Doses to Patients from Radiographic and Fluoroscopic X-ray Imaging Procedures in the UK – 2010 Review

D Hart, M C Hillier and P C Shrimpton

ABSTRACT

The National Patient Dose Database is used to collate the measurements made by X-ray departments in hospitals throughout the UK of radiation doses to patients undergoing radiographic and fluoroscopic imaging procedures. Since 2001 the database has also included measurements of doses from dental x-ray examinations. This report is the fourth in a series of five-yearly reviews of the database, and analyses the information collected during the period January 2006 to December 2010. It includes 165,000 entrance surface doses (ESD) and 185,000 dose-area products (DAP) for single radiographs, and 221,000 DAP measurements and 146,000 fluoroscopy times for complete examinations. These data were collected from 320 hospitals throughout the UK, representing nearly a quarter of all the hospitals with diagnostic X-ray facilities. Data on dental x-ray examinations were collected from 4000 dental practices, representing more than a third of all UK dental practices. Information on the patient dose distributions and exposure conditions for 49 types of X-ray imaging procedure on adults and 5 types of X-ray examination on children, including dental X-ray examinations, is presented. The influence of computed radiography and flat panel detectors on patient doses has been analysed. National reference doses, based on the rounded third quartile values of the distributions of room mean doses, are presented for 38 types of diagnostic X-ray examination on adults, 7 types of interventional procedure on adults, 3 types of medical X-ray examination on children, and for intra-oral and panoramic dental radiographs on adults and children. The reference doses are on average about 10% lower than corresponding values in the previous (2005) review, and are typically less than half the values of the original UK national reference doses that were derived from a survey in the mid-1980s.

The Health Protection Agency gratefully acknowledges the co-operation of hospital physicists and radiology department staff in supplying patient dose data for this key UK initiative.

Centre for Radiation, Chemical and Environmental Hazards
Chilton, Didcot, Oxfordshire OX11 0RQ

Approval: May 2012
Publication: June 2012
£21.00
ISBN 978-0-85951-716-4

EXECUTIVE SUMMARY

The exposure of patients to ionising radiation for diagnostic purposes is responsible for over 90% of the total dose to the UK population from man-made radiation, and accounts for 15% of the dose from all sources (natural and artificial). Patient exposures are therefore an important focus within radiation protection in order to ensure that all such doses are kept as low as reasonably practicable to meet each intended clinical purpose. For more than 20 years, the Health Protection Agency (and its predecessor organisation, the National Radiological Protection Board) has set national reference doses in order to facilitate improvements in patient protection. The purpose of these reference doses is to give an indication on a national scale of unusually high typical doses, against which hospitals and clinics can check their own performance. The reference doses are pragmatically set at the 75th percentile value of the distributions of mean doses observed in the National Patient Dose Database, which collates the results from local dose surveys in hospitals. These national reference doses have provided the basis for national diagnostic reference levels (DRLs) that are similar in purpose and are promulgated by the Department of Health in fulfilment of requirements under the Ionising Radiation (Medical Exposure) Regulations 2000.

This report is the fourth in a series of five-yearly reviews of the National Patient Dose Database that is maintained by the Health Protection Agency. The database stores information on radiation doses to patients undergoing medical and dental X-ray examinations and interventional procedures in both the National Health Service and the independent sector. As well as data on doses, information is stored on factors that might affect the dose, such as the size of the patient, the type of imaging equipment (digital or film-screen), and the examination technique. Data from a large number of hospitals (listed in Appendix A) and dental practices spread throughout the UK ensure as far as possible that the data are representative of national practice. As in previous reports, the anonymity of both patients and hospitals/clinics has been maintained. All the data are treated confidentially, and any published reviews of the database do not reveal the performance of specific hospitals.

In this report we analyse the data collected during the period January 2006 to December 2010 from 320 hospitals (about a quarter of all the hospitals with diagnostic X-ray facilities in the UK) and about 4,000 dental practices (more than a third of all UK dental practices). In total, the present data amount to nearly twice as many doses as collected for the 2005 review. Over the last 5 years in the UK, film-screen imaging has been almost entirely replaced by digital systems. These digital systems are commonly referred to as CR or DR; we shall use the terms computed radiography or flat panel detectors to distinguish the two main types of digital radiography that are currently used. Despite the wholesale changes, doses to patients have continued in general to follow a downward trend. We have analysed the distributions of typical doses used by different institutions to provide, on the basis of 75th percentile values, national reference doses for 38 types of diagnostic X-ray examination and 7 types of interventional procedure on adults, 3 types of medical X-ray examination on children, and intra-oral and panoramic dental radiographs on adults and children. The reference doses are on average about 10% lower than corresponding values in the previous (2005) review, and are typically

less than half the values of the original UK national reference doses that were derived from a survey in the mid-1980s. These new data should help inform any updated national DRLs.

There is a continuing need to collate patient dose information on a national scale in order to monitor trends following ongoing advances in X-ray equipment and clinical practice as the basis for promoting further improvements in patient protection.

CONTENTS

1 INTRODUCTION

The National Patient Dose Database (NPDD) was established in 1992 after the publication of a National Protocol for Patient Dose Measurements in Diagnostic Radiology (IPSM, 1992). The NPDD is intended to collate the measurements of radiation doses to patients from common X-ray examinations carried out in hospitals throughout the UK, excluding computed tomography (CT) which has been the subject of separate surveys (Shrimpton et al, 2005). Reviews of the NPDD have been conducted every 5 years, in which the observed distributions of patient doses for common radiographic and fluoroscopic X-ray procedures have been described and national reference doses have been recommended as a quality improvement tool in relation to the requirement to keep doses as low as reasonably practicable for the intended clinical purpose of each examination. The legal framework for the application in the UK of this concept, under the term diagnostic reference levels (DRLs), is provided by the Ionising Radiation (Medical Exposure) Regulations 2000 (IR(ME)R) (Department of Health, 2000). Guidance on the establishment and use of national reference doses and DRLs for medical and dental X-ray examinations (IPEM, 2004) and dose measurements in X-ray departments (IPEM, 2005) has been provided by joint working parties of relevant professional bodies. National DRLs are set formally by the Department of Health, most recently in April 2007 (Department of Health, 2007), on the basis of national data provided, inter alia, by the HPA and the NPDD.

Three previous reviews of data from the NPDD have been published for each of the five-year periods preceding 1995, 2000 and 2005 (Hart et al, 1996; Hart et al, 2002a; Hart et al, 2007). The 2005 review was the first one of the series to cover dental doses. This current report continues the review process by analysing the data collected in hospitals and dental clinics during the latest five-year period from January 2006 to December 2010. Patient radiation doses from CT examinations are not included in this review, although a third UK national CT survey is in progress that will in due course provide updated dose information, including national reference doses (Meeson et al, 2011).

This 2010 review of the National Patient Dose Database describes the methods used for collecting and analysing the data, describes the data sample, and presents results in relation to:

a) dose distributions for different types of procedure;

b) influence of imaging equipment on patient dose;

c) trends in doses over time;

d) and the values derived for 2010 national reference doses.

2 METHODS

2.1 Obtaining the data

Data were obtained through two distinct routes:

1) From hospitals and dental practices throughout the UK during the whole of the 5 year period, supplied mainly by hospital physicists (but also by radiographers and radiologists) (98.5% of the total number of dose measurements);

2) From dental practices throughout the UK for the period January 2006 to July 2010, supplied by the Dental X-ray Protection Service (DXPS) of the HPA (1.5% of the total).

More than 66% of the dental dose measurements came from the DXPS, the remainder being supplied by 8 hospital physicists.

The dose-related quantities included in the NPDD for medical X-ray examinations are entrance surface dose [ESD] for single radiographs, dose-area product [DAP] for single radiographs or complete examinations/procedures, and fluoroscopy time for complete examinations/procedures. For dental X-ray examinations, the measured patient dose quantities are the absorbed dose to air at the tip of the spacer/collimator for intra-oral radiographs [PED] and either the dose-area product [DAP] or dose-width product [DWP] for panoramic radiographs (IPEM, 2004; IPEM, 2005; Gulson et al, 2007).

Data were not only collected on dose but also on the patient, the location, the imaging equipment, and the examination technique. The forms shown in Appendix B list all of the data that are of interest for the NPDD, and highlight the data that are essential. There are four forms covering medical diagnostic radiographs, medical X-ray examinations/procedures, dental intra-oral radiographs, and dental panoramic radiographs. The first two of these forms are revised versions of those printed in the National Protocol for Patient Dose Measurements in Diagnostic Radiology (IPSM, 1992). They have been updated to include additional information on digital image acquisition techniques (e.g. computed radiography). The forms can be photocopied for use in local radiology departments, or can be freely downloaded from the HPA website at:

http://www.hpa.org.uk/Topics/Radiation/UnderstandingRadiation/UnderstandingRadiationTopics/MedicalRadiation/DiagnosticRadiology/diag_Npdd/.

A special effort was made for this review to acquire paediatric data for simple radiographs and complete examinations by contacting 16 children's hospitals in November 2008, with the approval of the British Society of Paediatric Radiology. These children's hospitals were encouraged to collect information on patient size as well as the dose.

Data were accepted in virtually any format, both on paper and as computer files. The overwhelming majority were sent by e-mail as a spreadsheet, which is the preferred format, since direct transfer into the database minimises the possibility of transcription errors.

2.2 Quality assurance of data

The data supplied were initially scrutinised by one of the authors (DH) and data providers were often contacted to verify details. Data were entered into the database by one person and then checked independently by a second person. A statistical programme was run on each set of data that produced the mean, standard deviation, sample size, and minimum and maximum for several key parameters. These parameters included the dose, patient age, patient weight, X-ray tube voltage, filtration, and exposure setting (mAs) for each radiograph or examination. Extreme values were investigated and any errors were corrected. The database was password-protected such that access to the programs or the data files in anything but a read-only manner was restricted to the one staff member (MCH) responsible for developing the database software. Analysis programs were checked against manual calculations with dummy datasets and the results of new calculations were compared to earlier ones to verify that the expected changes had occurred.

