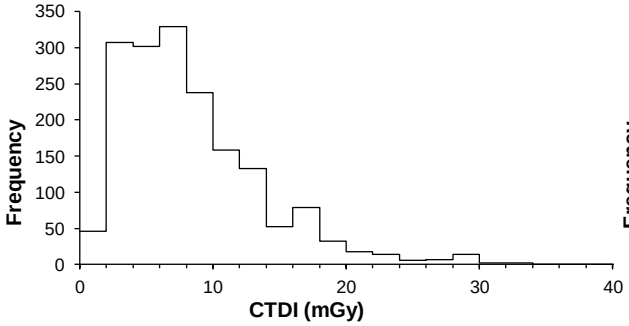
(d) Patient dimension: AP



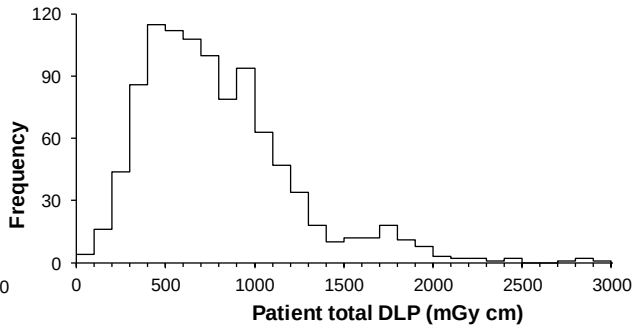
(e) Patient cross-sectional area



(f) Applied potential per individual sequence

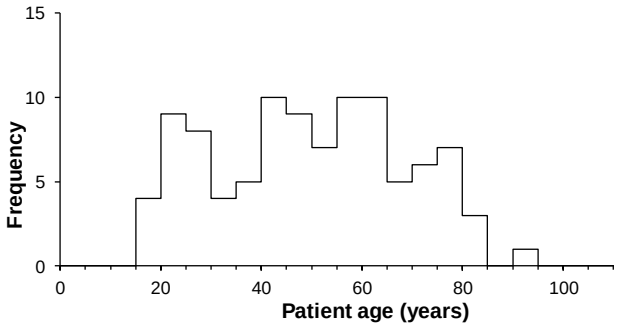


(g) $CTDI_{vol}$ per individual sequence

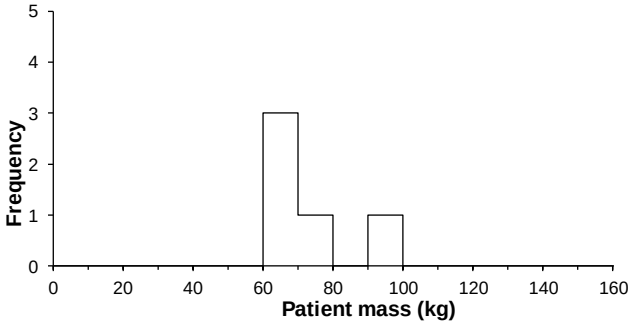


(h) Total DLP per patient

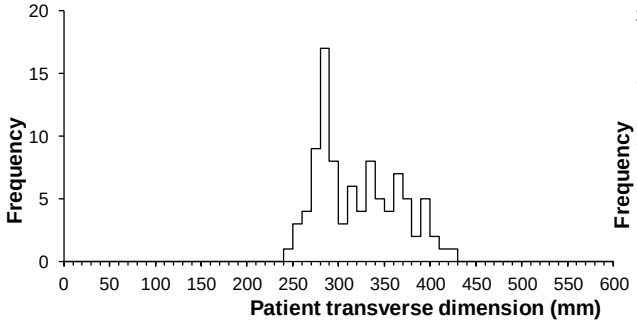
FIGURE D1.9 Virtual colonoscopy (polyps/tumour): distributions over individual patients (or sequences)



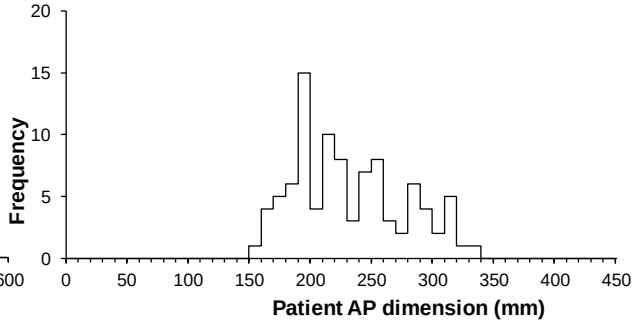
(a) Patient age



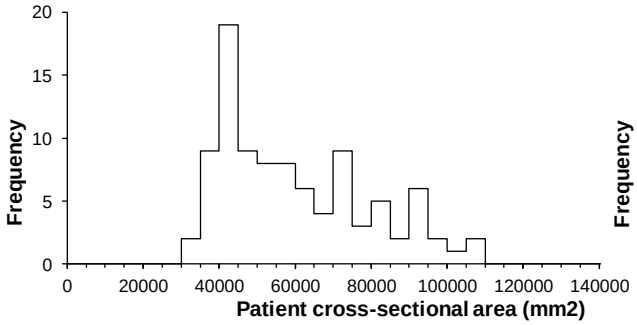
(b) Patient mass



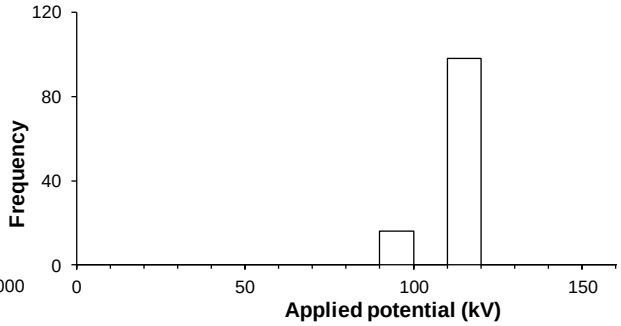
(c) Patient dimension: transverse



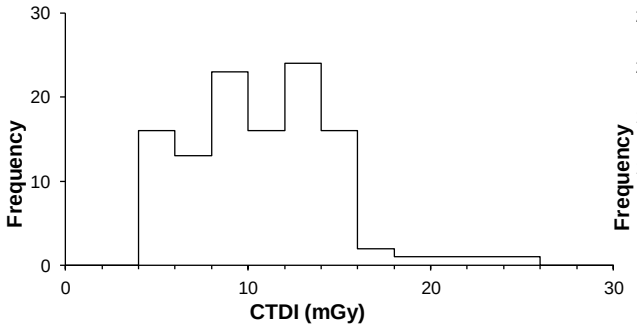
(d) Patient dimension: AP



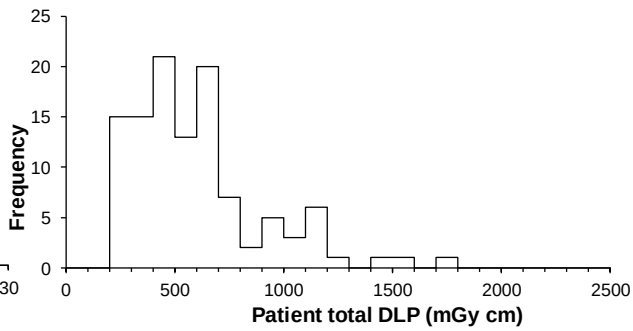
(e) Patient cross-sectional area



(f) Applied potential per individual sequence

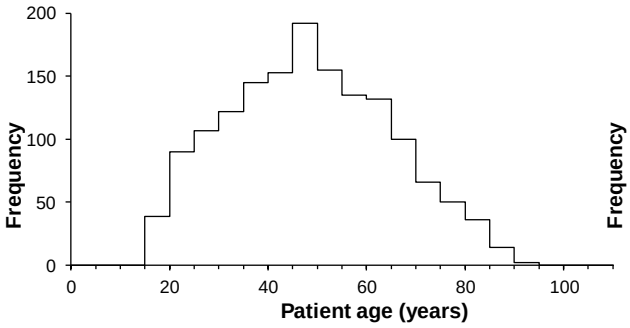


(g) $CTDI_{vol}$ per individual sequence

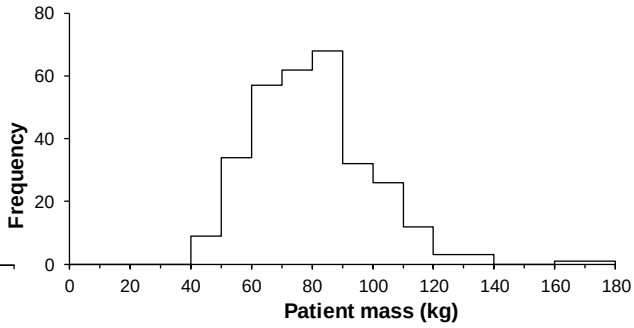


(h) Total DLP per patient

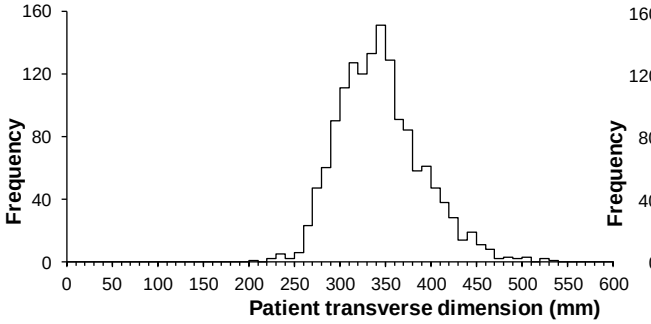
FIGURE D1.10 Enteroclysis (Crohn's disease): distributions over individual patients (or sequences)



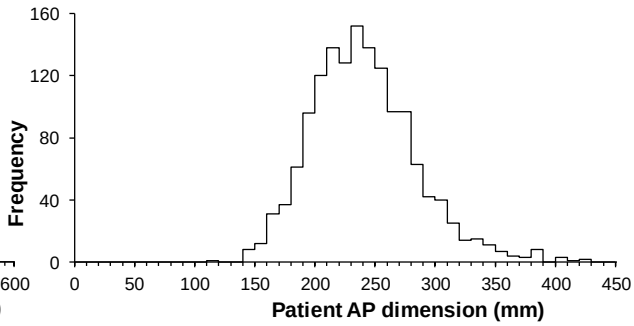
(a) Patient age



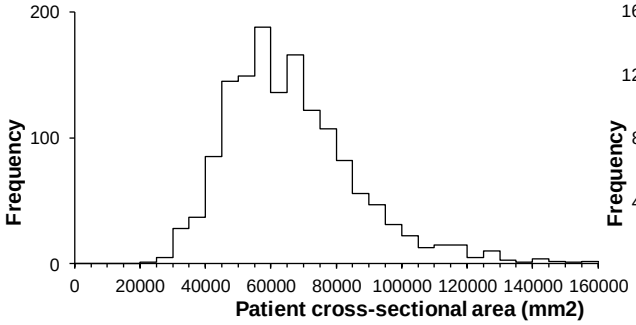
(b) Patient mass



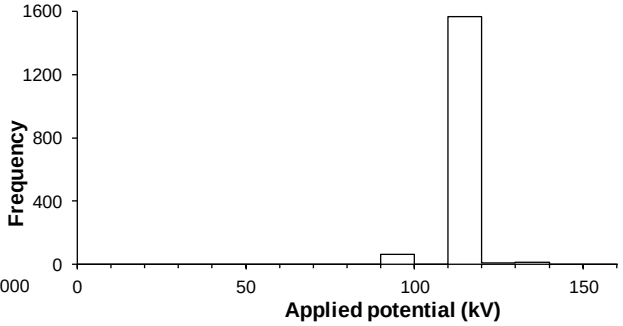
(c) Patient dimension: transverse



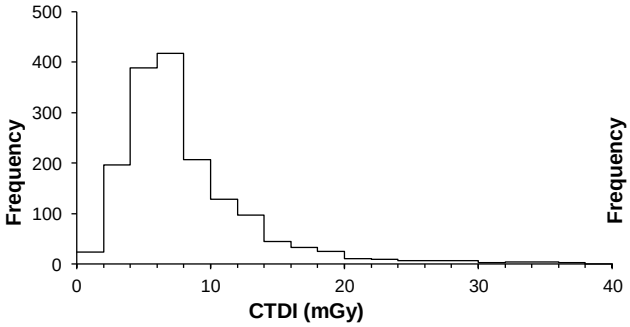
(d) Patient dimension: AP



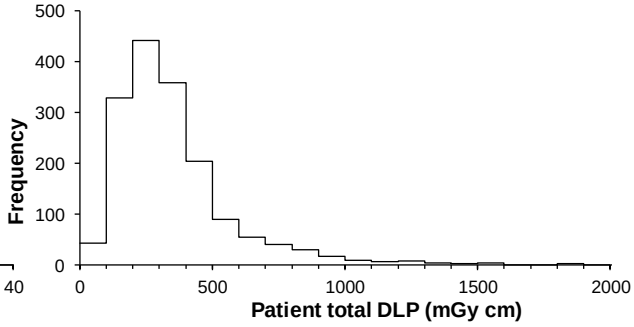
(e) Patient cross-sectional area



(f) Applied potential per individual sequence

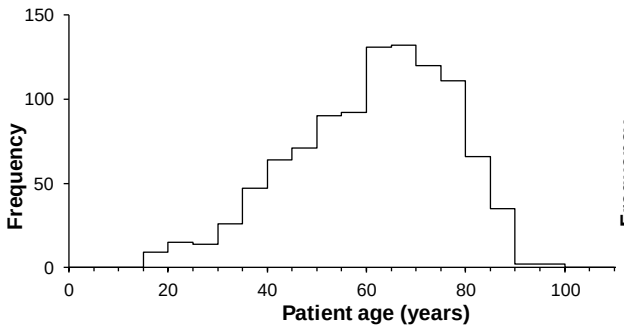


(g) $CTDI_{vol}$ per individual sequence

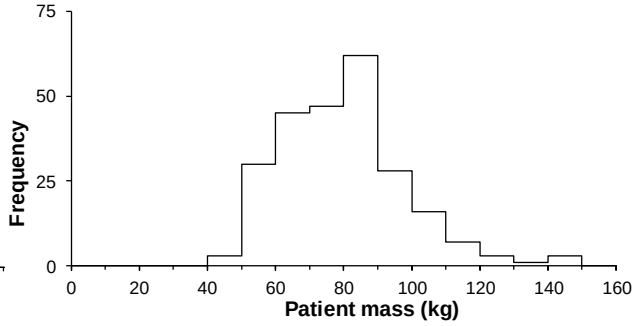


(h) Total DLP per patient

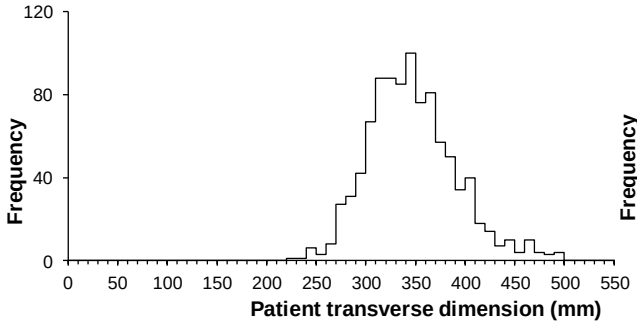
FIGURE D1.11 Kidney-ureters-bladder (KUB) (stones/colic): distributions over individual patients (or sequences)



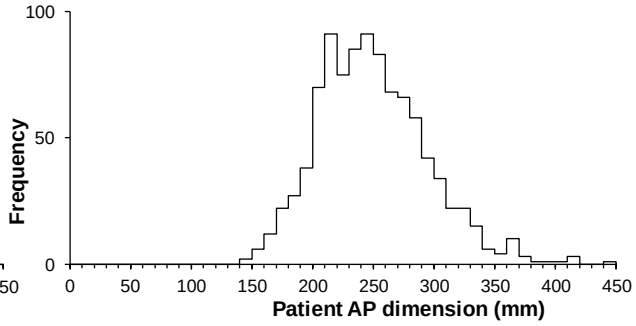
(a) Patient age



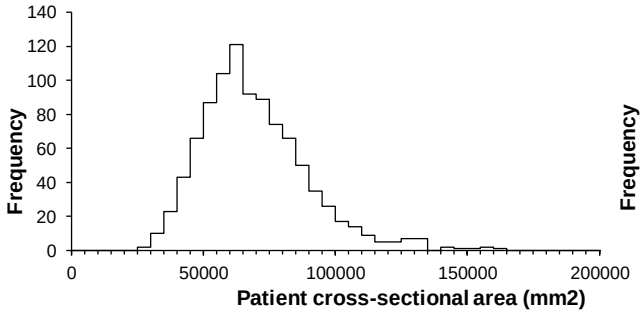
(b) Patient mass



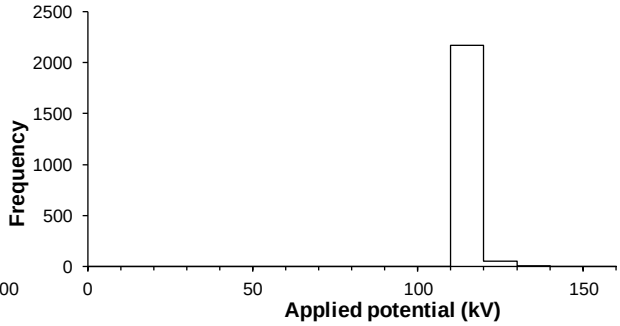
(c) Patient dimension: transverse



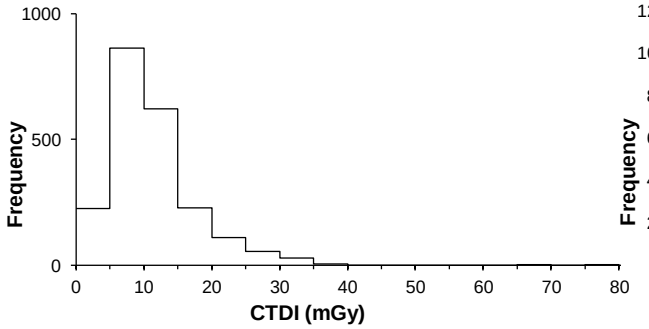
(d) Patient dimension: AP



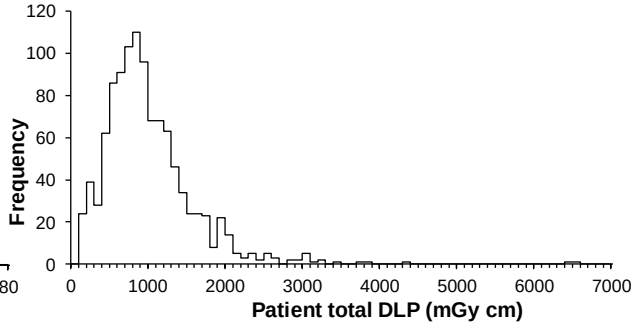
(e) Patient cross-sectional area



(f) Applied potential per individual sequence

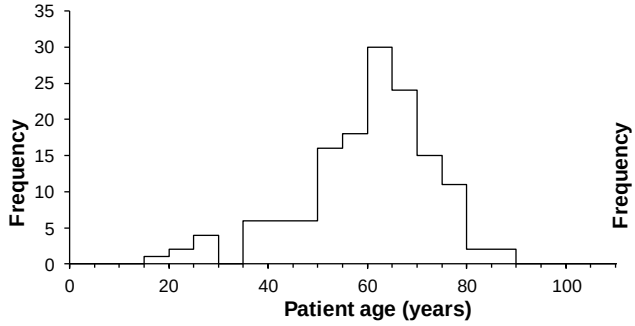


(g) $CTDI_{vol}$ per individual sequence

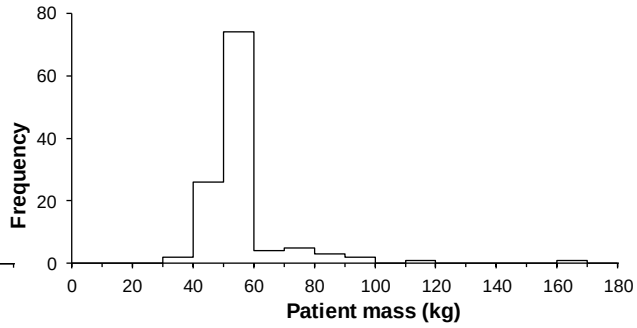


(h) Total DLP per patient

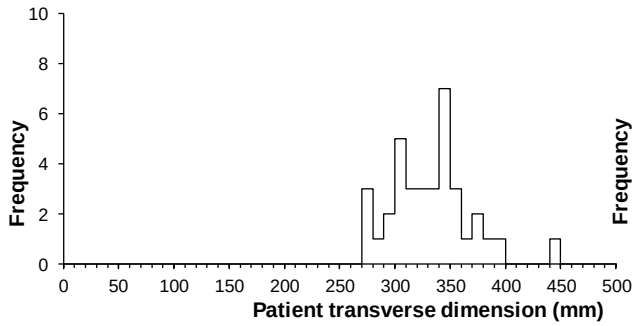
FIGURE D1.12 Urogram (stones/colic or tumour): distributions over individual patients (or sequences)



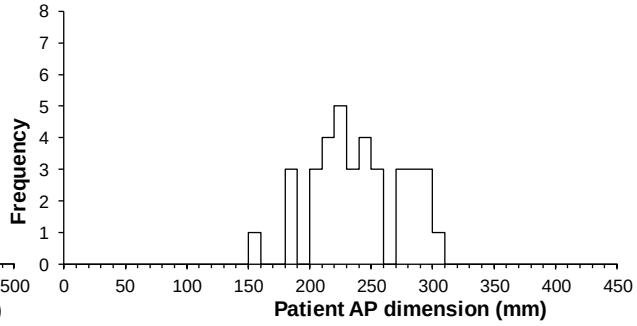
(a) Patient age



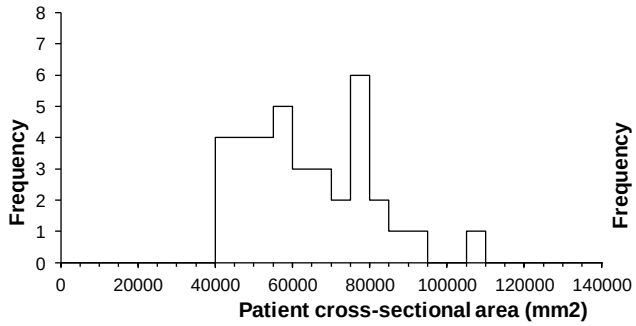
(b) Patient mass



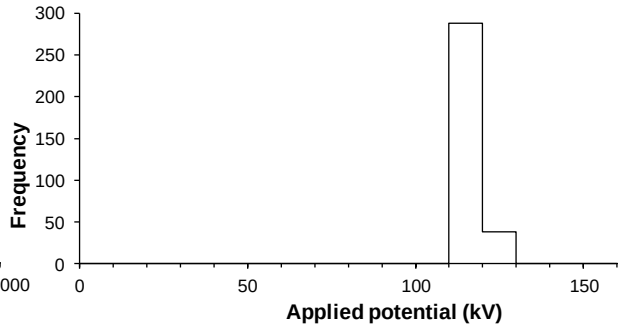
(c) Patient dimension: transverse



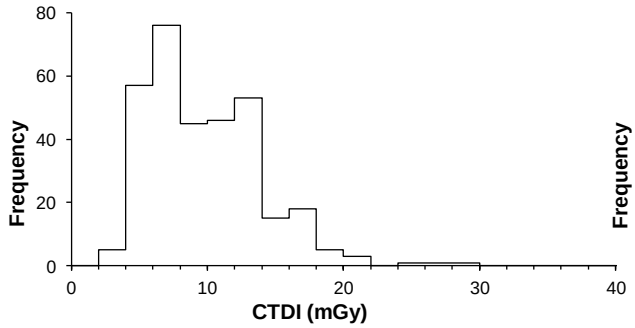
(d) Patient dimension: AP



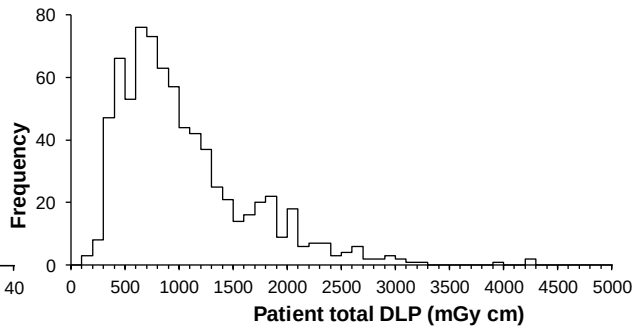
(e) Patient cross-sectional area



(f) Applied potential per individual sequence

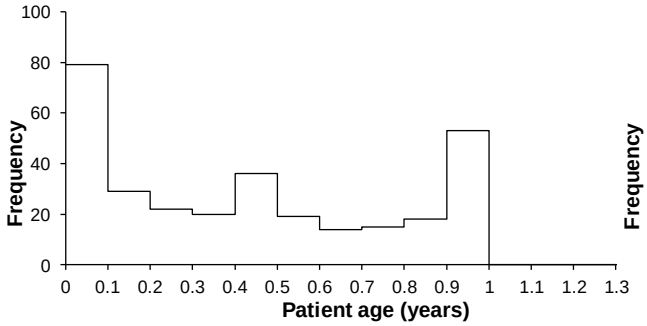


(g) $CTDI_{vol}$ per individual sequence

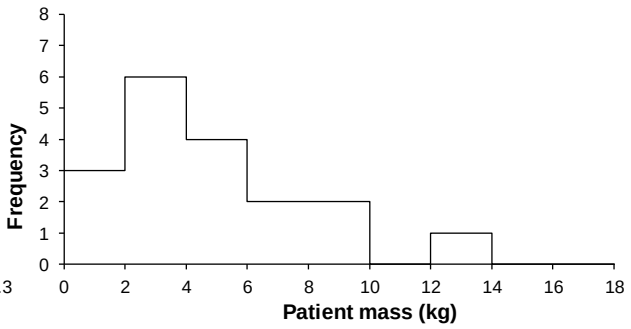


(h) Total DLP per patient

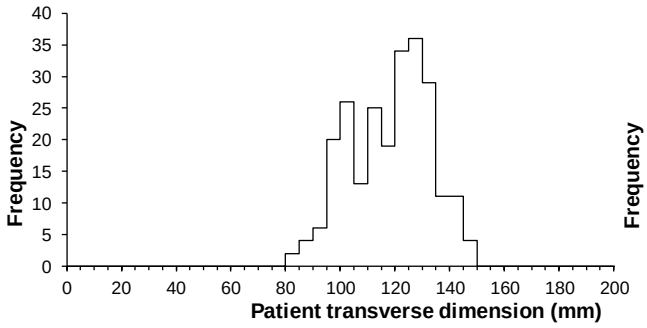
FIGURE D1.13 Chest-abdomen-pelvis (CAP) (cancer): distributions over individual patients (or sequences)



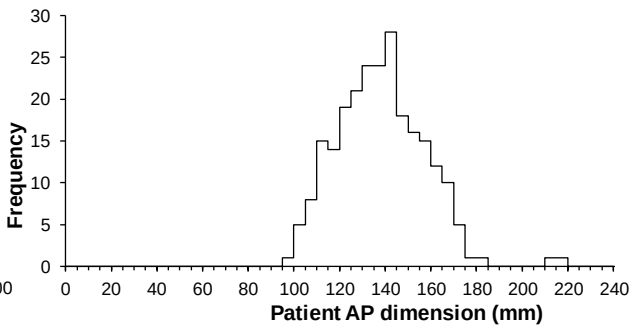
(a) Patient age



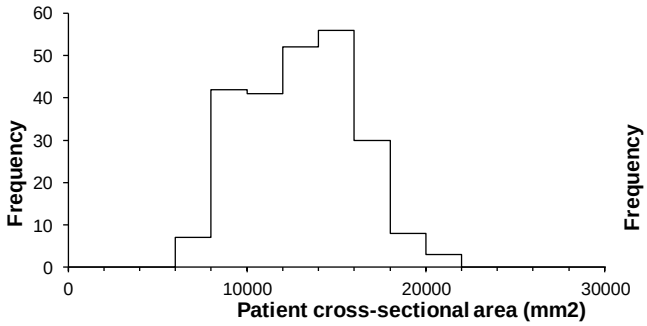
(b) Patient mass



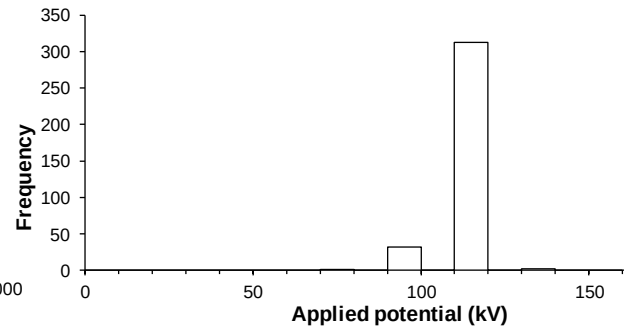
(c) Patient dimension: transverse



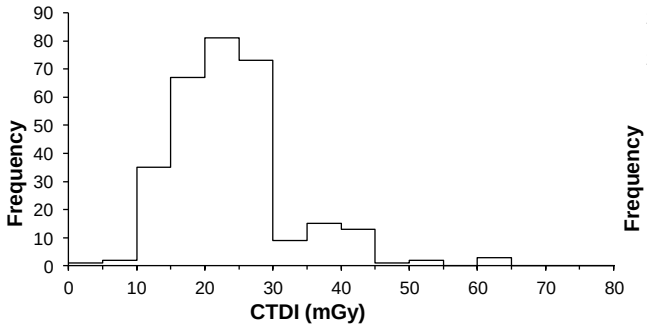
(d) Patient dimension: AP



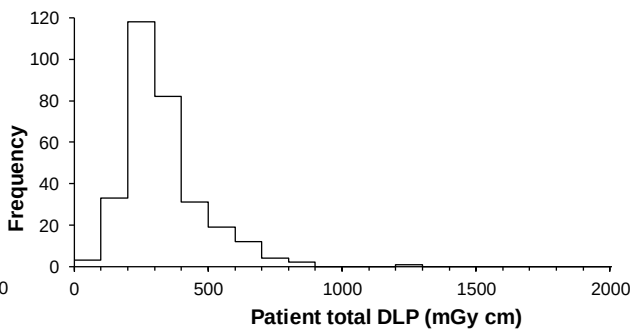
(e) Patient cross-sectional area



(f) Applied potential per individual sequence

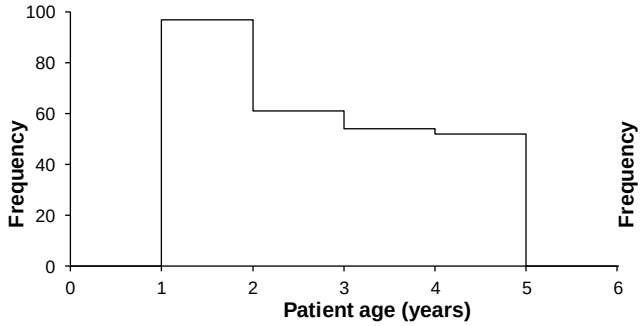


(g) $CTDI_{vol}$ per individual sequence

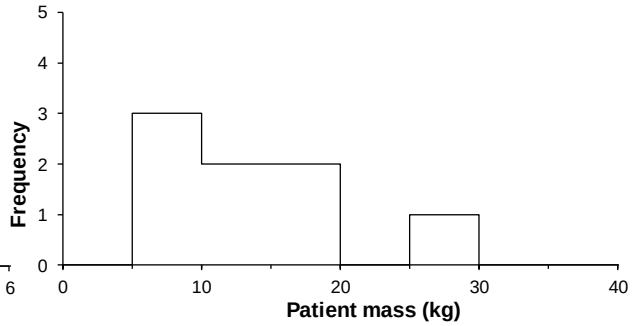


(h) Total DLP per patient

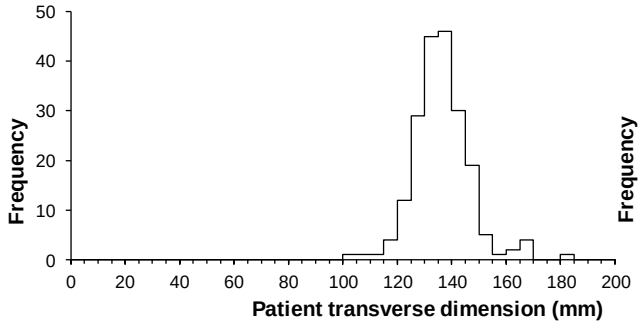
FIGURE D1.14 Paediatric head – age 0–1 y (trauma): distributions over individual patients (or sequences)