The National Protocol for Patient Dose Measurements in Diagnostic Radiology (IPSM, 1992) provides guidance on the calibration and use of TLD systems for measuring ESD and of DAP meters, so that patient dose measurements can be made with sufficient accuracy. It was assumed that all data providers were following this guidance and that the doses submitted to the NPDD were as reliable as the guidance predicts. Some data-providers included calibration data with their dose measurements, which suggested that the guidance in the National Protocol was being followed correctly and increased our confidence in the above assumption.

2.3 Organisation of database

Two separate databases, one for medical and the other for dental data, were established due to the different types of data from the two sectors. In the medical X-ray database, which uses Microsoft Access 97, information is organised into 4 main types of file, related to:-

a) individual patients (including age, height, weight, and dose measurement);

b) groups of patients (for whom the mean dose and the number of patients is supplied, but not the dose for each patient);

c) the hospital (the full address, and whether national health service (NHS) or independent);

d) the radiology room (mainly details of the X-ray imaging equipment used).

For the purposes of the database, a radiology room remains the same room only if it has the same radiological equipment in it. Thus, if a second set of measurements is carried out months later in nominally the same room, except that the equipment has been changed, then this is categorised in the database as a different room. Likewise, if it is not known whether the equipment remains the same, then this is also categorised as a different room.

In the dental X-ray database, which uses Microsoft Excel 2003, separate fields are used for adult and child doses, and the associated exposure parameters. Other information stored includes the X-ray equipment manufacturer and the model; and details of the film speed or digital imaging technique used.

2.4 Selection of data for analysis

2.4.1 Adult patients

The main purpose of performing patient dose measurements is to establish the typical dose that is being delivered to an average patient by the X-ray equipment and examination technique used in a specific radiology room for the particular types of radiograph or examination under study. Doses can be expected to vary with patient size, so as a first step adult patients are considered separately from paediatric patients.

The National Protocol for Patient Dose Measurements in Diagnostic Radiology (IPSM, 1992) recommends that measurements should be made on at least ten adults of either sex to find a typical dose for a specific radiology room and compare it with national reference doses. Since patients' doses are dependent on patient size, the protocol also suggests that the mean weight of the sample should lie in the range 65 to 75 kg for the mean dose to be indicative of the typical dose to an average (70kg) adult patient. To help achieve this, the protocol advocated excluding those patients weighing less than 50 kg or more than 90 kg. Not all data-providers were able to do this. Therefore we used a selection procedure in which data were included if either the mean patient weight for a room was in the range 65 to 75 kg or, where the patient weights were unknown, there was a minimum of 10 patients per room. This was the same selection procedure as used for the 2000 (Hart et al, 2002a) and 2005 reviews (Hart et al, 2007).

To derive a typical patient dose for dental X-ray examinations on adults, a single dose measurement is made on each X-ray set using typical exposure conditions for an adult but without a patient present. There is therefore no need to select the data on the basis of patient size, and all the dose measurements were included in the analysis.

2.4.2 Paediatric patients

In this review, as in previous ones, children have been defined as being aged up to and including fifteen years old. There is an enormous variation in patient size over the age range from new born babies to 15 year old children, so markedly different patient doses can be expected for children of different ages. About 3% of all the dose measurements in the database for this review relate to children. This is a similar proportion to that for the 2005 review (Hart et al, 2007), which was 4%.

For medical X-ray examinations, a method has been developed (Hart et al, 2000) for adjusting doses measured on children of any age to derive the dose that would have been given to the nearest standard-sized patient representing a 0, 1, 5, 10 or 15 year old child. The adjustment of measured doses was based on the relationship between the thickness of the body part being X-rayed in the patient and the corresponding thickness in the nearest standard-sized child. This could either be measured directly or, if more convenient, could be calculated from the height and weight of the patient. These

methods have been applied to the limited amount of data on paediatric patients in the NPDD, where thickness or height and weight data were included.

Some, but not all, intra-oral dental X-ray units have a pre-set child exposure setting. Such settings generally reduce the exposure time compared to that used for adults. To derive a typical patient dose for dental X-ray examinations on children, a single dose measurement is made on each dental X-ray set using typical exposure conditions for children of all ages but without a patient present. (The diameter of the skull only increases by about 17% between a 1 year old and a 15 year old, and radiation doses across all ages of children would increase in a similarly moderate way (Bohmann, 1990).) There is therefore no need to select the data on the basis of patient size, and all the dose measurements were included in the analysis.

2.5 Deriving national reference doses

National reference doses have been derived for those medical X-ray examinations and interventional procedures where dose measurements on adult patients are available from a sufficiently large sample size to be representative of national practice. Following established practice in previous reviews, a sufficient sample is taken to be from at least 10 hospitals, 20 rooms and 100 patients. National reference doses are based on rounded third quartile values for the room mean dose distributions observed for each examination or procedure. Reference doses set at this level are intended to be a simple indication of abnormally high doses in relation to current national practice.

It has previously been shown (Hart et al, 2000) that it was feasible to establish reference doses for medical X-ray examinations for a set of standard-sized children, by taking the third quartile of the distribution of adjusted mean doses at each age from several hospitals. Other hospitals could then compare their local performance with these reference doses.

In dental radiography the typical patient dose used by each dental X-ray set for a particular type of examination is derived from a single dose measurement using typical exposure conditions for an adult or a child, but without a patient being present. The national reference doses for dental radiography are based on the third quartile value of the distribution of such measurements for each type of examination and patient.

3 DATA SAMPLE

3.1 Medical X-ray data

3.1.1 Geographical distribution

We have continued the practice followed in previous reports of analysing the data by hospital rather than by NHS Trust. A list of the participating hospitals, 235 in England, 3 in Northern Ireland, 52 in Scotland, and 30 in Wales. is given in Appendix A. Throughout this report, infirmaries, radiology practices, clinics, prisons and health

centres, are included within the term ‘hospitals’. The total number of hospitals (320) is estimated to cover at least 23% of all hospitals and clinics with diagnostic X-ray facilities in the UK (Binley’s, 2009). Of this total, 272 hospitals were in the NHS, 47 were in the independent sector, and there was 1 prison. Thus 15% of the hospitals in this review were in the independent sector, whereas independent hospitals generally comprise about 20% of the numbers of all hospitals with radiology departments in the UK (Binley’s, 2009).

Figure 1 shows a map of the location of all the identifiable hospitals that supplied data for the 2010 review. The hospitals are well spread across the UK and can be seen to be distributed roughly in accordance with population density. The map is truncated at the latitude of Aberdeen, since there were no sampled hospitals north of that point.

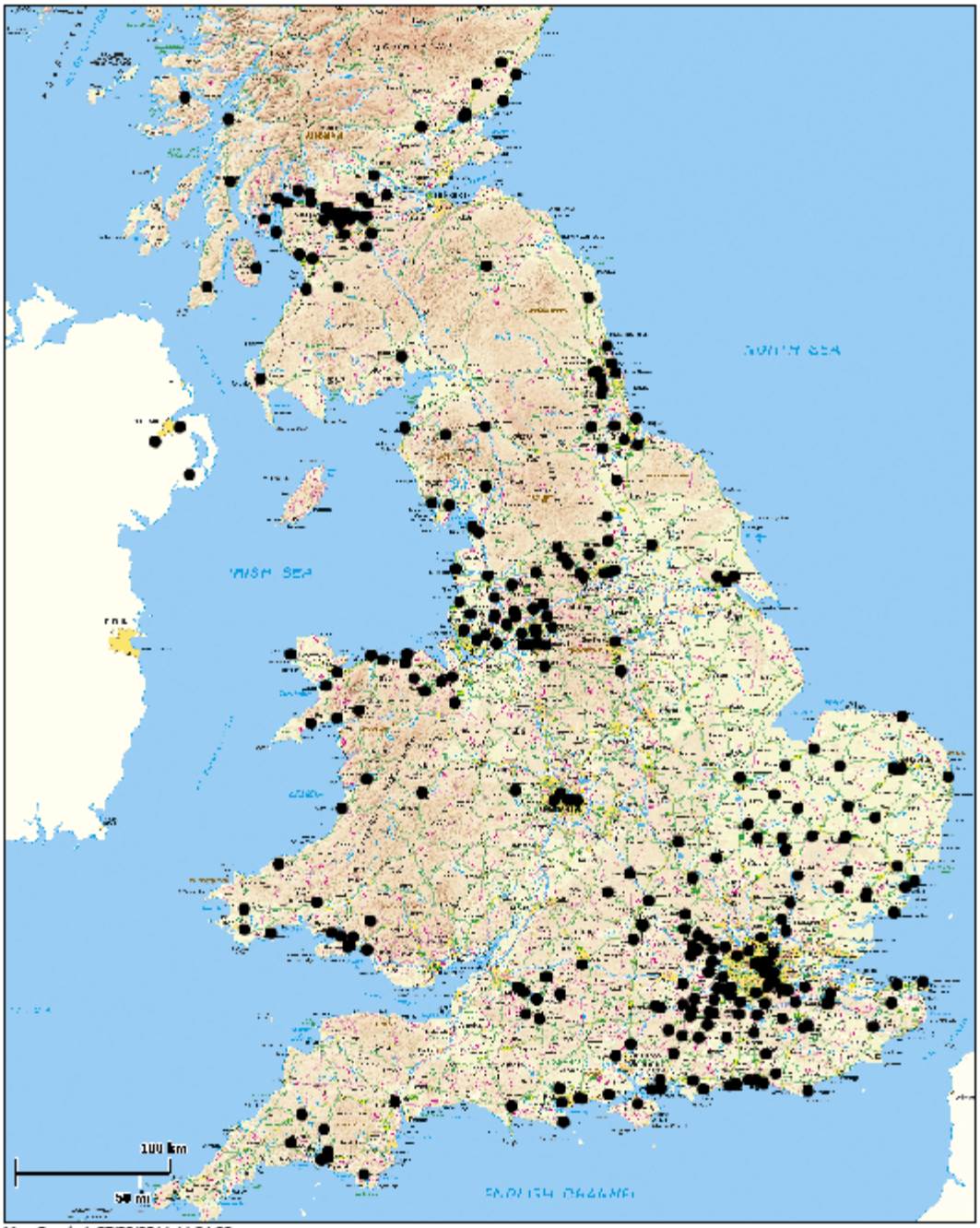
To assess how representative the geographical distribution of the database is of NHS radiology practice, we have compared the percentage of the UK radiology workload, in each region, with the percentage of NHS hospitals contributing to the database and with the percentage of room mean doses per examination in the database. The results are shown in Table 1. The radiology workload statistics for England for the financial year 2008/09 were taken from KH12 data published by the Department of Health (2010). Similar workload statistics were derived for Scotland, Wales and Northern Ireland on the basis of their relative population sizes in comparison to England.