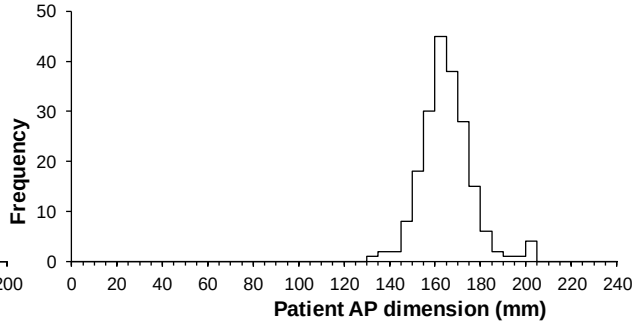
(a) Patient age



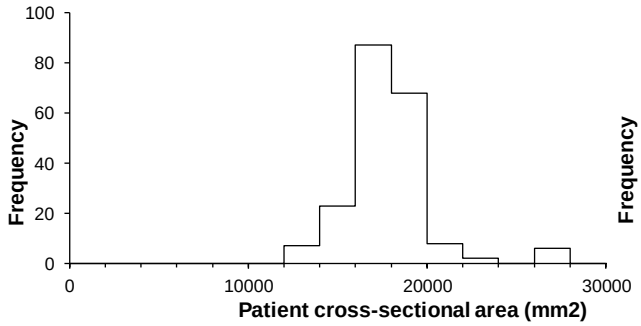
(b) Patient mass



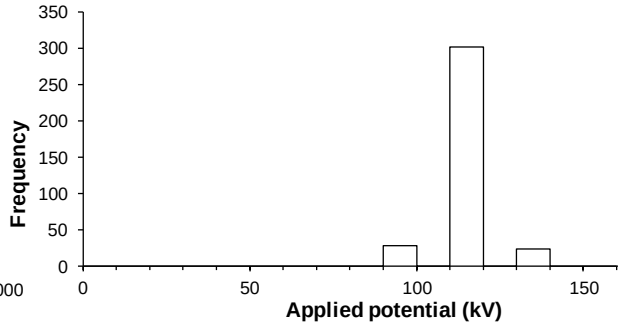
(c) Patient dimension: transverse



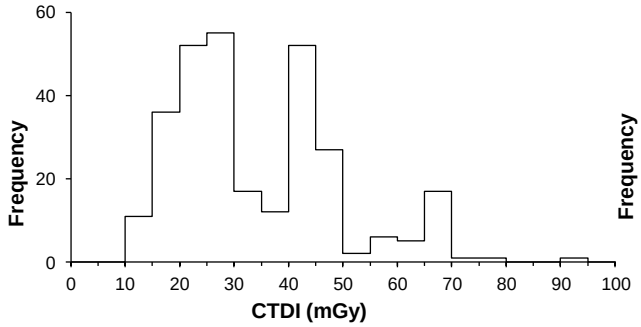
(d) Patient dimension: AP



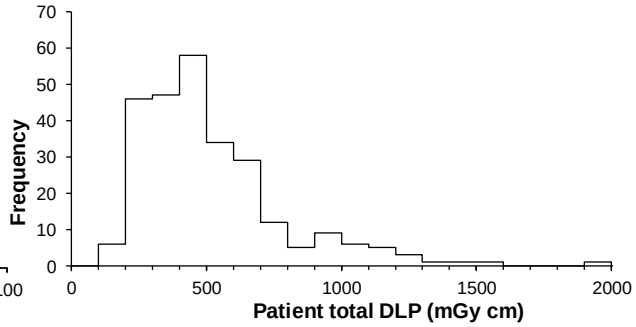
(e) Patient cross-sectional area



(f) Applied potential per individual sequence

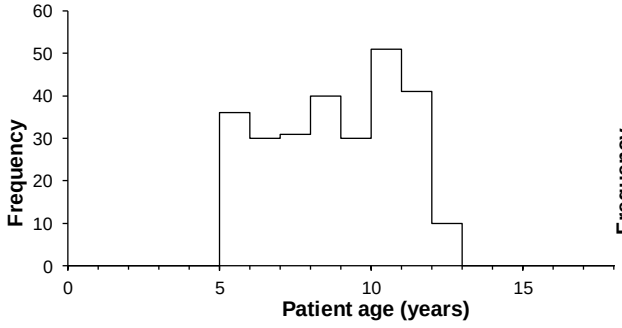


(g) $CTDI_{vol}$ per individual sequence

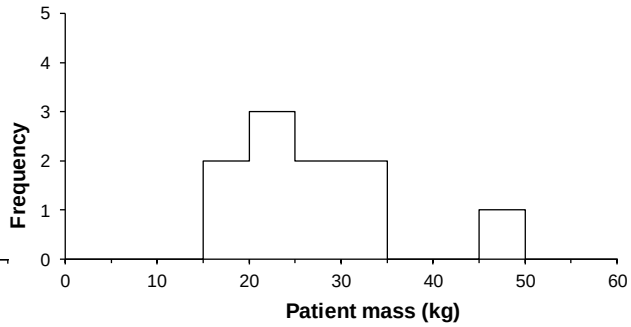


(h) Total DLP per patient

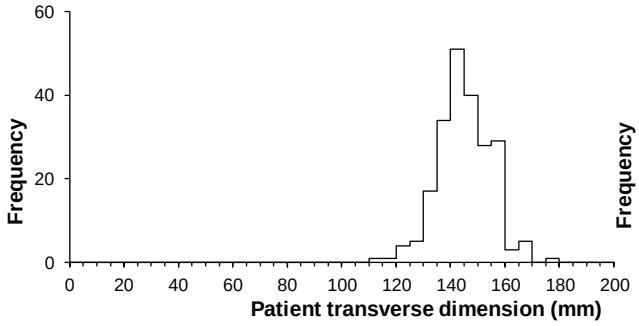
FIGURE D1.15 Paediatric head – age >1–5 y (trauma): distributions over individual patients (or sequences)



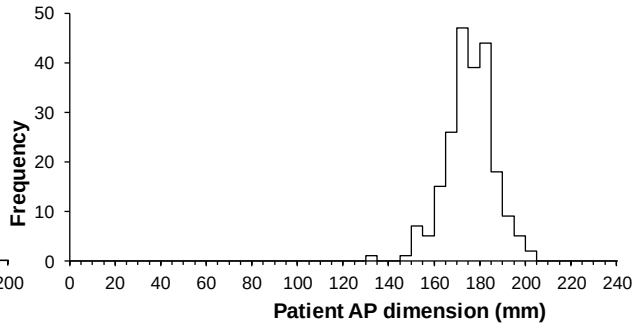
(a) Patient age



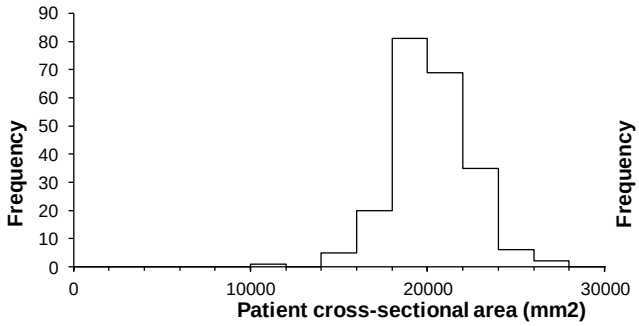
(b) Patient mass



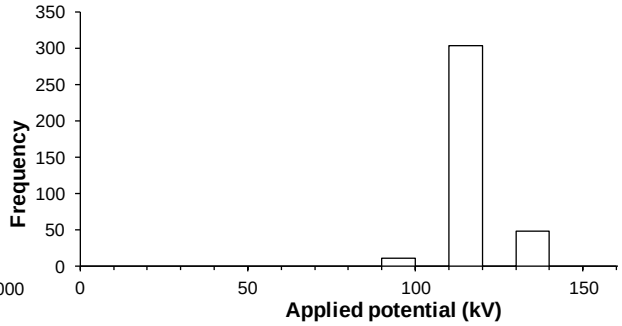
(c) Patient dimension: transverse



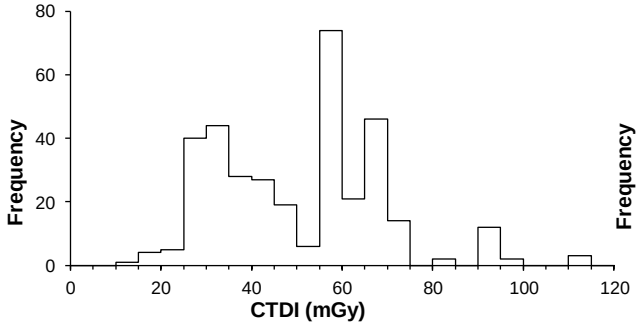
(d) Patient dimension: AP



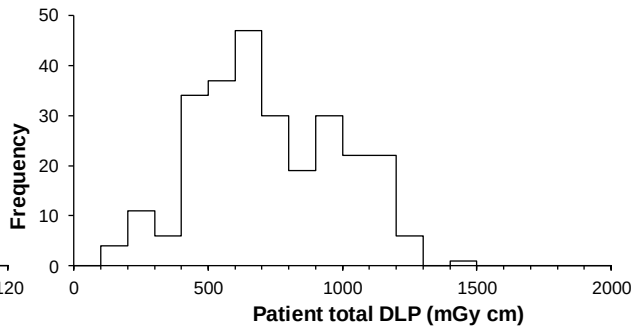
(e) Patient cross-sectional area



(f) Applied potential per individual sequence



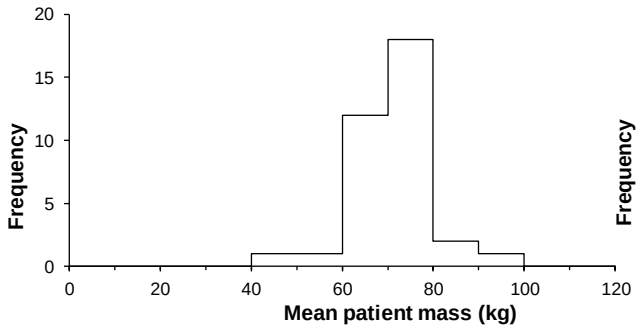
(g) $CTDI_{vol}$ per individual sequence



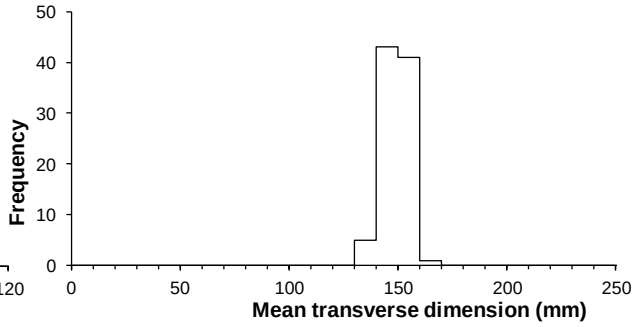
(h) Total DLP per patient

FIGURE D1.16 Paediatric head – age >5 y (trauma): distributions over individual patients (or sequences)

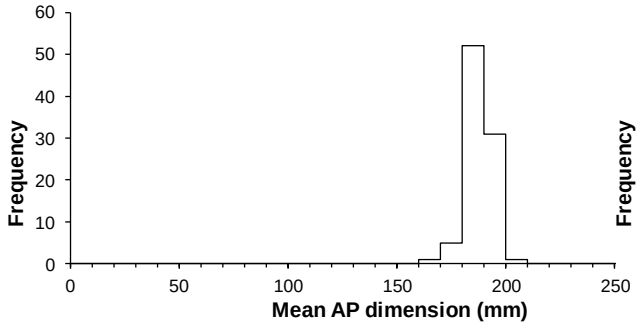
D2 Distributions over Mean Data (Sample Size *n* > 4) from Participating CT Centres by Examination Type



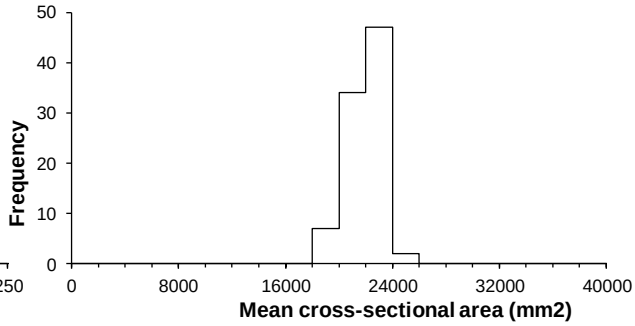
(a) Mean patient mass



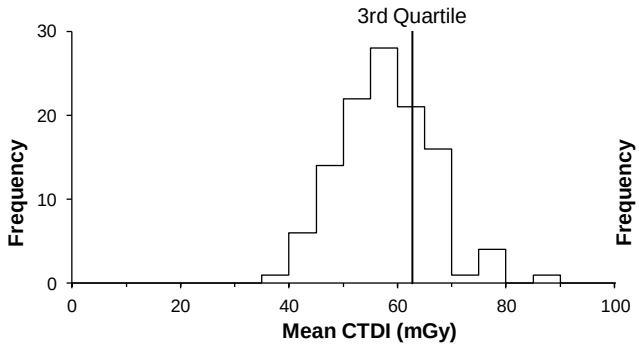
(b) Mean patient dimension: transverse



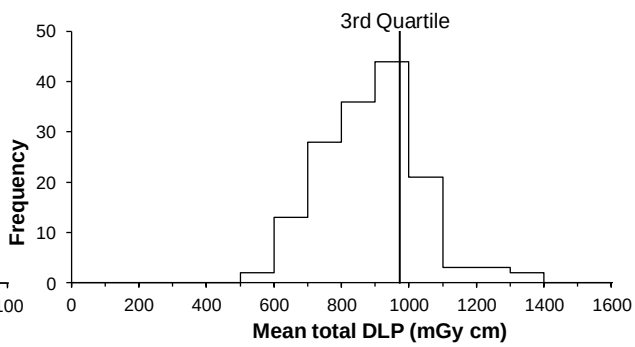
(c) Mean patient dimension: AP



(d) Mean patient cross-sectional area

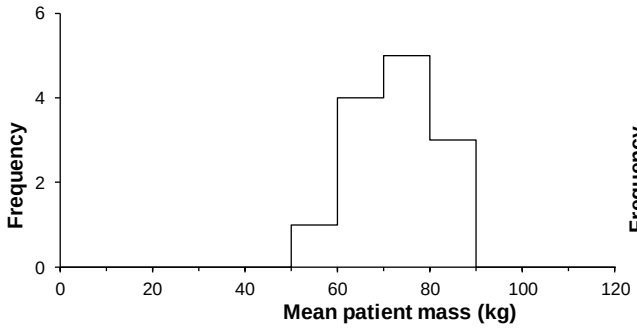


(e) Mean $CTDI_{vol}$ for patient sample

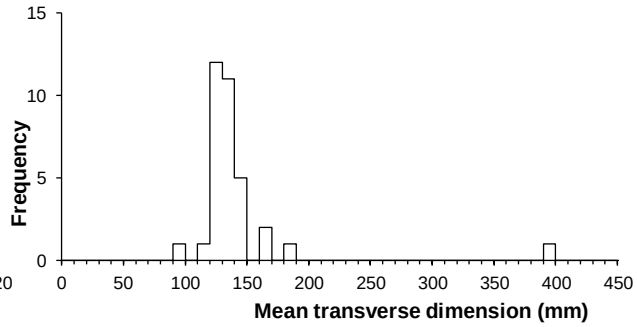


(f) Mean total DLP for patient sample

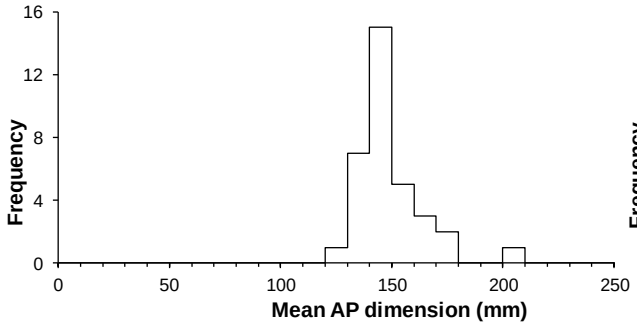
FIGURE D2.1 Head (stroke): distributions over mean data (*n* > 4) from participating CT centres



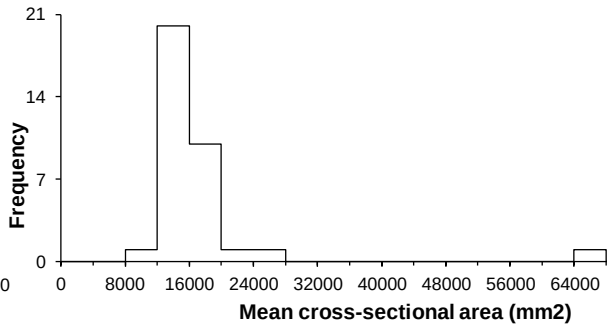
(a) Mean patient mass



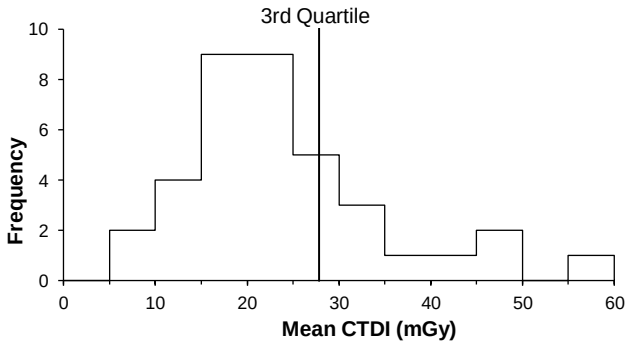
(b) Mean patient dimension: transverse



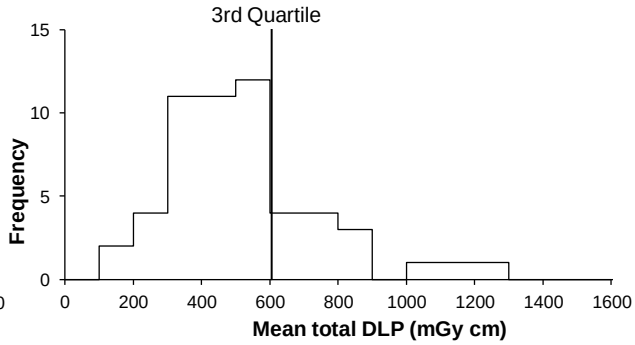
(c) Mean patient dimension: AP



(d) Mean patient cross-sectional area

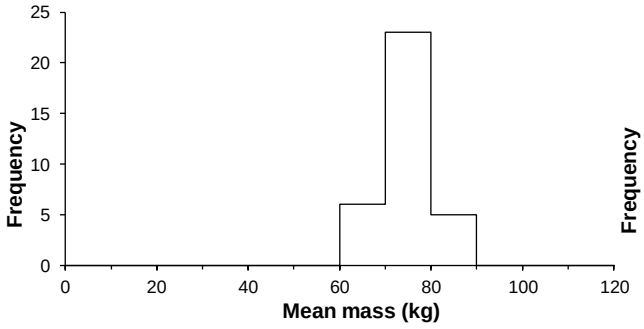


(e) Mean $CTDI_{vol}$ for patient sample

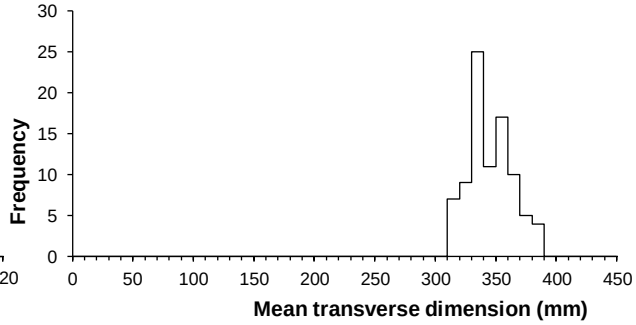


(f) Mean total DLP for patient sample

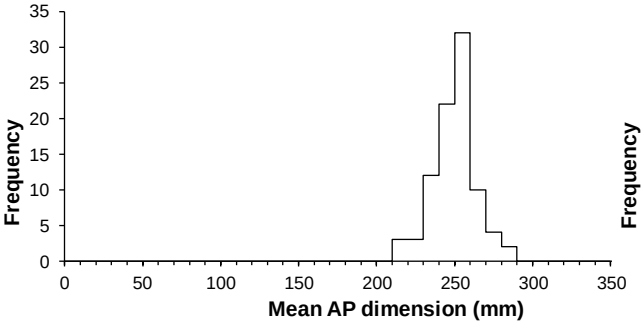
FIGURE D2.2 Cervical spine (fracture): distributions over mean data (n > 4) from participating CT centres



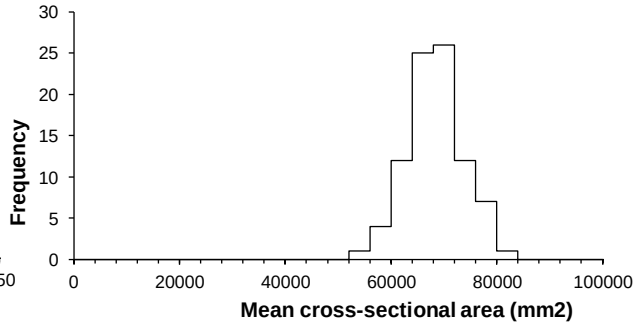
(a) Mean patient mass



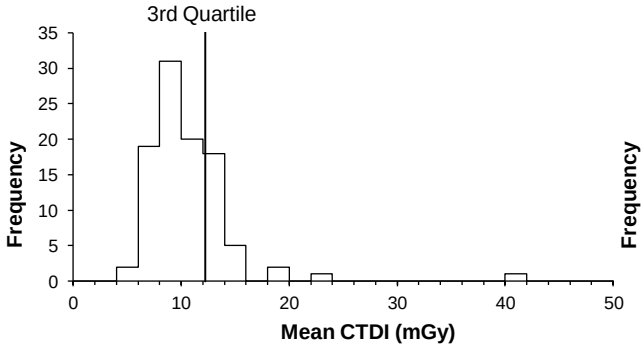
(b) Mean patient dimension: transverse



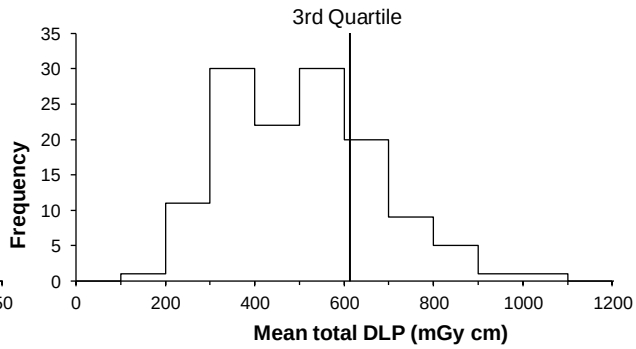
(c) Mean patient dimension: AP



(d) Mean patient cross-sectional area

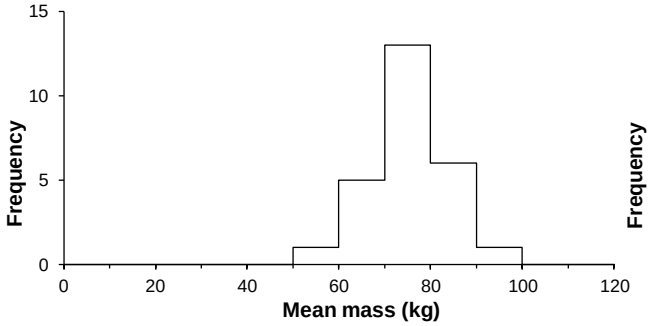


(e) Mean $CTDI_{vol}$ for patient sample

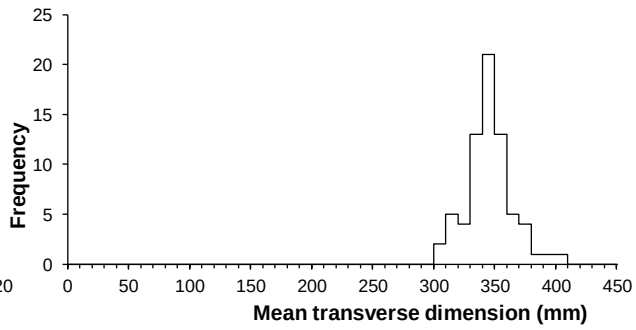


(f) Mean total DLP for patient sample

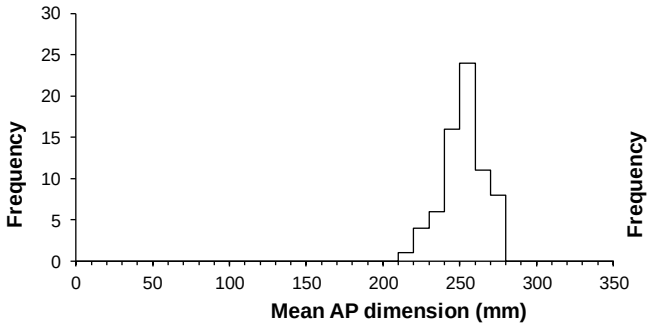
FIGURE D2.3 Chest (lung cancer): distributions over mean data (*n* > 4) from participating CT centres



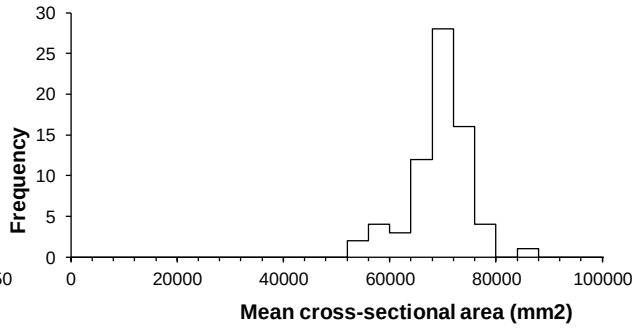
(a) Mean patient mass



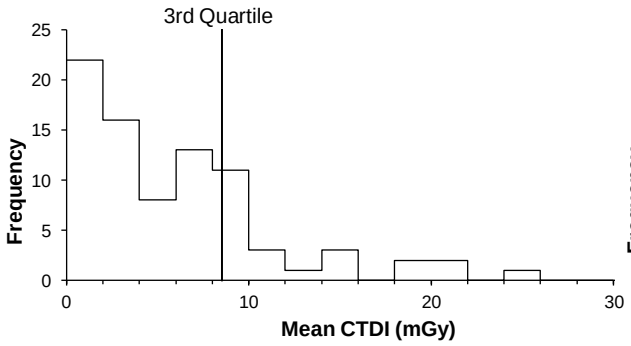
(b) Mean patient dimension: transverse



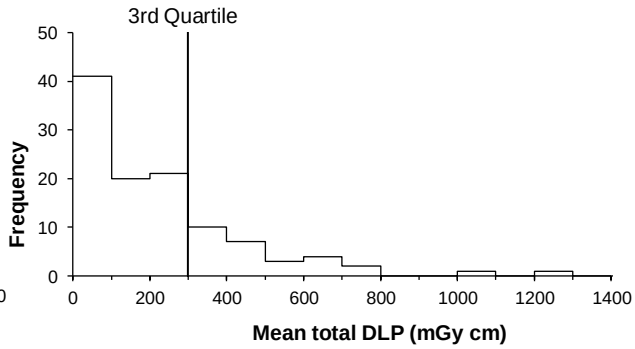
(c) Mean patient dimension: AP



(d) Mean patient cross-sectional area

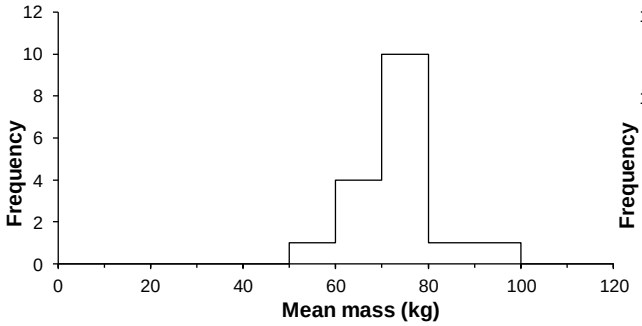


(e) Mean $CTDI_{vol}$ for patient sample

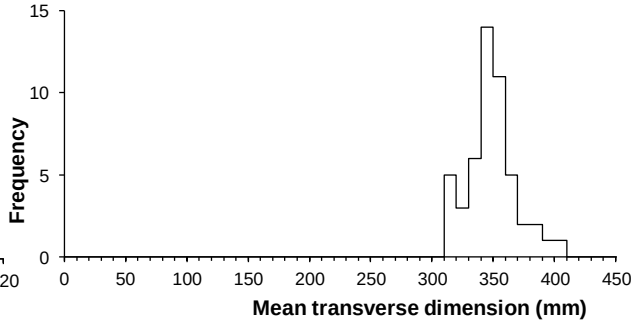


(f) Mean total DLP for patient sample

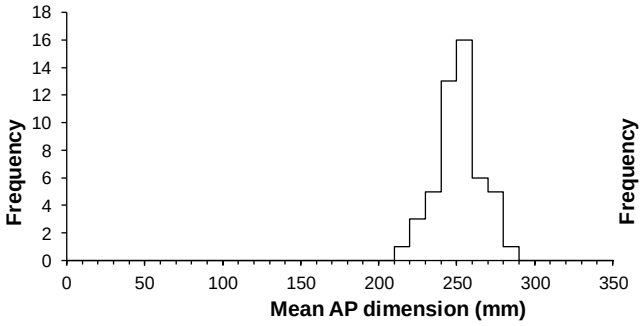
FIGURE D2.4 Chest – high resolution (interstitial lung disease): distributions over mean data (for all techniques) (*n* > 4) from participating CT centres