TABLE 1 Comparison of NHS radiology workload with database sample size on a regional basis

Region	% of UK radiology workload	% of NHS hospitals in database	% of room mean doses per exam in database
England – North	26	21	55.9
England – Midlands & East	23	11	6
England – South	21	32	18
England – London	14	10	7
Scotland	8	16	11
Wales	5	9	2
Northern Ireland	3	1	0.1
ALL	100	100	100

In terms of dose measurements, it can be seen that the Midlands & East and Northern Ireland are somewhat under-represented, and the north of England has again kindly contributed more than its share of data, but the other regions are covered reasonably well.

Figure 1 Geographical distribution of hospitals in sample



Map Created: 07/09/2011 11:04:33

Map generated using the HPA-GIS Intranet Application.
For further information please contact: gis@hpa.org.uk

3.1.2 Distribution by size of trust

In previous reviews, we have compared the size of hospitals in the UK (excluding psychiatric hospitals) with the size of hospitals in the NPDD. The Department of Health now collects data for NHS trusts and not hospitals. Table 2 therefore shows the percentage of trusts offering acute services in the 2010 review of the NPDD and in England & Scotland as a function of the number of beds. (For Northern Ireland and Wales, it was not possible to separate acute services from mental health services.) Both sets of data have been taken from the Health and Social Care Yearbook 2009/10 (Binley's, 2009). Overall, there is a reasonable match between the two distributions, although there is a slight tendency to include in the present analysis more of the larger trusts, where medical physics support may be more readily available and this could affect patient doses. However, it should also be noted that this analysis by the number of beds does not include independent hospitals which mostly have fewer beds than NHS hospitals, so this review, as a whole, does include a sufficiently wide range of sizes of hospitals and trusts.

TABLE 2 Percentage of NHS trusts in England & Scotland and the National Patient Dose Database (NPDD) as a function of the number of beds

Number of beds per trust	Percentage of NHS trusts (%)	
	England & Scotland	NPDD 2010
1-499	29	24
500-999	42	40
1000-1499	20	21
1500-1999	6	10
2000+	3	5
ALL	100	100

Source: Binley's, 2009.

3.1.3 Type and amount of data

During the period January 2006 to December 2010, data were received from 55 individuals working in medical physics or radiology departments throughout the UK, as listed in the Acknowledgements. A total of 165,000 ESD values for single radiographs, 185,000 DAP values for single radiographs, 221,000 DAP values for complete examinations, and 146,000 fluoroscopy times per examination, were supplied between 2006 and 2010. Of the data above, 16,000 ESD values (10%), 77,000 DAP/radiograph values (42%), 211,000 DAP/examination values (95%), and 142,000 fluoroscopy times per examination (97%) were supplied for individual patients. The rest were supplied in the form of averaged values for several patients, usually more than ten.

The number of ESD values per radiograph collected for this report has risen by a factor of seven compared with the previous analysis (Hart et al, 2007). The number of DAP values for single radiographs has risen by a factor of three, and the number of DAP values for complete examinations has risen by 6%. About 4% of the ESD values were measured by TLDs, and 96% were calculated. The percentage of calculated ESD values has almost doubled since the 2005 review.

Table 3 shows the amount of data provided in relation to some of the factors that are most likely to affect patient dose. This is expressed as the percentage of dose measurements of each type for which information on the specified factor was supplied. The percentage has increased since 2005 for 5 of these factors, and stayed the same in one case. All the rest have decreased. Greater quantities of dose data have been supplied for the current review, but this has been accompanied by less detailed information. For ESD/radiograph, the type of detector used is known for 94% of the doses. For DAP/radiograph, the type of detector used is known for 80% of the doses.

TABLE 3 Data provision on factors likely to affect patient dose

Factor	Percentage of dose measurements (%)		
	DAP/exam	ESD/radiograph	DAP/radiograph
Patient weight	48	50	22
Patient height	46	44	7
Patient age	56	38	43
Patient gender	54	34	42
Radiographic kV		98	44
AEC/AERC used	2	2	7
Fluoroscopic kV	0.03		
Fluoroscopy time	66		
Fluoroscopy pulsed	2		
Last image hold used	2		
Filtration		8	19
CR used	5	80	52
DDR used	8	13	27
Film-screen used	0.5	1	1

AEC/AERC = Automatic exposure control/ Automatic exposure rate control.

CR = Computed radiography.

DDR = Direct digital radiography.

3.2 Dental X-ray data

3.2.1 Types and amount of data

Data were supplied for two types of radiograph:

a) intra-oral radiograph of a mandibular molar tooth;

b) panoramic radiograph of all the teeth.

For intra-oral dental radiography, the dosimetric parameter that is used to indicate patient dose is the absorbed dose to air at the tip of the spacer/collimator. This is sometimes referred to as the patient entrance dose (PED), but it differs from the ESD used in medical radiography. This is because it is measured using typical exposure conditions for an adult or for a child, but without the patient being present, and therefore does not include backscattered radiation from the patient (IPEM, 2004; Gulson et al, 2007).

Dose measurements for panoramic radiographs are made in terms of either dose-width product or dose-area product. Dose-width product (DWP) is determined by measuring the maximum dose in the centre of the beam and the width of the X-ray beam in front of the post-patient collimator in the absence of the patient. These two quantities are then multiplied together to give the DWP (in mGy mm). Dose-area product (DAP) can be derived from DWP by multiplying by the height of the X-ray beam, or it can be measured directly with a suitable DAP meter. It is expressed in terms of mGy cm^2 in this report to be comparable with the DAP measurements for medical X-ray procedures. The majority of the DAP measurements reported in this review were derived from a DWP and height measurement.

The intra-oral dataset contained more than 9,000 measurements of the patient entrance dose. The panoramic dataset contained just over 2,000 measurements of dose-area product and over 1,500 of dose-width product. The overwhelming majority of the panoramic X-ray sets were in dental practices covered by the intra-oral survey. About 4,000 general dental practices were included in the intra-oral survey. There are approximately 11,000 general dental practices in the UK (British Dental Association, 2011). The clinics sampled in this survey therefore represent about 36% of all general dental practices.

3.2.2 Geographical distribution

Dental X-ray data was supplied by eight hospital physicists in addition to the extensive data from the Dental X-ray Protection Service of the HPA. The latter service covers the UK and provided 65% of the intra-oral dose measurements and 68% of the panoramic doses. Six of the hospital physicists providing data were located in England, one in Scotland and one in Wales.

Every postcode in the UK was covered by the dental data, with the single exception of ZE (the Shetland Isles). All other postcodes, from AB (Aberdeen) to YO (Yorkshire) had at least one X-ray set (and mostly many more) included in this survey. The Isle of Man, Guernsey, and Jersey, all supplied data. Data were supplied for 7,839 intra-oral X-ray sets in England (84% of sample), 260 sets in Wales (3%), 1053 in Scotland (11%), and 175 in Northern Ireland (2%).

4 RESULTS

4.1 Medical X-ray examinations on adults

4.1.1 ESD per radiograph

For each type of radiograph, having used the selection procedure described in Section 2.4.1, a mean ESD value was calculated for each set of dose measurements in one room (where a room is defined as in Section 2.3). Table 4 shows the key parameters for the distribution of room mean ESD values. These distributions are for whatever mix of detector systems that was supplied to the database, i.e. film-screen, computed radiography or flat panel detectors. (The influence of the detector system on patient

dose is discussed in Section 5.) The key parameters are shown for those radiographs with data from a sufficiently large sample size - at least 10 hospitals, 20 rooms and 100 patients, which was the minimum sample size used in the previous reviews (Hart et al, 2002a; Hart et al, 2007). *Chest AP* and *Skull Lateral* do not quite meet this criterion because they fall short by just one hospital. *Chest AP* is tabulated because it has a huge number of patients; and *Skull Lateral* is tabulated to accompany the data for *Skull AP/PA* (it is normal practice to take both radiographs). *Lumbar spine LSJ* only had data from 3 rooms at 2 hospitals, so is not included in Table 4. Whereas 270,000 LSJ radiographs were taken per year in the UK in 1998, by 2008 this had reduced to 45,000 (Hart and Wall, 2002b; Hart et al, 2010). Three radiographs are tabulated for the first time, due to a great increase in data for them, namely *Knee AP and Lateral*, and Shoulder AP.

TABLE 4 Radiographs: distribution of mean entrance surface dose per room (adults)

Radiograph	Number			Room mean ESD distribution (mGy)					
	Hospitals	Rooms	Patients	Mean	Min.	Max.	1st quartile	Median	3rd quartile
Abdomen AP	70	167	11987	3.6	0.1	11	2.4	3.2	4.4
Chest AP	9	53	23524	0.16	0.03	0.56	0.1	0.15	0.2
Chest LAT	23	47	1211	0.48	0.22	1.26	0.3	0.4	0.54
Chest PA	95	285	43562	0.12	0.02	1.1	0.1	0.11	0.15
Knee AP	17	40	3295	0.26	0.09	0.9	0.17	0.24	0.3
Knee LAT	13	32	2767	0.33	0.1	1.9	0.2	0.3	0.34
Lumbar spine AP	80	192	5280	4.6	1.1	12.6	2.9	3.9	5.7
Lumbar spine LAT	80	185	5524	7.9	1.5	26.9	5.3	6.9	10
Pelvis AP	84	204	9132	3.2	0.8	8.3	2.2	2.8	3.9
Shoulder AP	15	34	4373	0.4	0.1	1.0	0.3	0.4	0.46
Skull AP/PA	10	21	1439	1.8	0.3	3.5	1.6	1.7	1.8
Skull LAT	9	21	300	1.1	0.7	2.3	0.9	1.0	1.1
Thoracic spine AP	38	104	1528	2.9	0.7	16	1.7	2.4	3.3
Thoracic spine LAT	40	104	1650	5.2	0.7	17	2.8	4.1	7.2

Table 5 shows the mean and range of the patient characteristics and exposure parameters from the selected dataset for the radiographs listed in Table 4. The mean patient weight is close to 70 kg for all the radiographs in Table 5. The final row of the table shows the data for all the relevant records in the current National Patient Dose Database. For this row, it can be seen that the range of exposure settings is extremely wide, because these include radiographs of small items, such as fingers, and large items, such as hips.