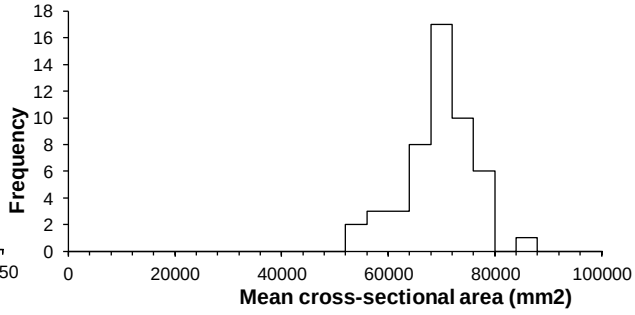
(a) Mean patient mass



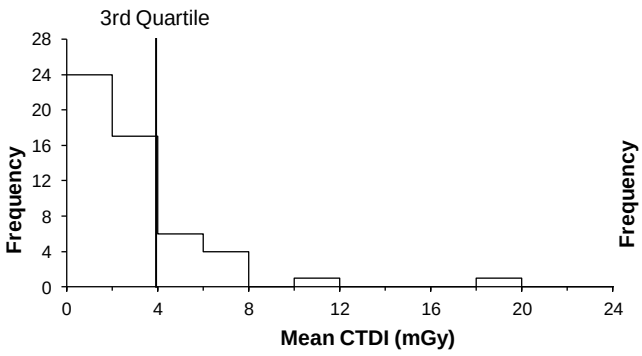
(b) Mean patient dimension: transverse



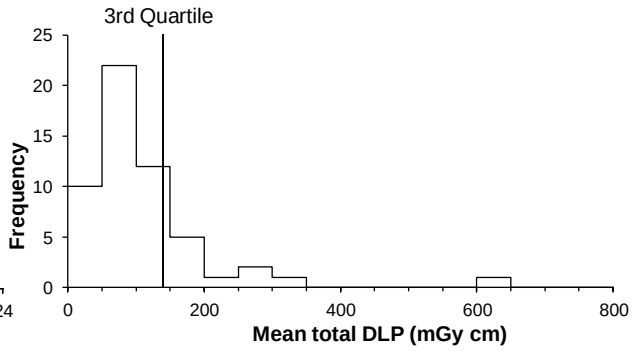
(c) Mean patient dimension: AP



(d) Mean patient cross-sectional area

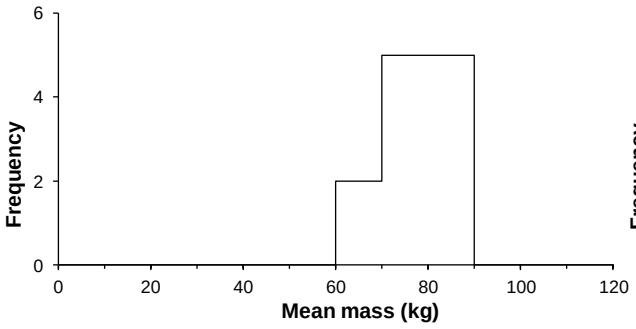


(e) Mean $CTDI_{vol}$ for patient sample

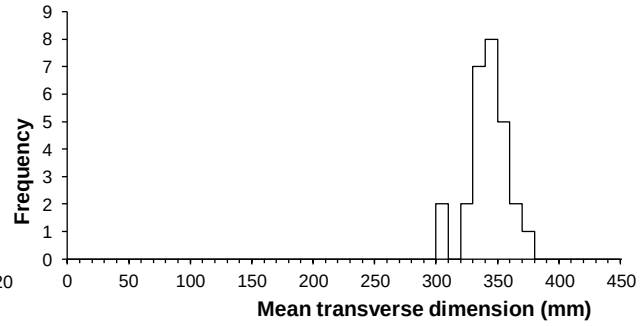


(f) Mean total DLP for patient sample

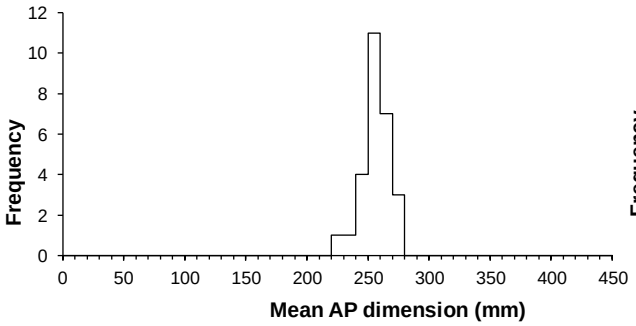
FIGURE D2.5 Chest – high resolution (interstitial lung disease): distributions over mean data (for axial scanning only) (*n* > 4) from participating CT centres



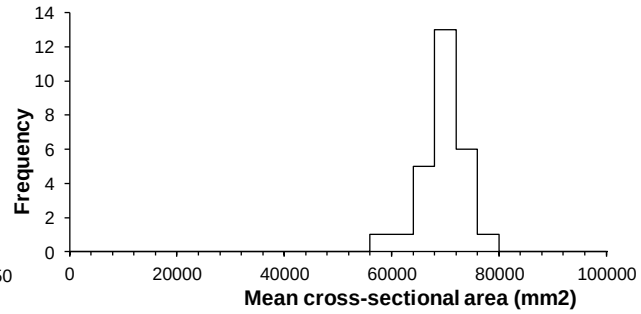
(a) Mean patient mass



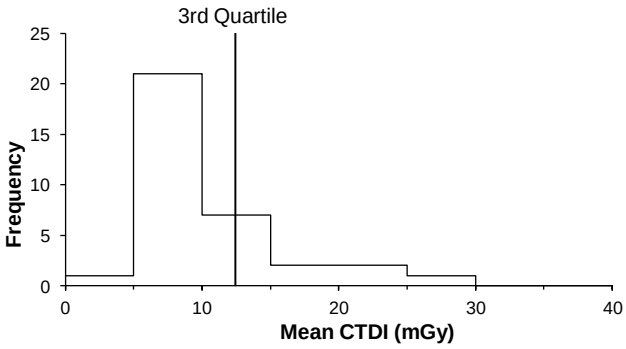
(b) Mean patient dimension: transverse



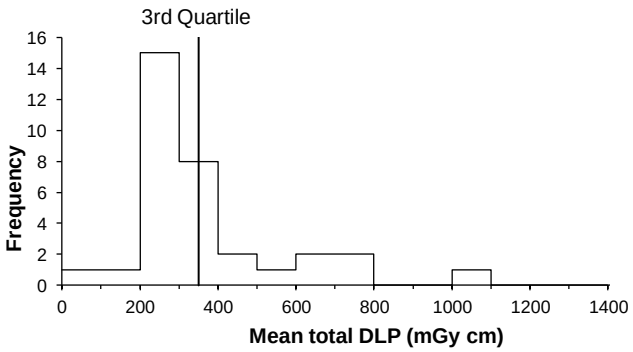
(c) Mean patient dimension: AP



(d) Mean patient cross-sectional area

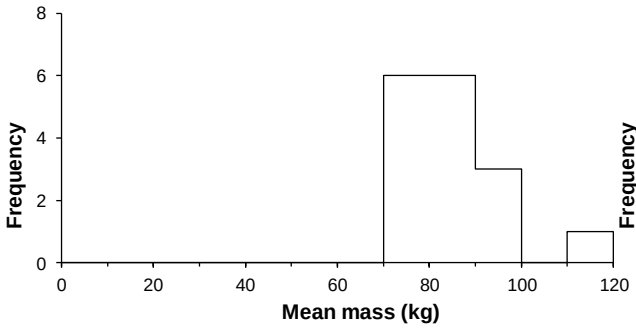


(e) Mean $CTDI_{vol}$ for patient sample

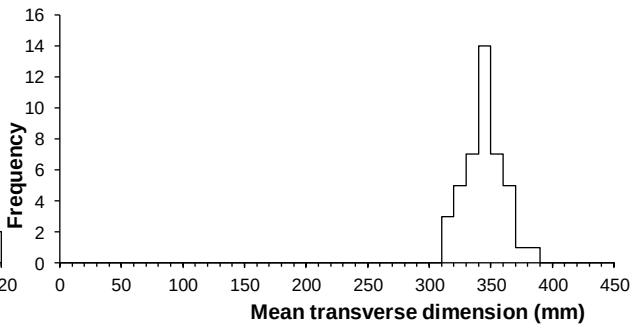


(f) Mean total DLP for patient sample

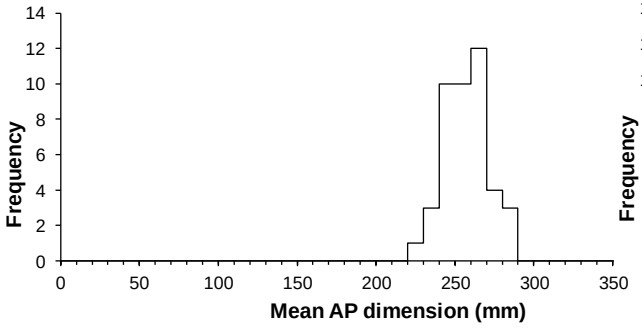
FIGURE D2.6 Chest – high resolution (interstitial lung disease): distributions over mean data (for helical scanning only) (*n* > 4) from participating CT centres



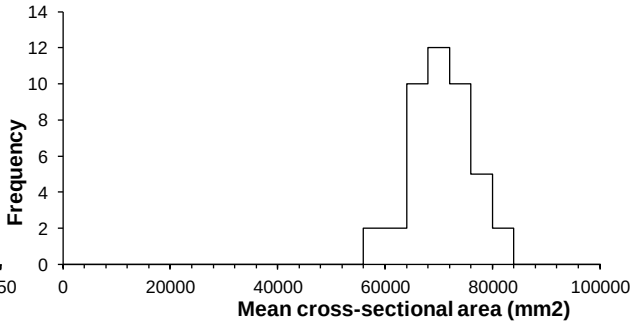
(a) Mean patient mass



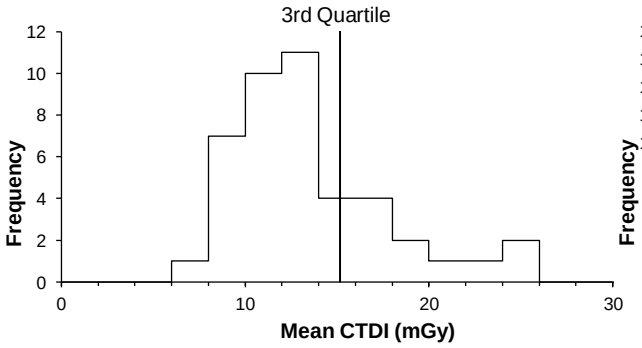
(b) Mean patient dimension: transverse



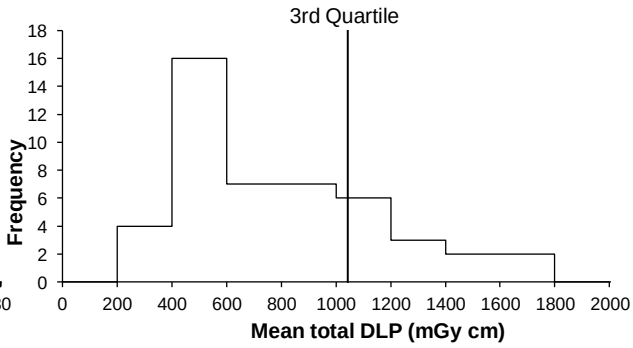
(c) Mean patient dimension: AP



(d) Mean patient cross-sectional area

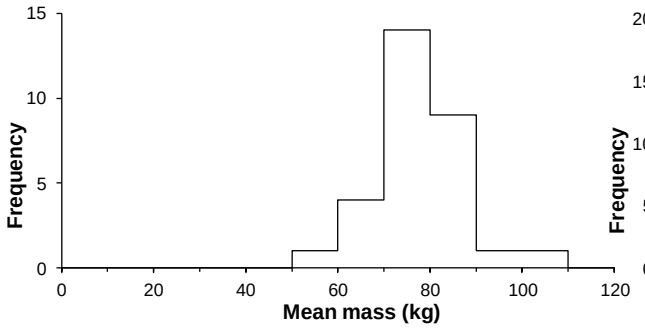


(e) Mean $CTDI_{vol}$ for patient sample

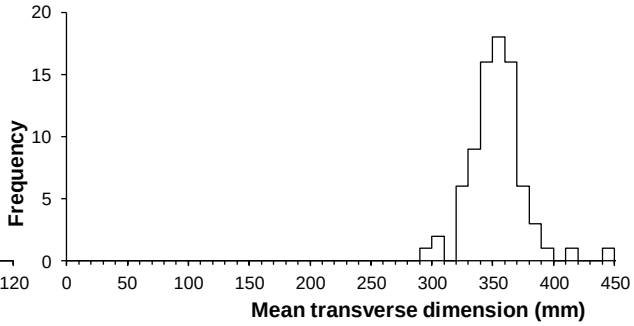


(f) Mean total DLP for patient sample

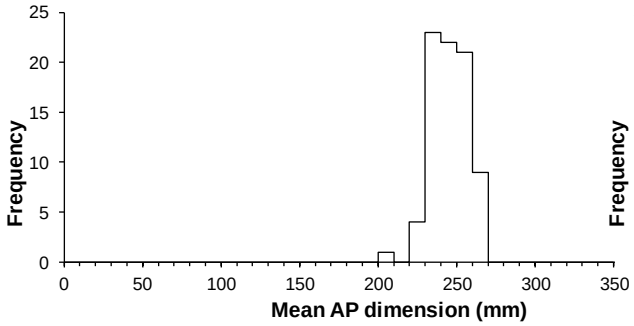
FIGURE D2.7 CT angiography (CTA) (blood vessels): distributions over mean data (*n* > 4) from participating CT centres



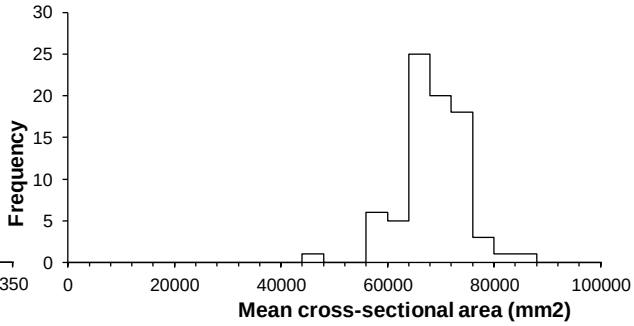
(a) Mean patient mass



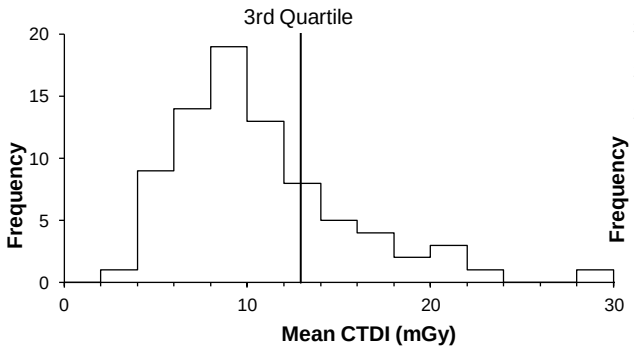
(b) Mean patient dimension: transverse



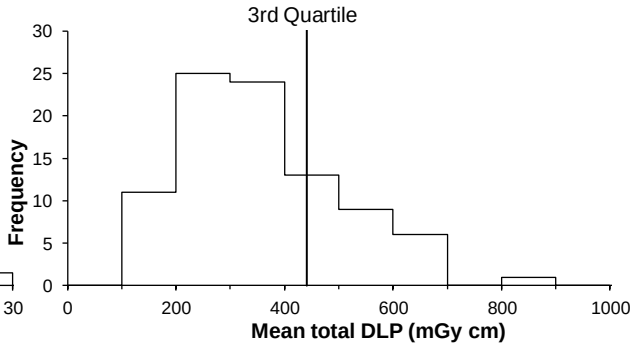
(c) Mean patient dimension: AP



(d) Mean patient cross-sectional area

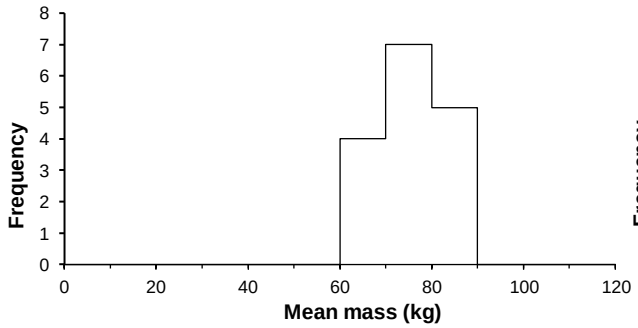


(e) Mean $CTDI_{vol}$ for patient sample

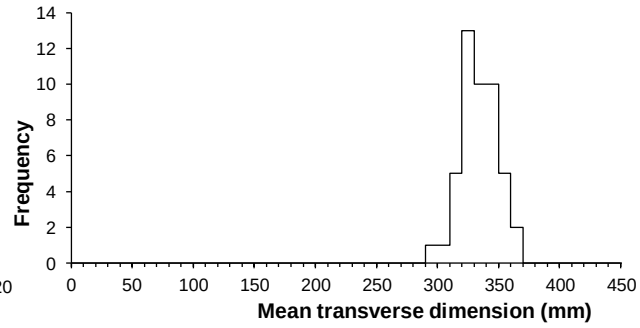


(f) Mean total DLP for patient sample

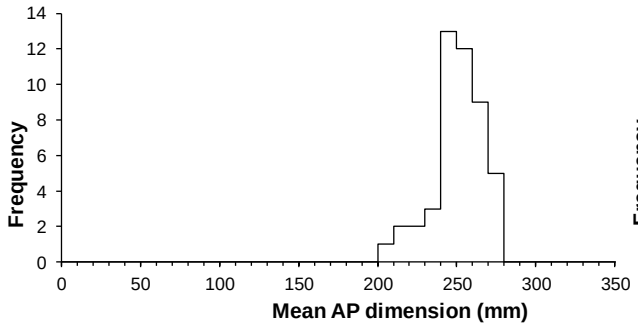
FIGURE D2.8 CT pulmonary angiography (CTPA) (pulmonary embolism): distributions over mean data (*n* > 4) from participating CT centres



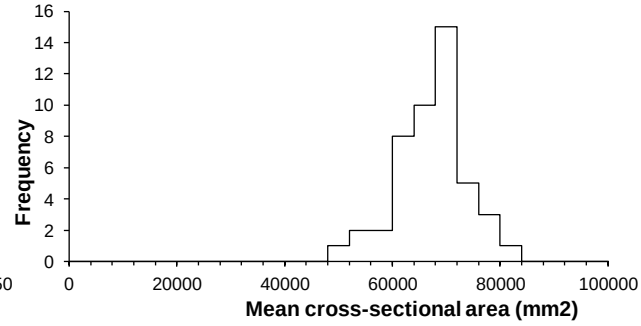
(a) Mean patient mass



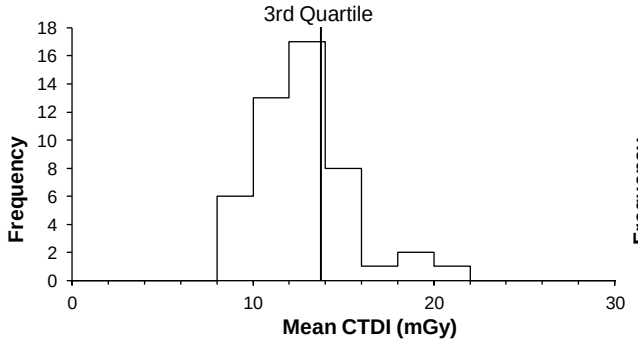
(b) Mean patient dimension: transverse



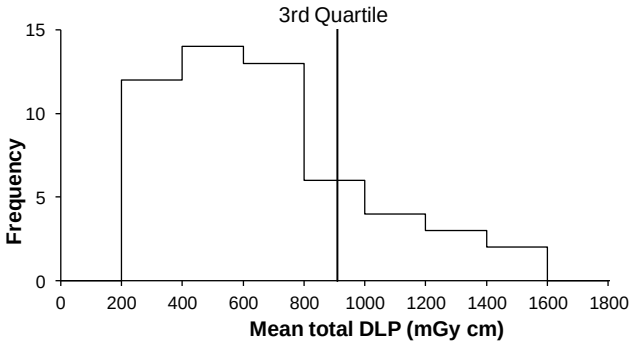
(c) Mean patient dimension: AP



(d) Mean patient cross-sectional area

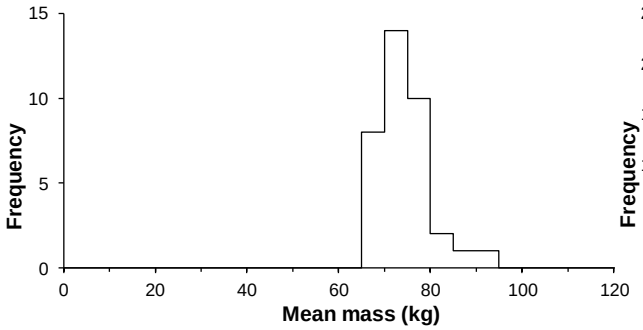


(e) Mean $CTDI_{vol}$ for patient sample

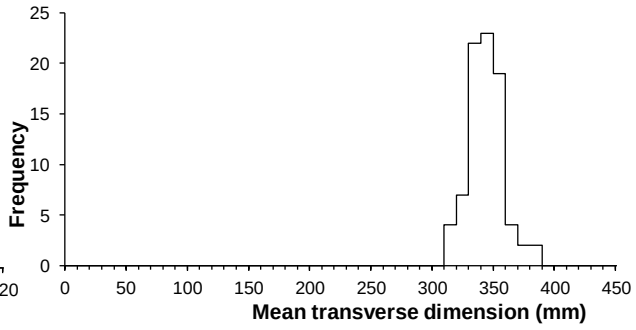


(f) Mean total DLP for patient sample

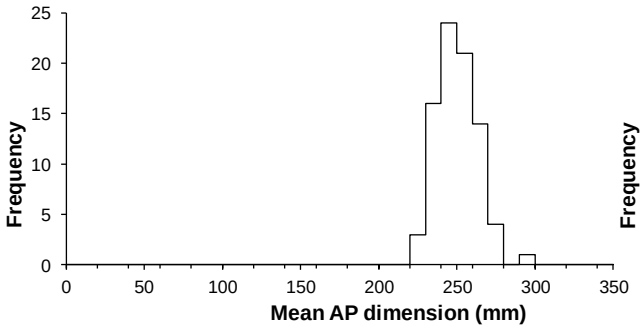
FIGURE D2.9 Abdomen (liver metastases): distributions over mean data (*n* > 4) from participating CT centres



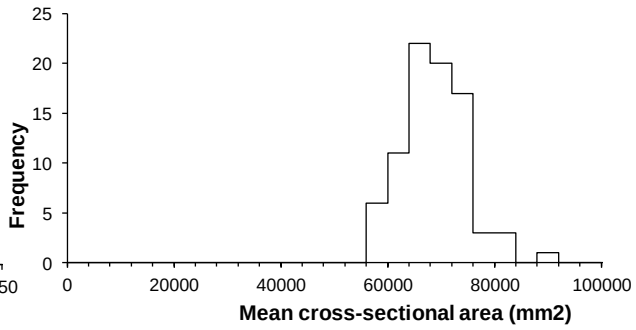
(a) Mean patient mass



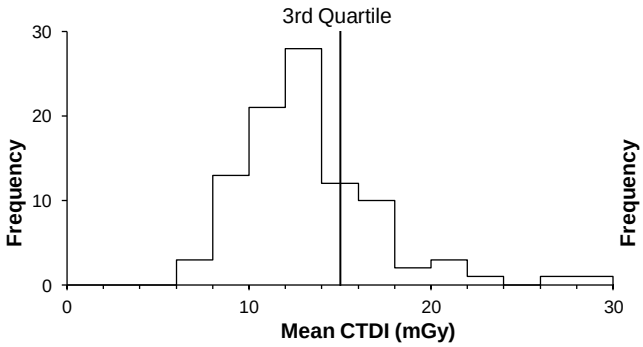
(b) Mean patient dimension: transverse



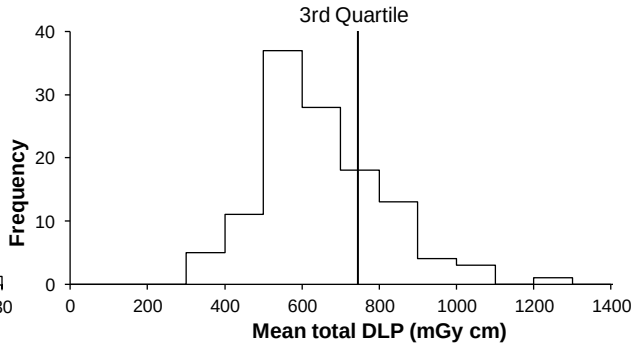
(c) Mean patient dimension: AP



(d) Mean patient cross-sectional area

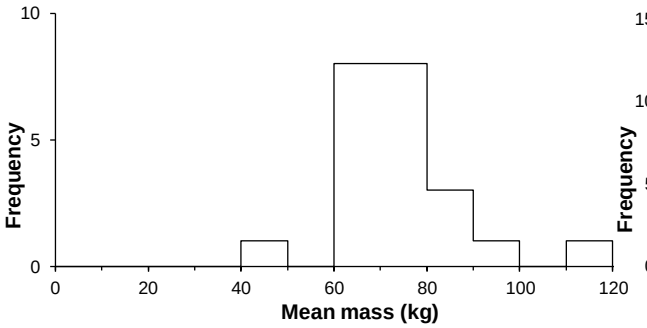


(e) Mean $CTDI_{vol}$ for patient sample

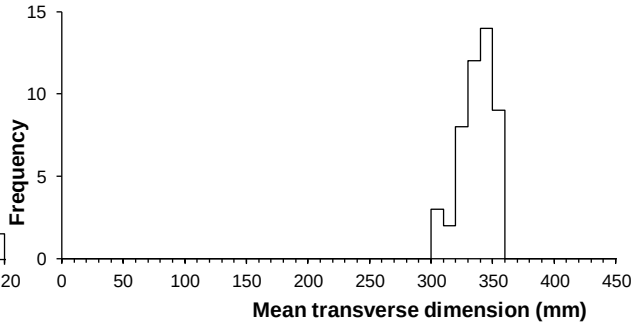


(f) Mean total DLP for patient sample

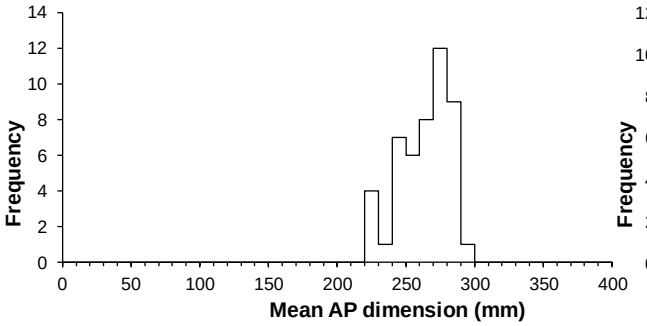
FIGURE D2.10 Abdomen and pelvis (abscess): distributions over mean data (*n* > 4) from participating CT centres



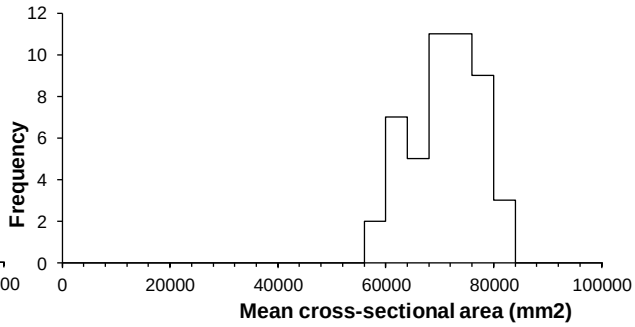
(a) Mean patient mass



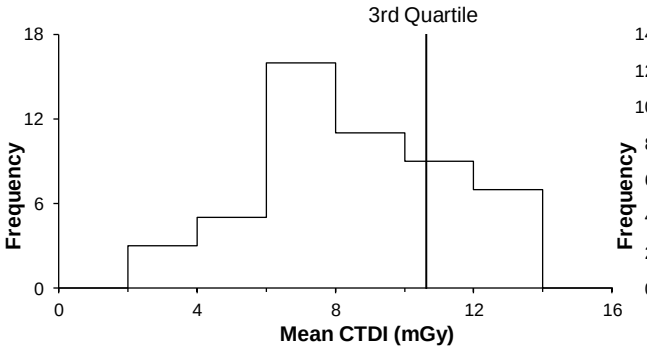
(b) Mean patient dimension: transverse



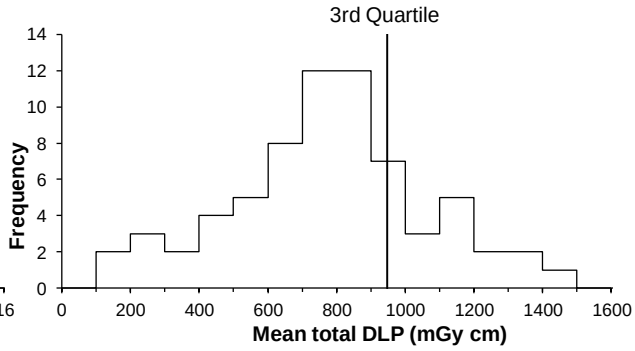
(c) Mean patient dimension: AP



(d) Mean patient cross-sectional area



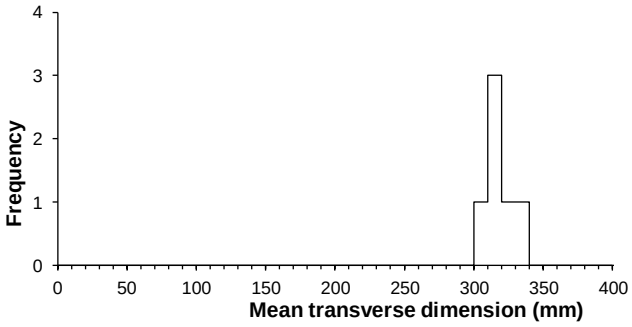
(e) Mean $CTDI_{vol}$ for patient sample



(f) Mean total DLP for patient sample

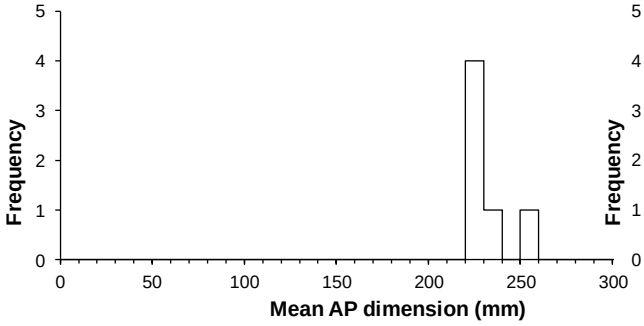
FIGURE D2.11 Virtual colonoscopy (VC) (polyps/tumour): distributions over mean data (*n* > 4) from participating CT centres