Figure 2 shows histograms of X-ray room mean ESD values for the 14 types of radiograph in Table 4. These histograms are drawn from the selected dataset. The vertical axes in Figure 2 show the number of X-ray rooms in each dose band of the histogram. The total number of X-ray rooms and the total number of patients (i.e. dose measurements) contributing to the histogram of room mean values are indicated for each type of radiograph. The solid vertical line indicates the third quartile of the current data. The dotted vertical line indicates the third quartile of the corresponding 2005 data.

Where a radiograph did not have sufficient data to feature in the 2005 review (for instance, *Knee AP* or *Knee LAT*) this 2005 third quartile is less reliable than for radiographs which did feature in the 2005 review. There were no data for *Shoulder AP* in the 2005 review so no such third quartile can be shown.

TABLE 5 Radiographs (entrance surface dose data): mean patient characteristics and exposure parameters (adults)

Radiograph	Patient age (years)	Patient weight (kg)	Tube voltage (kV)	Total filtration (mm Al)	Exposure setting (mAs)
Abdomen AP	57 (16-106)	70 (36-114)	76 (60-94)	3.1 (2.6-3.6)	41 (1-440)
Chest AP	68 (16-107)	70 (49-93)	83 (62-104)	2.8 (2.5-3.3)	5 (0.3-315)
Chest LAT	64 (16-96)	70 (48-89)	89 (70-125)	2.5	13 (0.8-400)
Chest PA	59 (16-108)	70 (35-178)	88 (65-125)	3.0 (2.5-3.6)	5 (0.3-405)
Knee AP	56 (16-100)	72	61 (52-68)		4 (1-125)
Knee LAT	58 (16-100)	72	61 (52-71)		4 (1-96)
Lumbar spine AP	60 (16-100)	70 (43-139)	78 (65-109)	3.1 (2.6-3.6)	46 (1-556)
Lumbar spine LAT	60 (16-100)	70 (43-139)	89 (74-110)	3.1 (2.6-3.6)	56 (1-941)
Pelvis AP	66 (16-101)	70 (38-111)	75 (62-90)	3.1 (2.6-3.5)	33 (1-400)
Shoulder AP	57 (16-102)	71	64 (58-69)		5 (1-100)
Skull AP/PA	41 (16-98)	71 (70-80)	72 (69-83)		20 (1-246)
Skull LAT	47 (16-98)	70	66 (63-74)		11 (2-49)
Thoracic spine AP	60 (16-99)	70 (45-96)	78 (65-102)	3.0 (2.6-3.4)	30 (1-403)
Thoracic spine LAT	60 (16-99)	69 (45-96)	74 (60-96)	3.0 (2.6-3.4)	82 (2-480)
ALL	59 (16-108)	70 (35-178)	75 (50-125)	3.0 (2.5-3.6)	16 (0.02-1420)

Note: the range from minimum to maximum is given in brackets.

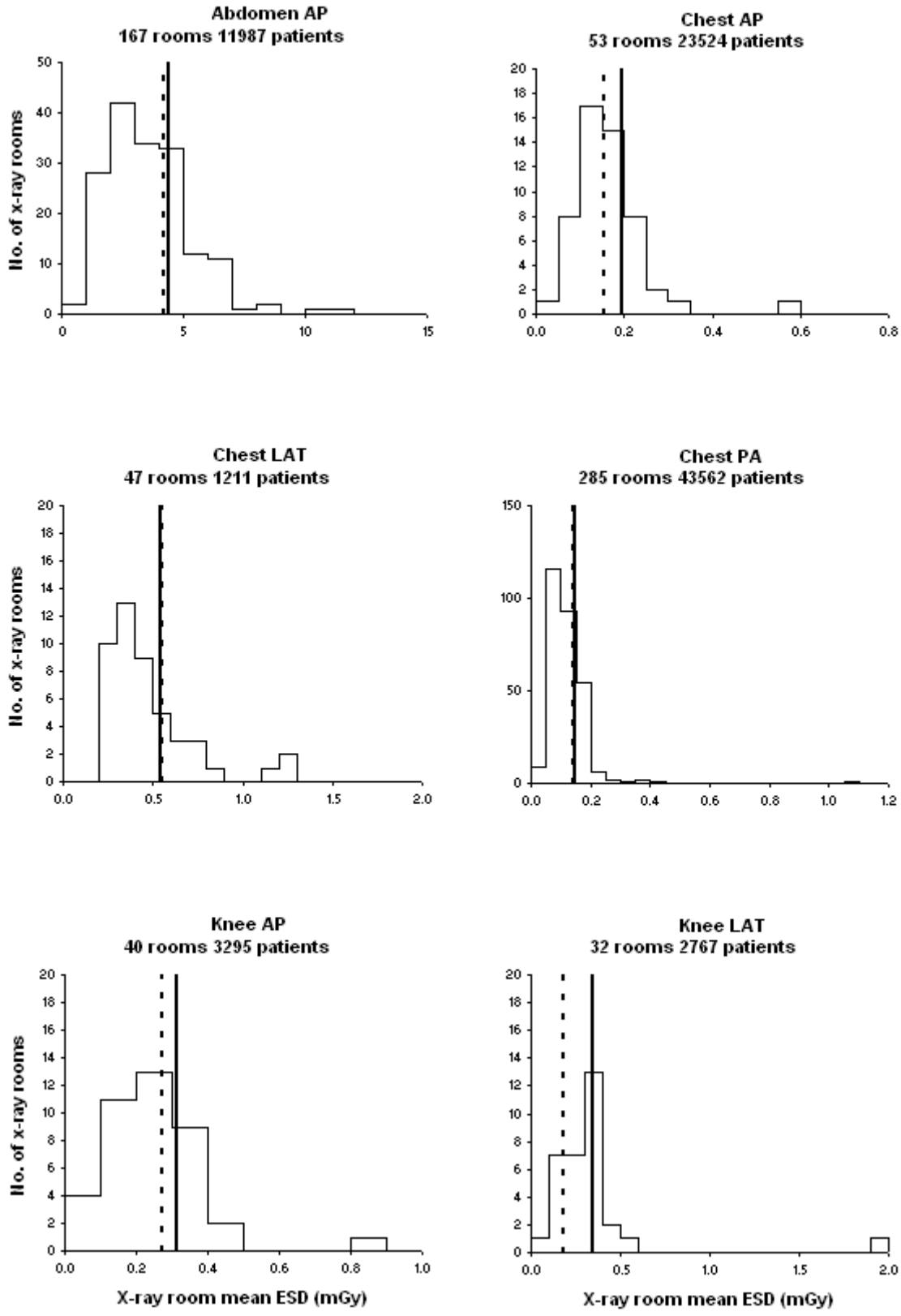


FIGURE 2 Distribution of X-ray room mean entrance surface dose (adults)

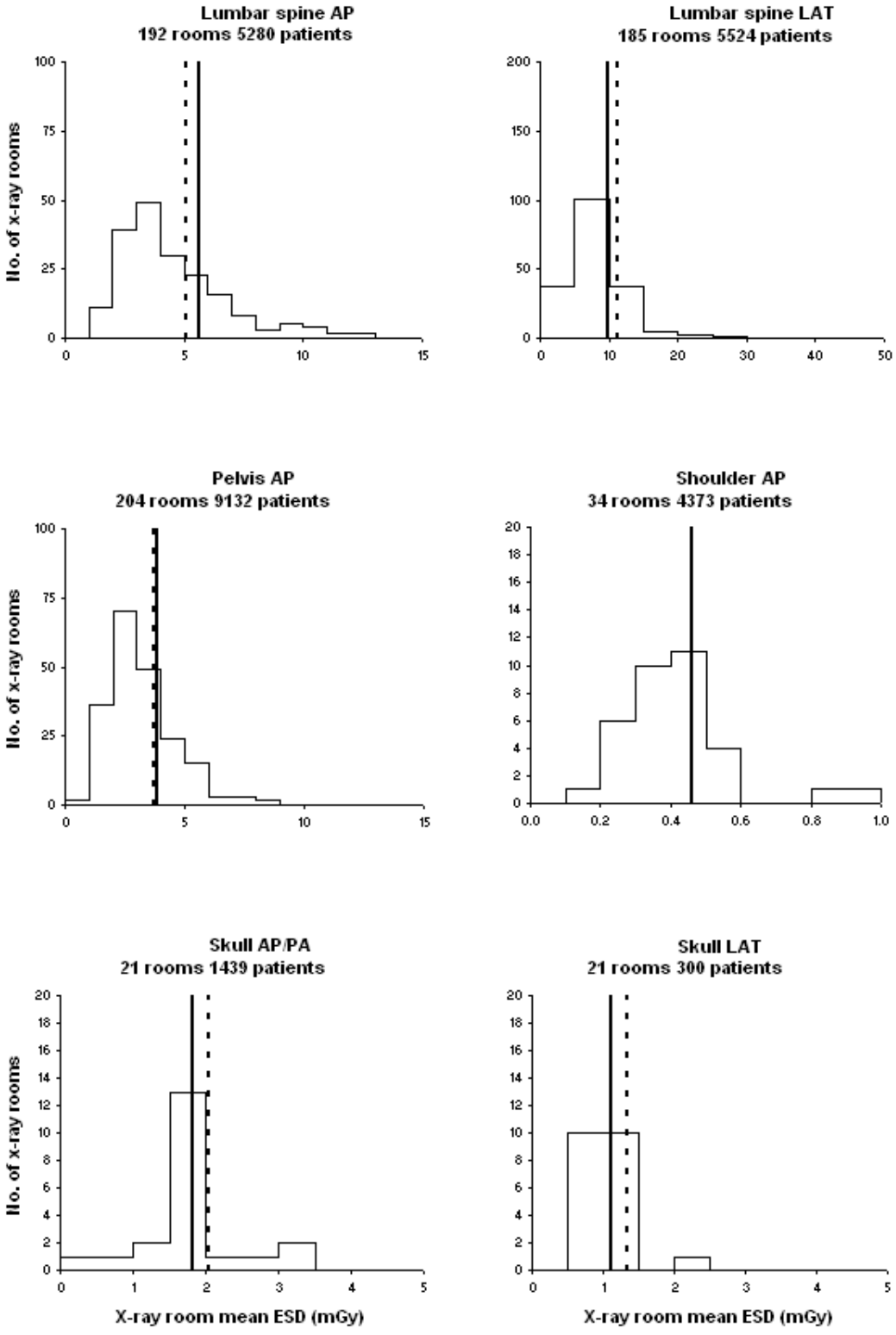


FIGURE 2 (continued)

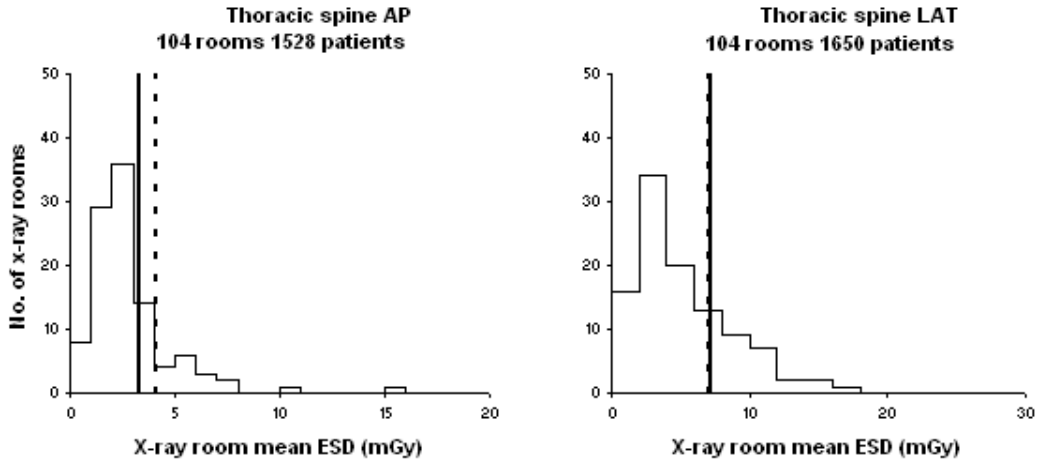


FIGURE 2 (continued)

4.1.2 DAP per radiograph

Table 6 shows the distribution for the selected dataset of room mean DAP values for those radiographs with data for at least 10 hospitals, 20 rooms and 100 patients. *Chest Lateral*, *Lumbar Spine LSJ*, *Skull AP/PA*, and *Skull Lateral*, did not reach this criterion. In 1998, 550,000 skull radiographs were taken per year in the UK, but by 2008 this had reduced to 55,000 (Hart and Wall, 2002b; Hart et al, 2010). LSJ radiographs (as mentioned in Section 4.1.1) are also used much less frequently than a few years ago, and this trend probably explains the paucity of the data for both LSJ and skull radiographs.

Table 7 shows the mean and range for the patient characteristics and exposure parameters from the selected dataset for the radiographs listed in Table 6. The mean patient weight is close to 70 kg for all the radiographs in Table 7. The final row of Table 7 shows the data for all the relevant records in the current National Patient Dose Database.

Figure 3 shows histograms of X-ray room mean DAP values for all the radiographs in Table 6. These histograms are again drawn from the selected dataset and the same information is given for each histogram as in Figure 2. The solid vertical line indicates the current third quartile. The dotted vertical line indicates the third quartile for the 2005 review.

TABLE 6 Radiographs: distribution of mean dose-area product per room (adults)

Radiograph	Number			Room mean DAP distribution (Gy.cm^2)					
	Hospitals	Rooms	Patients	Mean	Min.	Max.	1st quartile	Median	3rd quartile
Abdomen AP	78	188	17831	2	0.5	6.1	1.4	1.8	2.5
Cervical spine AP	18	40	844	0.23	0.03	4.7	0.05	0.1	0.15
Cervical spine LAT	21	44	982	0.2	0.03	2.1	0.07	0.1	0.16
Chest AP	22	41	3986	0.18	0.01	1.9	0.1	0.11	0.15
Chest PA	162	433	110491	0.09	0.01	0.8	0.06	0.08	0.1
Lumbar spine AP	101	206	5475	1.3	0.3	6.7	0.9	1.2	1.5
Lumbar spine LAT	125	278	6636	2.1	0.6	6.6	1.4	1.9	2.5
Pelvis AP	144	305	19048	1.8	0.1	6.5	1.3	1.7	2.2
Thoracic spine AP	54	92	1320	0.8	0.2	2.7	0.5	0.7	1.0
Thoracic spine LAT	54	96	1450	1.3	0.2	6.5	0.8	1.1	1.5

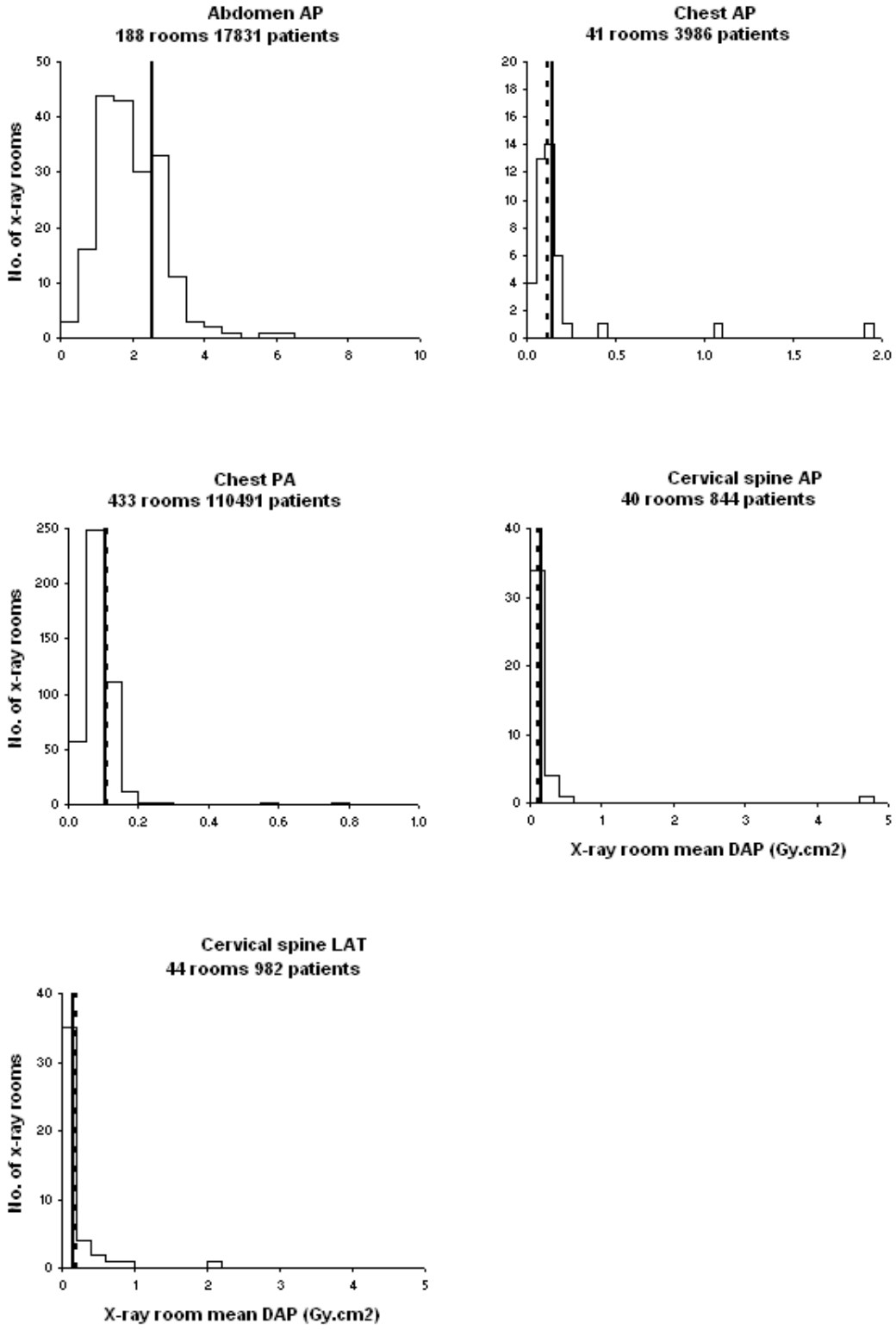


FIGURE 3 Distribution of X-ray room mean dose-area product per radiograph (adults)