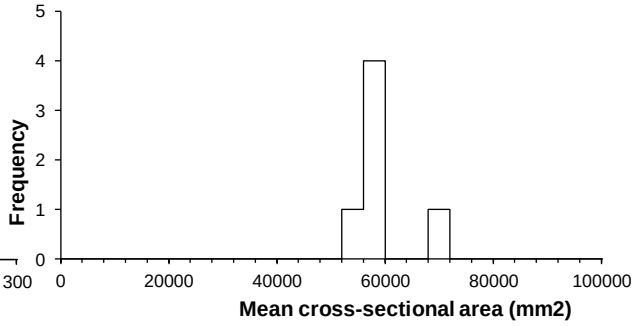
Insufficient data



(a) Mean patient mass

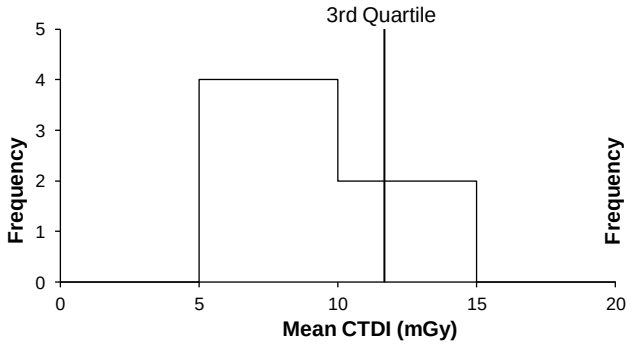
(b) Mean patient dimension: transverse

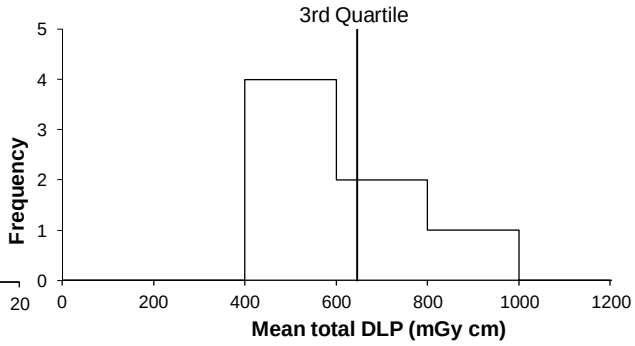




(c) Mean patient dimension: AP

(d) Mean patient cross-sectional area

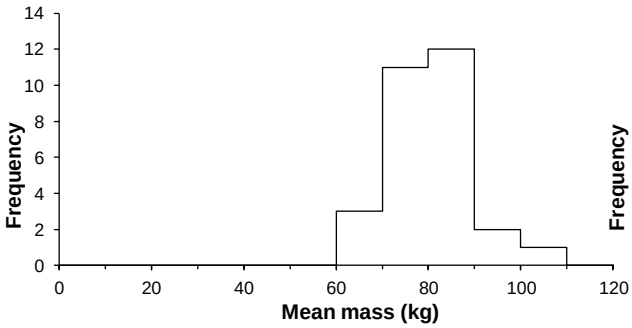




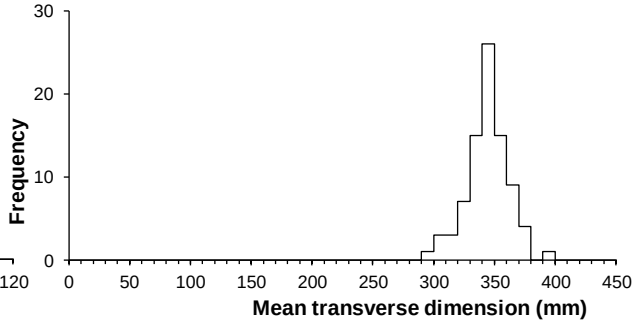
(e) Mean $CTDI_{vol}$ for patient sample

(f) Mean total DLP for patient sample

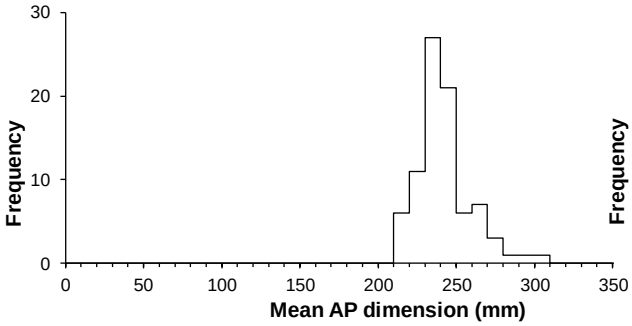
FIGURE D2.12 Enteroclysis (Crohn's disease): distributions over mean data (*n* > 4) from participating CT centres



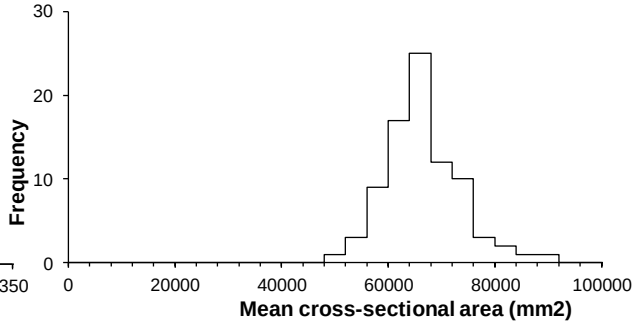
(a) Mean patient mass



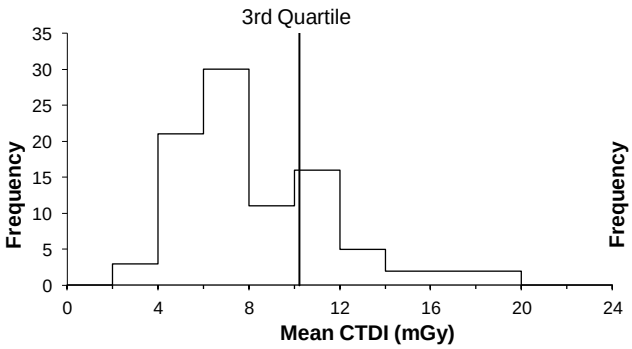
(b) Mean patient dimension: transverse



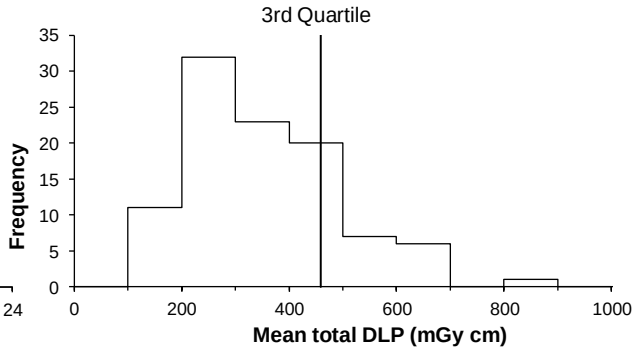
(c) Mean patient dimension: AP



(d) Mean patient cross-sectional area

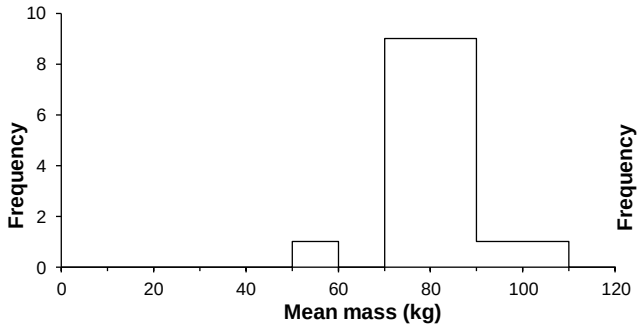


(e) Mean $CTDI_{vol}$ for patient sample

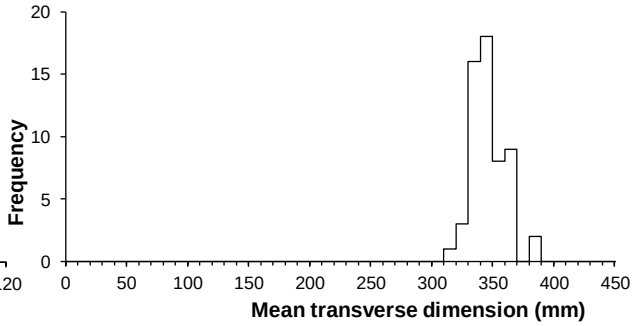


(f) Mean total DLP for patient sample

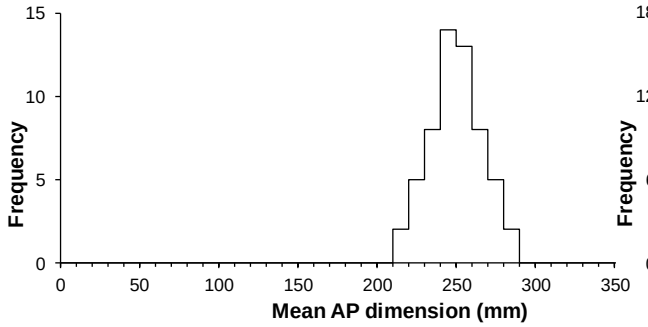
FIGURE D2.13 Kidney-ureters-bladder (KUB) (stones/colic): distributions over mean data (n > 4) from participating CT centres



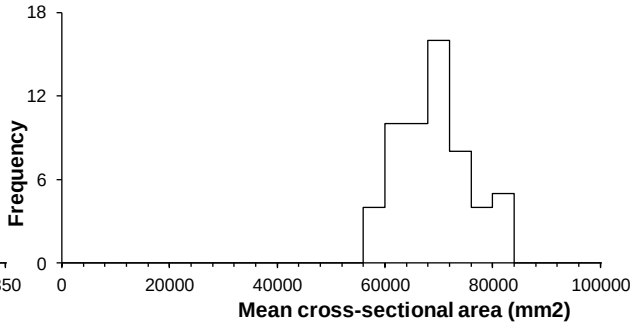
(a) Mean patient mass



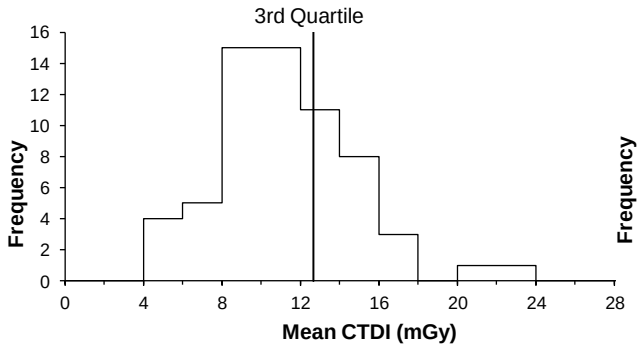
(b) Mean patient dimension: transverse



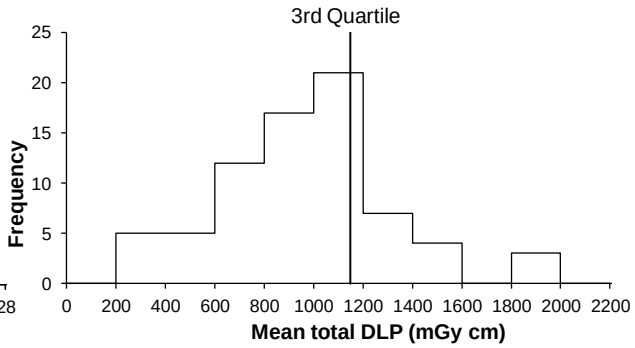
(c) Mean patient dimension: AP



(d) Mean patient cross-sectional area



(e) Mean $CTDI_{vol}$ for patient sample



(f) Mean total DLP for patient sample

FIGURE D2.14 Urogram (stones/colic or tumour): distributions over mean data (*n* > 4) from participating CT centres

Insufficient data

(a) Mean patient mass

Insufficient data

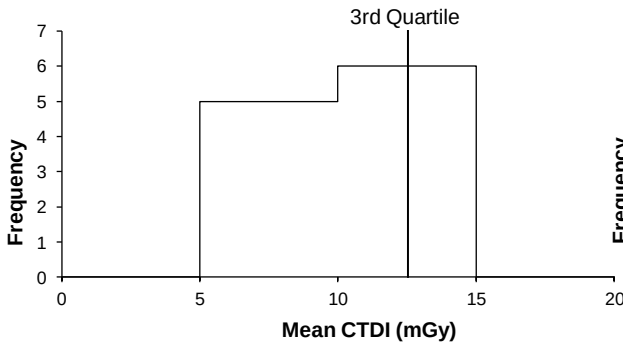
(b) Mean patient dimension: transverse

Insufficient data

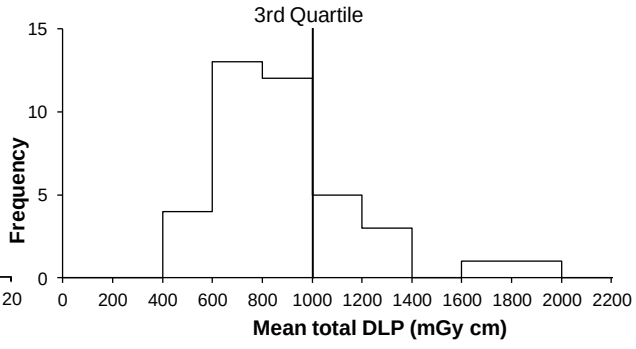
(c) Mean patient dimension: AP

Insufficient data

(d) Mean patient cross-sectional area

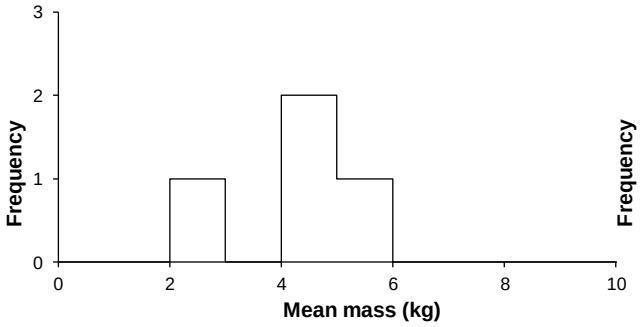


(e) Mean $CTDI_{vol}$ for patient sample

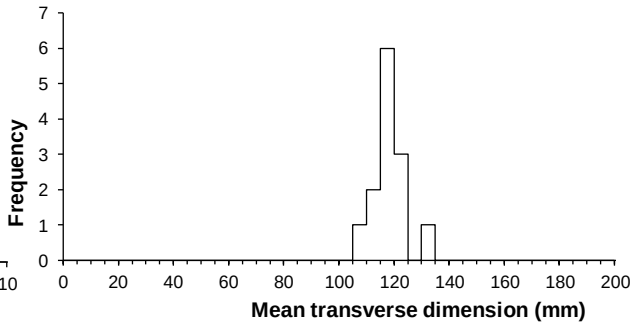


(f) Mean total DLP for patient sample

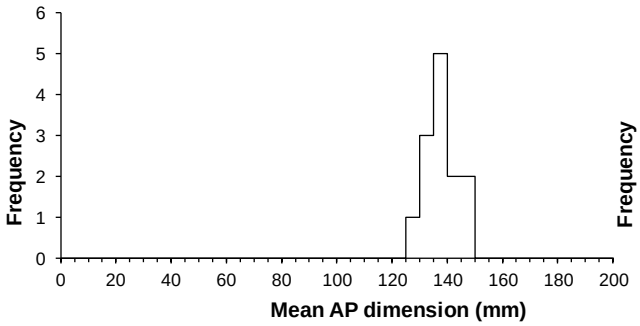
FIGURE D2.15 CAP (cancer): distributions over mean data (*n* > 4) from participating CT centres