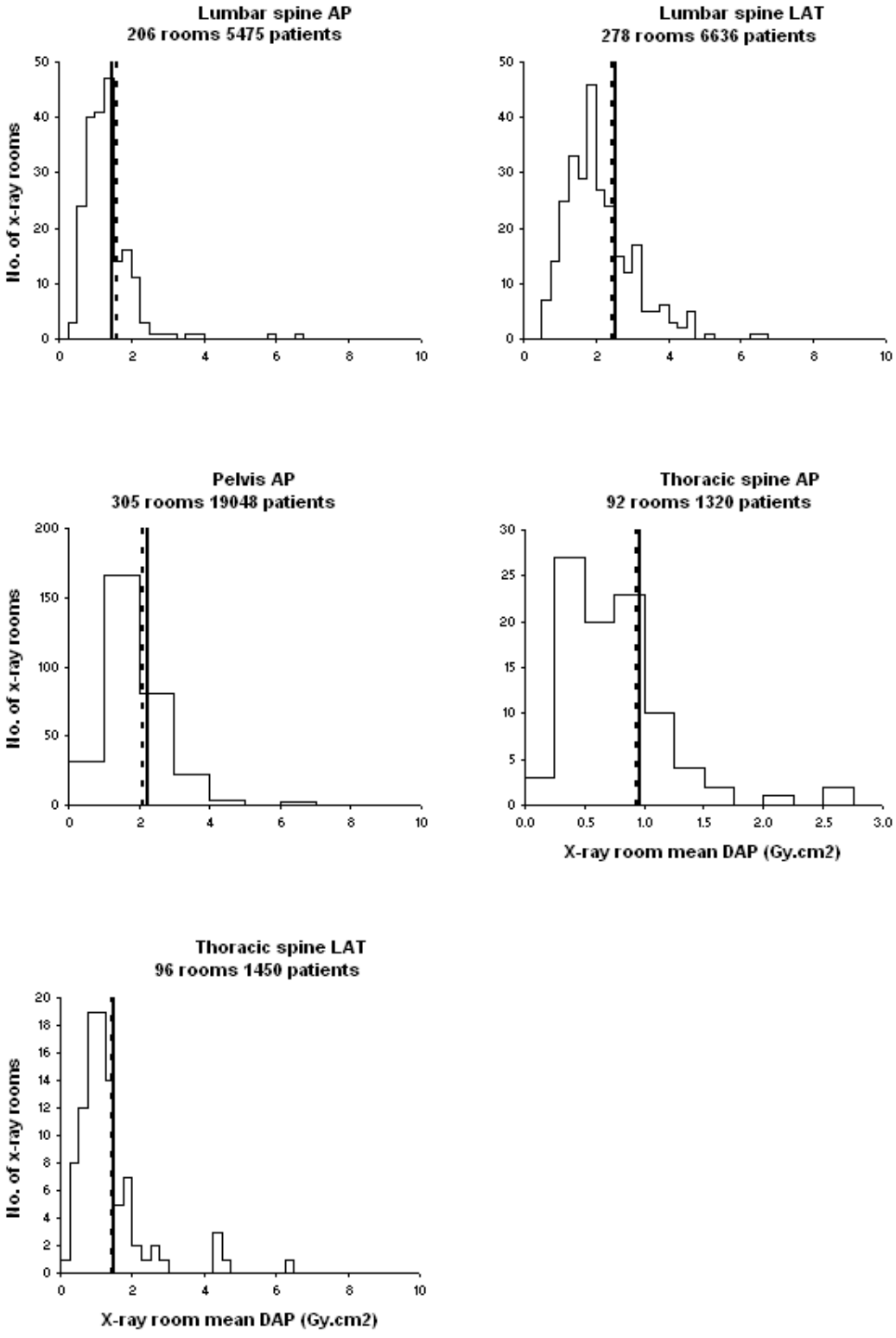


FIGURE 3 (continued)

TABLE 7 Radiographs (dose-area product data): mean patient characteristics and exposure parameters (adults)

Radiograph	Patient age (years)	Patient weight (kg)	Tube voltage (kV)	Total filtration (mm Al)	Exposure setting (mA s)
Abdomen AP	57 (16-100)	71 (41-130)	77 (68-90)	3.1 (2.5-4)	39 (1-499)
Cervical spine AP	57 (19-103)	71 (50-89)	68 (60-80)	3.0 (2.5-4.2)	7 (0.7-36)
Cervical spine LAT	56 (18-103)	71 (50-92)	72 (64-85)	3.0 (2.5-4.2)	10 (0.9-169)
Chest AP	73 (17-100)	69 (38-121)	85 (64-119)	3.0 (2.6-3.5)	5 (0.1-90)
Chest PA	64 (16-104)	70 (34-170)	90 (60-135)	3.1 (2.4-4.3)	3 (0.02-302)
Lumbar spine AP	60 (17-103)	71 (38-121)	79 (70-90)	3.1 (2.4-4.3)	38 (1-297)
Lumbar spine LAT	61 (17-98)	71 (38-121)	88 (75-118)	3.1 (2.4-4.3)	48 (1-560)
Pelvis AP	66 (16-104)	71 (38-114)	76 (64-90)	3.1 (2.4-4.3)	33 (1-336)
Thoracic spine AP	61 (16-95)	69 (44-102)	78 (70-90)	3.0 (2.5-3.6)	22 (2-132)
Thoracic spine LAT	61 (16-95)	69 (44-102)	77 (64-96)	3.0 (2.5-3.6)	45 (2-579)
ALL	62 (16-104)	70 (34-170)	79 (46-135)	3.1 (2.4-4.3)	18 (0.02-579)

Note: the range from minimum to maximum is given in brackets

4.1.3 DAP per diagnostic examination

Table 8 shows the distribution of room mean DAP values for complete diagnostic examinations with data for at least 10 hospitals, 20 rooms and 100 patients. (Interventional procedures are considered in Section 4.2). A brief description of each examination is given in a glossary in Appendix C. Table 8 contains 6 examinations that were not included in the corresponding table in the 2005 review. These are *Abdomen*, *Barium Swallow (video), Chest, Coronary Graft Angiography, Lumbar Spine*, and *Proctography*. *Barium Swallow (video), Coronary Graft Angiography* and *Proctography* usually involved fluoroscopy, but the other 3 examinations did not. However, it is clear that these complete examinations of the *Abdomen, Chest* and *Lumbar Spine* involve higher doses than tabulated for DAP/radiograph in Table 6 (or for the usual projections AP + LAT for Lumbar Spine). Presumably non-routine projections are being used.

As was found in the previous review (Hart et al, 2007), the mean weight for *Coronary Angiography* patients was above the normal selection range (65-75 kg). A range of 75-85 kg was therefore used again for this examination in order to maximise the sample of patients. The same approach was applied for *Coronary Graft Angiography*.

TABLE 8 Complete examinations: mean dose-area product per room (adults)

Examination	Number			Room mean DAP distribution (Gy.cm^2)					
	Hospitals	Rooms	Patients	Mean	Min.	Max.	1st Quartile	Median	3rd Quartile
Abdomen	14	42	8127	4.3	0.3	38	1.8	3.1	4.4
Barium Enema	73	152	20555	16	1.4	99	7.6	13	21
Barium Follow Through	46	94	4027	7	0.3	36	3.4	5.6	8.4
Barium Meal	38	74	1116	9	0.1	76	3.9	6.5	11.8
Barium Meal & Swallow	26	62	2641	8	1.9	42	3.5	6.3	10.3
Barium Small Bowel Enema	15	26	469	18	2	64	8.9	12.8	23
Barium Swallow	66	130	9710	7	1.1	167	3	4.7	7.5
Barium Swallow (video)	25	61	1554	2.4	0.1	8.5	1.0	1.5	3.4
Chest	11	35	11484	0.7	0.01	7.4	0.07	0.1	0.3
Coronary Angiography*	53	140	36087	25	8	87	16	23	31
Coronary Graft Angiography*	17	49	1278	40	20	98	26	31	47
Femoral Angiography	22	48	2534	46	0.9	197	18	35	56
Fistulography	13	24	530	7	0.1	28	2.4	5	7.7
Hysterosalpingography	40	89	4248	1.7	0.1	22	0.5	1.1	1.9
IVU	18	22	1531	11.5	1.5	26	7.4	12	14
Lumbar Spine	10	29	1745	5	0.6	35	2	3	6
MCU	18	33	274	5	0.3	20	2.4	3.7	7
Nephrostography	19	36	522	6	0.1	25	2.5	4	8.7
Proctography	10	26	703	15	0.2	150	4.9	9.6	14
Sialography	13	22	340	3	0.02	20	0.4	1.8	2.8
Sinography	15	25	124	4.3	0.6	12	1.2	2.7	7.2
T Tube Cholangiography	14	32	301	4	0.2	16	2.1	3.4	4.9
Water Soluble Enema	21	58	1117	14	0.6	156	6	9	13
Water Soluble Swallow	13	36	1082	7	0.9	37	3.4	4.6	6.4

* Mean patient weight range 75-85 kg.

Table 9 shows the mean and range for the patient characteristics and exposure parameters from the selected dataset for the examinations listed in Table 8. The number of digital spot images per examination is included in the last column of Table 9. The mean patient weight is close to 70 kg for all the examinations in Table 9, apart from the two types of coronary angiography, for which a patient weight range of 75-85 kg has been chosen. In these two cases, the mean patient weight is close to 80 kg. The ranges for fluoroscopy times are very large and, given the minimum values, it appears that some incomplete examinations may have been included. However, these are balanced by some very long fluoroscopy times for individual patients. The mean fluoroscopy time may therefore be reasonably typical. However, it would generally be preferable to use the mean fluoroscopy times given on a room by room basis in Table 10, since these are less influenced by extreme individual values.

TABLE 9 Complete examinations (dose area product data): mean patient characteristics and exposure parameters (adults)

Examination	Patient age (years)	Patient weight (kg)	Radiographic tube voltage (kV)	Fluoroscopy time (seconds)	No. of images per exam
Abdomen	60 (16-97)	70 (46-86)	74 (70-90)	122 (7-840)	3 (2-20)
Barium Enema	64 (16-97)	72 (37-155)	88 (50-120)	96 (0.1-8796)	16 (1-1230)
Barium Follow Through	49 (16-99)	71 (33-171)	86 (50-120)	95 (0.3-6371)	6 (1-110)
Barium Meal	59 (16-96)	70 (40-134)	86 (50-120)	126 (1-960)	17 (1-107)
Barium Meal & Swallow	62 (16-98)	72 (37-150)	82 (50-120)	103 (0.1-3300)	27 (1-534)
Barium Small Bowel Enema	51 (16-88)	70 (38-108)	84 (50-120)	404 (6-1452)	8 (1-32)
Barium Swallow	62 (16-100)	72 (30-190)	81 (50-120)	113 (1-9960)	30 (1-2122)
Barium Swallow (video)	65 (16-99)	68 (32-118)	70 (50-120)	183 (5-6180)	63 (1-1155)
Chest	67 (16-100)	70	85 (80-95)	225 (100-474)	2 (2-16)
Coronary Angiography*	63 (17-100)	80 (38-177)	72 (50-120)	243 (1-8880)	333 (1-7373)
Coronary Graft Angiography*	68 (27-88)	81 (44-136)	70 (70-120)	649 (213-1157)	757 (1-3032)
Femoral Angiography	68 (19-102)	73 (40-134)	73 (50-110)	288 (6-10200)	84 (1-1132)
Fistulography	63 (17-89)	71 (50-108)	77 (70-120)	237 (6-1669)	41 (1-150)
Hysterosalpingography	32 (18-95)	70 (40-166)	76 (50-120)	38 (0.1-3420)	4 (1-86)
IVU	59 (16-94)	74 (39-175)	71 (60-120)	21 (6-2400)#	7 (1-22)
Lumbar Spine	61 (16-95)	69 (50-111)			3 (2-9)
MCU	58 (18-101)	72 (41-111)	86 (60-120)	68 (0.4-840)	7 (1-49)
Nephrostography	63 (16-90)	71 (39-123)	82 (50-120)	175 (1-3300)	6 (1-38)
Proctography	51 (16-86)	70 (42-121)	90 (60-120)	59 (6-5820)	23 (1-480)
Sialography	53 (18-92)	72 (50-116)	71 (50-90)	48 (5-480)	10 (1-64)
Sinography	59 (20-91)	70 (41-108)	82 (50-120)	80 (3-258)	5 (1-17)
T Tube Cholangiography	64 (25-93)	70 (46-115)	78 (60-120)	94 (4-2580)	5 (1-58)
Water Soluble Enema	65 (16-101)	71 (33-127)	84 (50-120)	112 (1-6480)	9 (1-67)
Water Soluble Swallow	65 (18-97)	71 (41-129)	81 (50-120)	90 (1-1800)	12 (1-150)

Note: the range from minimum to maximum is given in brackets.

27% of IVU examinations included fluoroscopy.

* Mean patient weight range 75-85 kg.

Figure 4 shows histograms of X-ray room mean DAP values for the examinations listed in Table 8. These histograms are again drawn from the selected dataset and the same information is given for each histogram as in Figure 2. The solid vertical line indicates the third quartile of the current data. The dotted vertical line indicates the third quartile of the corresponding 2005 data. Where an examination did not have sufficient data to feature in the 2005 review (for instance, *Abdomen* or *Barium Swallow (video)*), this third quartile is less reliable than for examinations which did feature in the 2005 review.

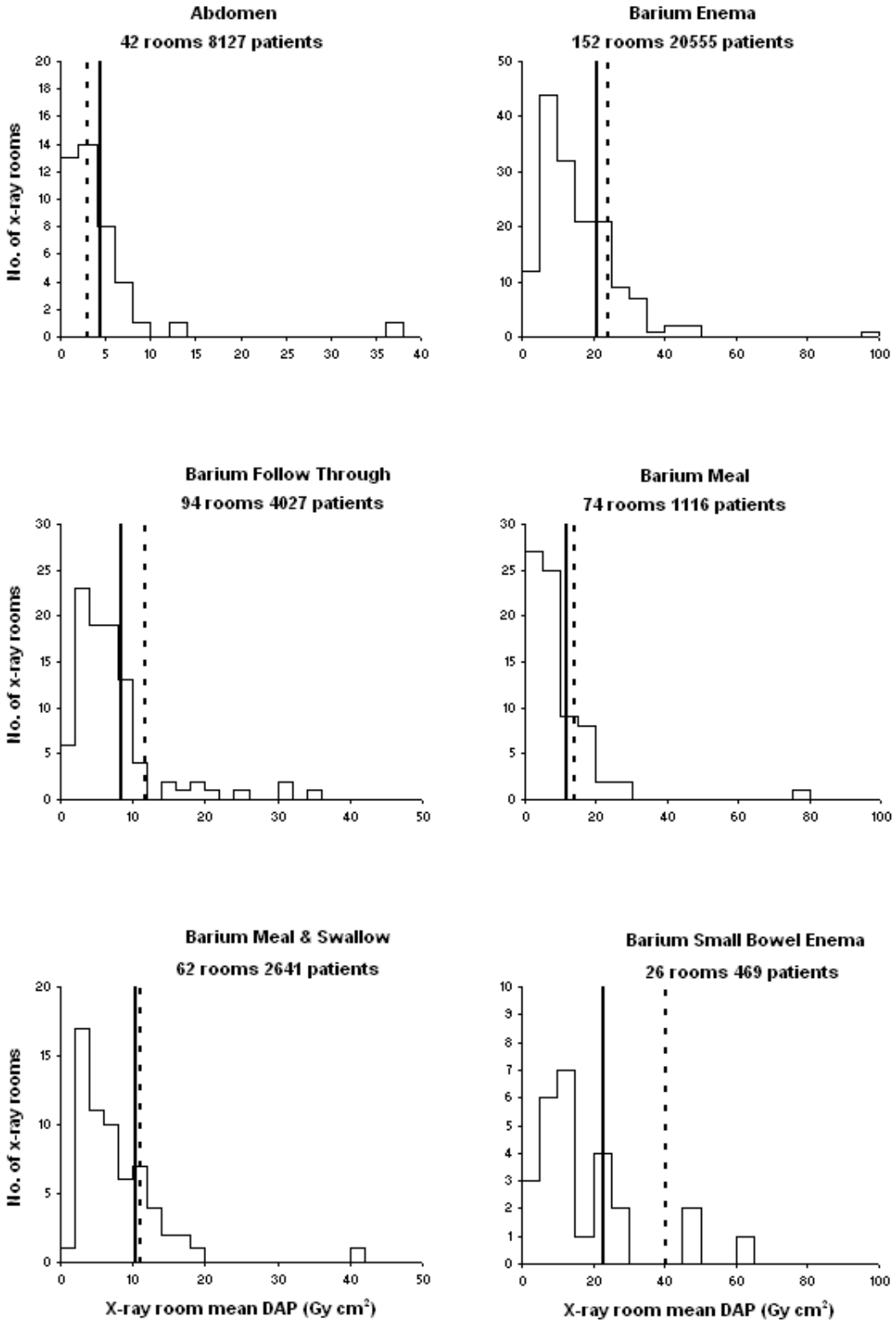


FIGURE 4 Distribution of X-ray room mean dose-area product per examination (adults)

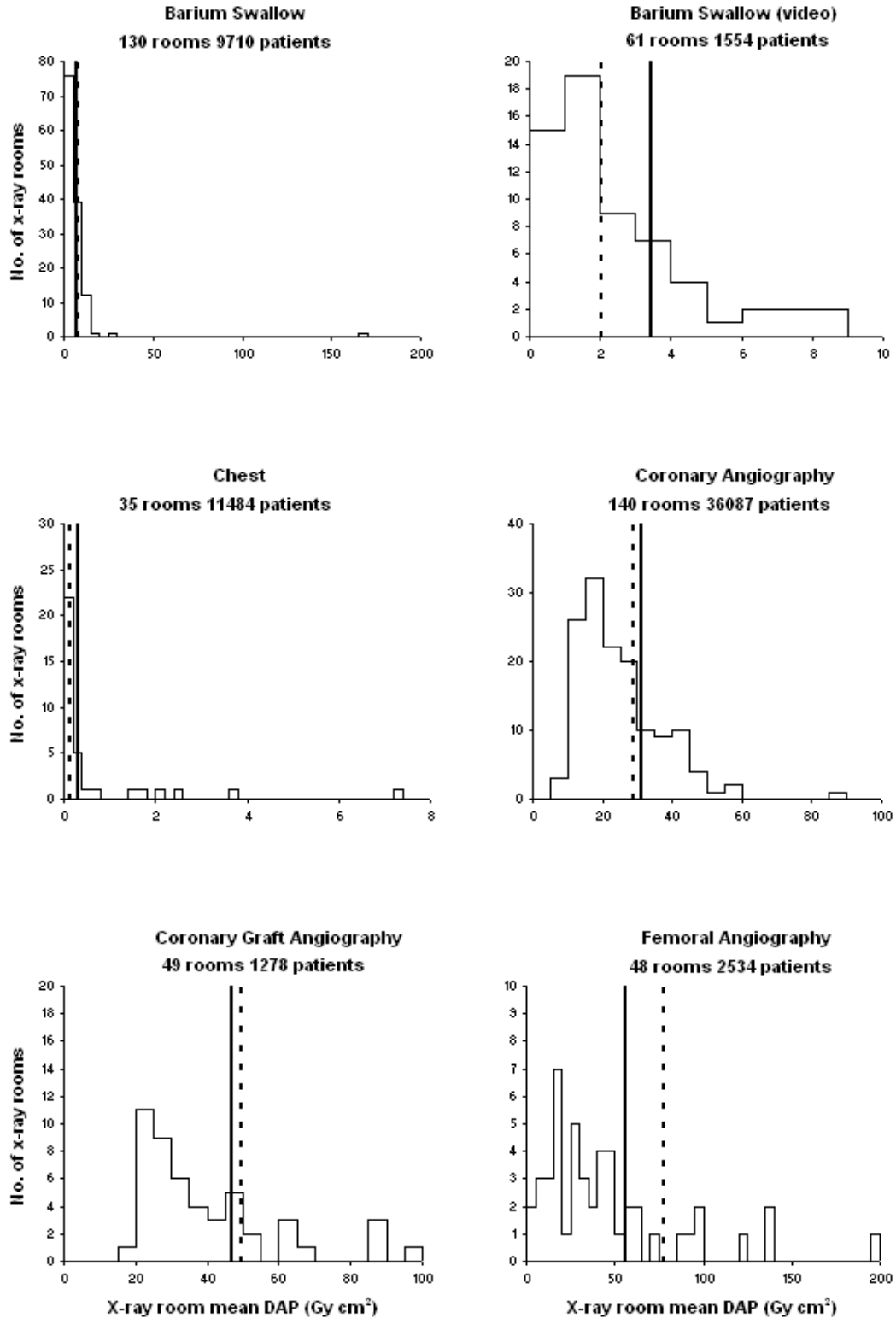


FIGURE 4 (continued)