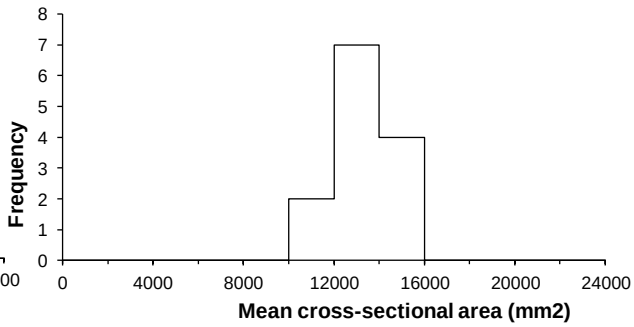
(a) Mean patient mass



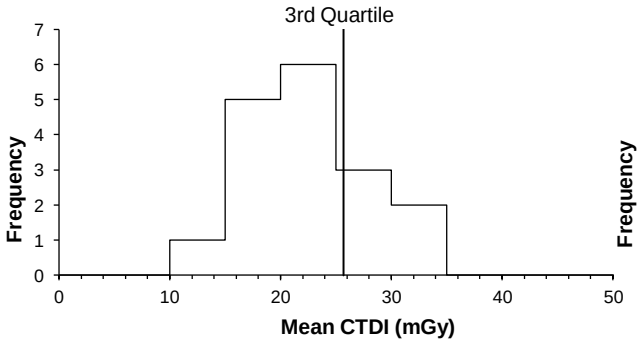
(b) Mean patient dimension: transverse



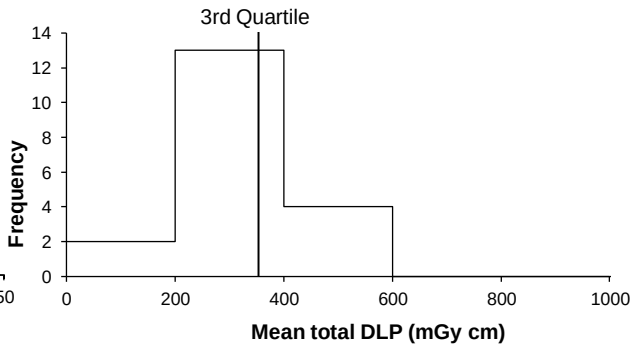
(c) Mean patient dimension: AP



(d) Mean patient cross-sectional area



(e) Mean $CTDI_{vol}$ for patient sample

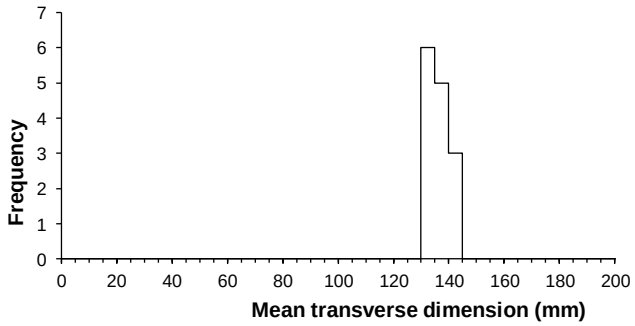


(f) Mean total DLP for patient sample

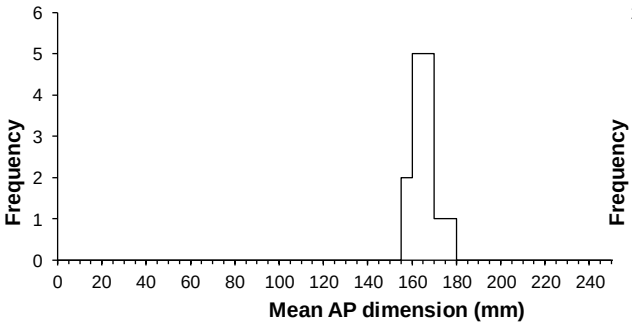
FIGURE D2.16 Paediatric head – age 0–1 y (trauma): distributions over mean data (n > 4) from participating CT centres

Insufficient data

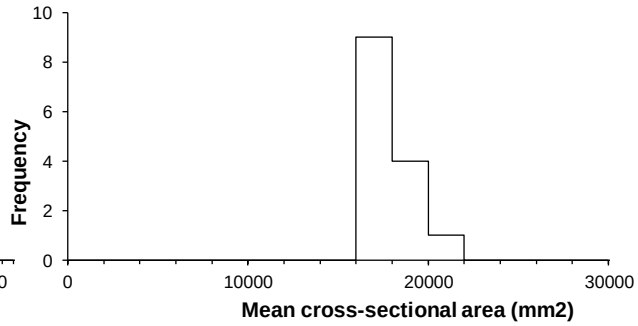
(a) Mean patient mass



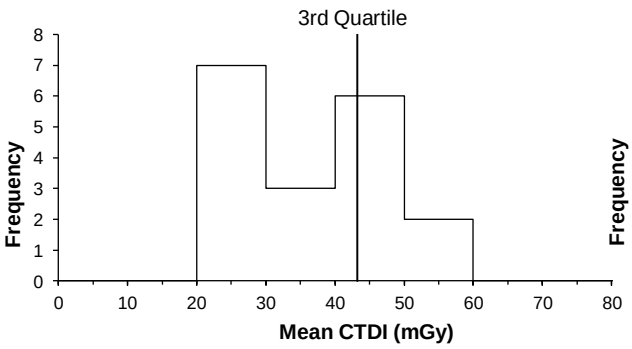
(b) Mean patient dimension: transverse



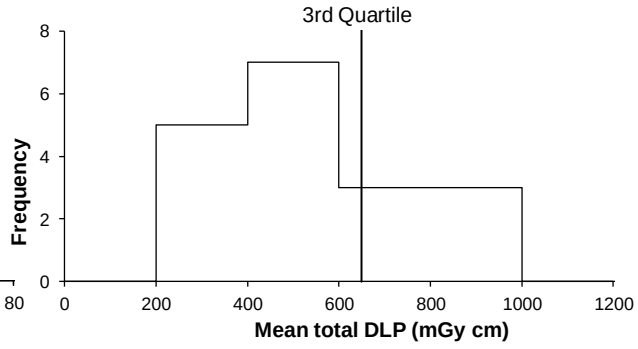
(c) Mean patient dimension: AP



(d) Mean patient cross-sectional area



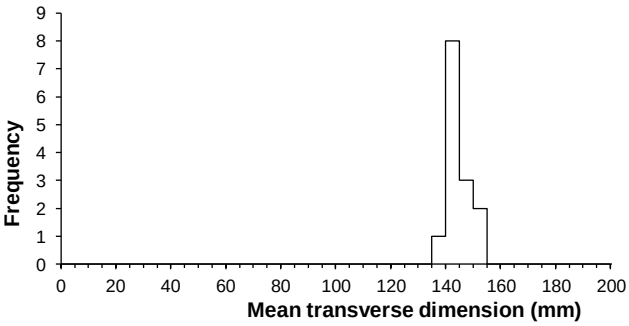
(e) Mean $CTDI_{vol}$ for patient sample



(f) Mean total DLP for patient sample

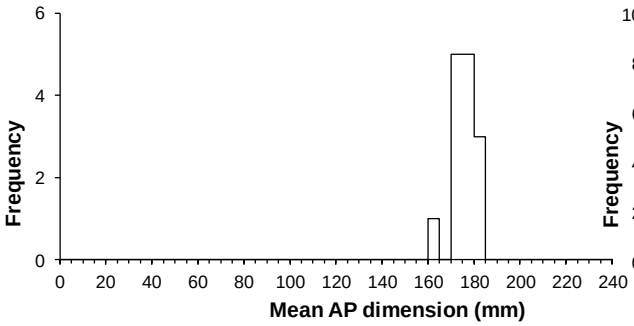
FIGURE D2.17 Paediatric head – age >1 to 5 y (trauma): distributions over mean data (*n* > 4) from participating CT centres

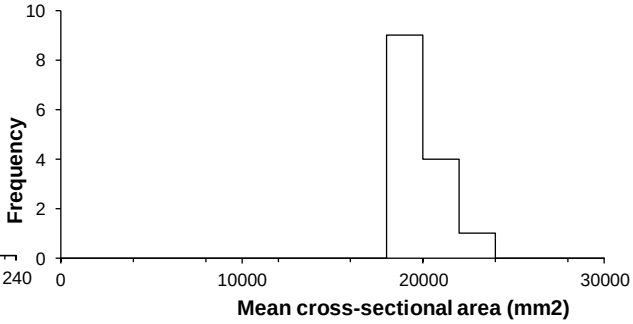
Insufficient data



(a) Mean patient mass

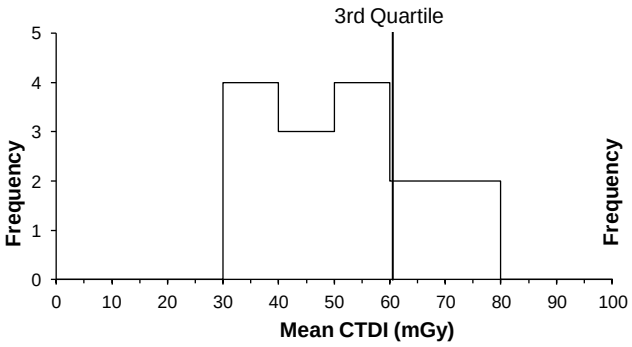
(b) Mean patient dimension: transverse

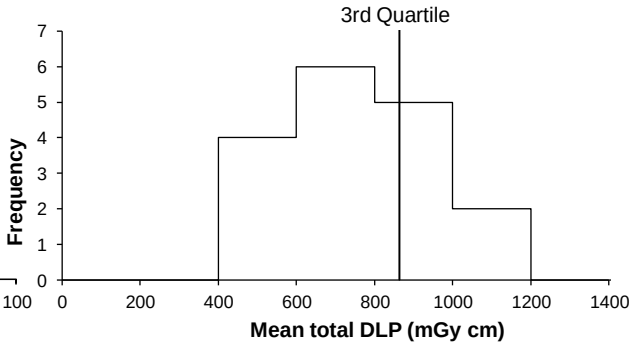




(c) Mean patient dimension: AP

(d) Mean patient cross-sectional area



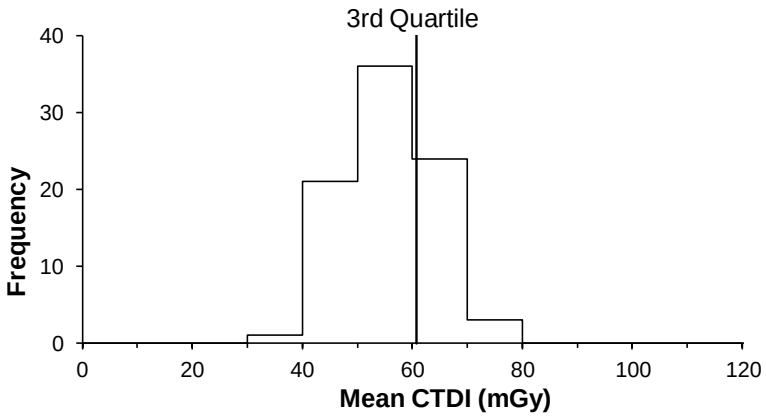


(e) Mean $CTDI_{vol}$ for patient sample

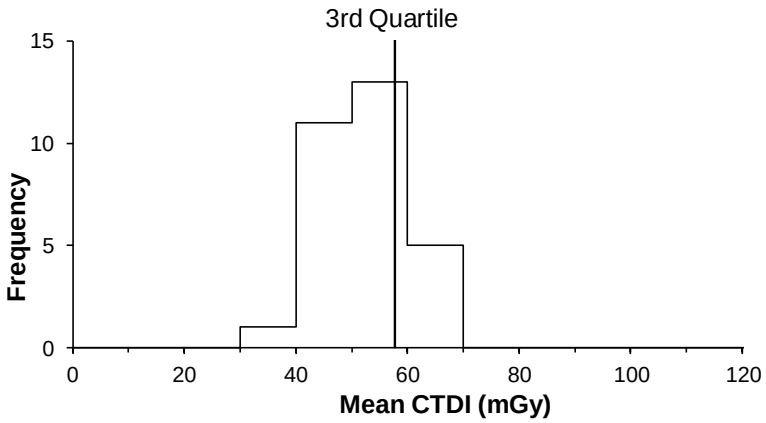
(f) Mean total DLP for patient sample

FIGURE D2.18 Paediatric head – age >5 y (trauma): distributions over mean data (*n* > 4) from participating CT centres

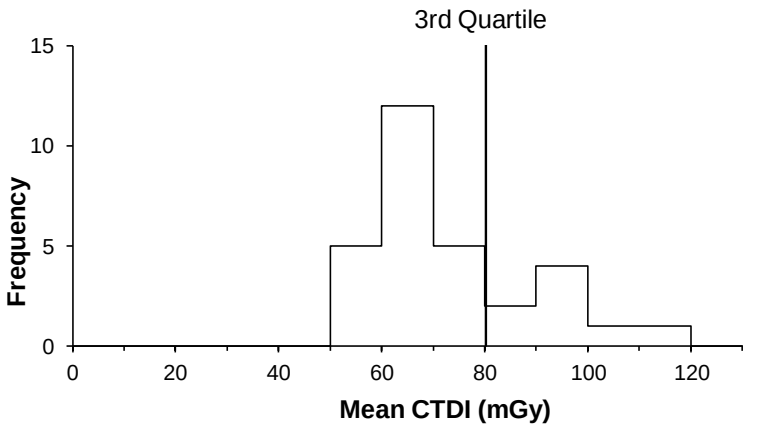
D3 Distributions over Mean Data (Sample Size *n* > 4) from Participating CT Centres by Examination and Sequence Type



(a) Scan sequence 'whole brain'

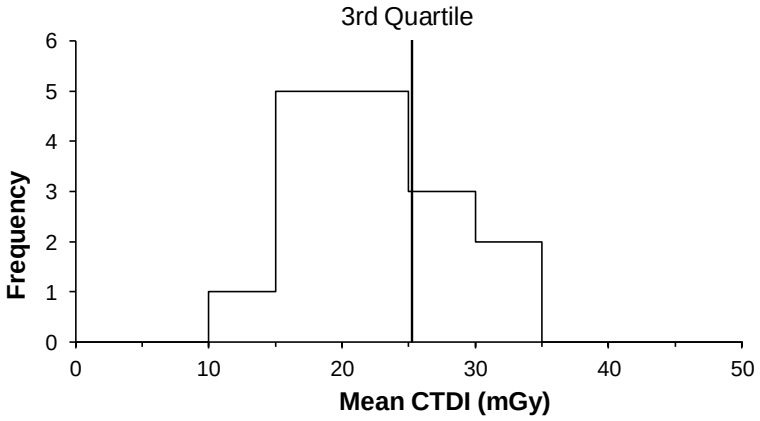


(b) Scan sequence 'cerebrum'

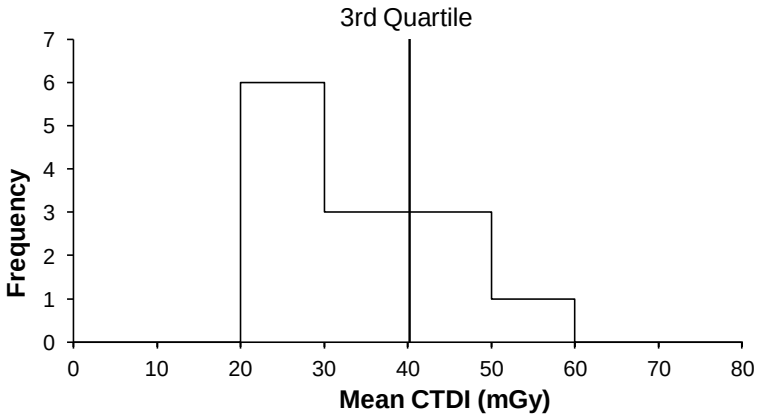


(c) Scan sequence 'posterior fossa'

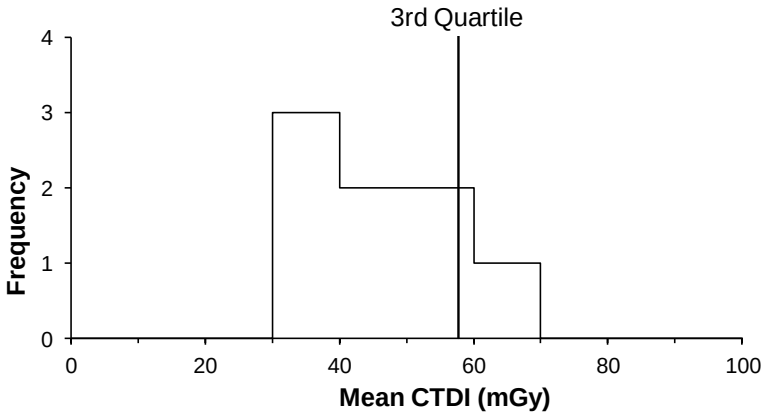
FIGURE D3.1 Head (acute stroke): distributions for mean values of $CTDI_{vol}$ from patient samples (*n* > 4) for selected types of scan sequence during CT examinations



(a) Patient age 0–1 y: scan sequence 'whole brain'



(b) Patient age >1–5 y: scan sequence 'whole brain'



(c) Patient age >5 y: scan sequence 'whole brain'

FIGURE D3.2 Paediatric head (trauma): distributions for mean values of $CTDI_{vol}$ from patient samples (n > 4) for selected types of scan sequence during CT examinations