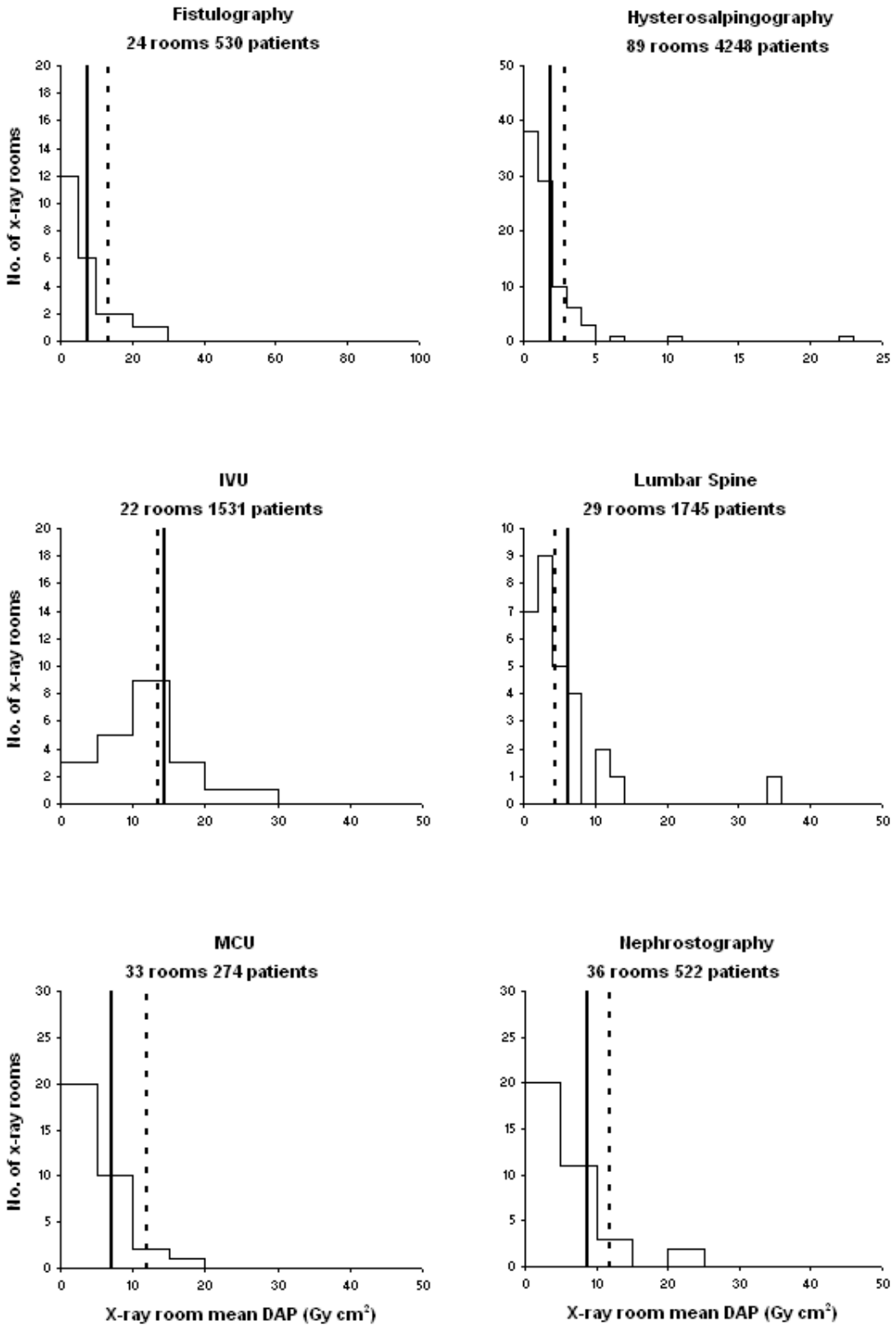


FIGURE 4 (continued)

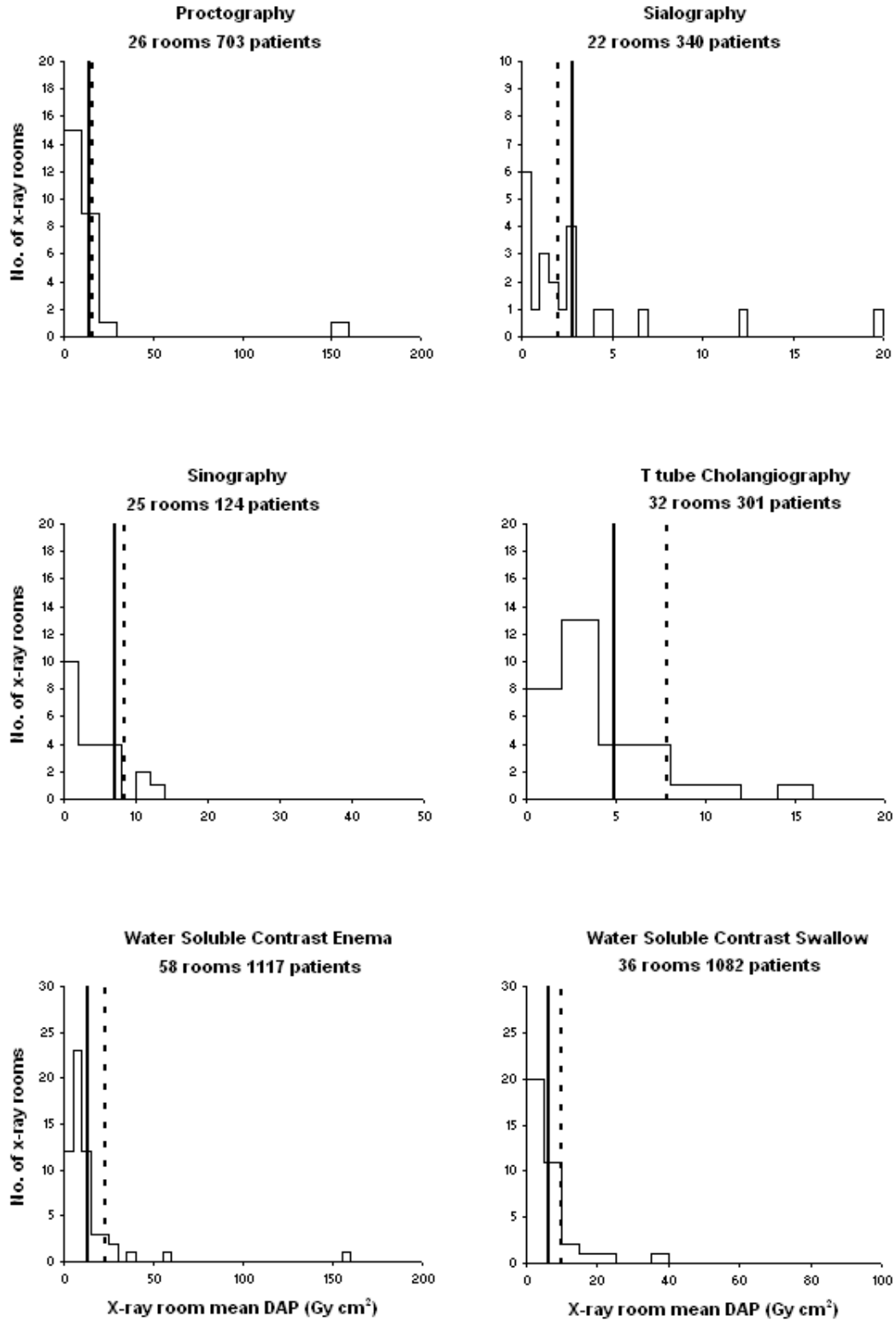


FIGURE 4 (continued)

4.1.4 Fluoroscopy time per diagnostic examination

Dose-area product is the preferred dose quantity for complete examinations, but for any radiology rooms without DAP meters, the fluoroscopy time offers an alternative means of obtaining a partial indication of patient exposure. It makes no allowance for the influence of fluoroscopic dose rate or field size or the contribution from spot imaging to the patient dose, but if these other parameters are held fairly constant, the fluoroscopy time provides a relative indication of the patient dose.

Table 10 shows key parameters for the distribution of mean fluoroscopy time per room for the same examinations as listed in Table 9, with the exception of *Abdomen*, *Chest* and *Lumbar Spine* which are, generally, purely radiographic examinations, and also excluding *IVUs* for which only a minority of examinations involve fluoroscopy. The fluoroscopy times shown in Table 10 differ from those in Table 9 because the former are based on room mean data and the latter on individual patient data. Figure 5 shows histograms of the distribution of X-ray room mean fluoroscopy time per examination. The solid vertical line indicates the third quartile of the current distribution. The dotted vertical line indicates the third quartile of the corresponding 2005 distribution.

TABLE 10 Complete examinations: mean fluoroscopy time per room (adults)

Examination	Number			Room mean fluoroscopy time distribution (seconds)					
	Hospitals	Rooms	Patients	Mean	Min.	Max.	1st Quartile	Median	3rd Quartile
Barium Enema	57	129	17490	123	1	272	88	121	156
Barium Follow Through	39	84	3304	92	2	238	62	86	118
Barium Meal	29	62	857	119	6	234	95	120	155
Barium Meal & Swallow	24	61	2638	122	1	312	88	114	140
Barium Small Bowel Enema	13	24	351	406	98	762	232	418	533
Barium Swallow	55	115	8267	107	24	423	75	98	126
Barium Swallow (video)	23	58	1280	175	21	362	137	149	210
Coronary Angiography*	46	120	31324	221	89	620	172	215	255
Coronary Graft Angiography*	14	45	1045	649	213	1157	512	669	784
Femoral Angiography	17	41	2186	323	85	1188	190	289	355
Fistulography	11	21	179	259	24	786	84	190	399
Hysterosalpingography	35	82	3131	38	1	160	26	33	44
MCU	16	31	236	75	19	185	42	57	96
Nephrostography	15	31	440	174	24	509	82	147	234
Proctography	9	25	657	74	18	306	44	60	80
Sialography	10	16	207	65	6	243	15	49	91
Sinography	14	24	121	82	24	162	56	88	104
T Tube Cholangiography	13	30	247	114	18	918	49	74	105
Water Soluble Enema	18	52	1008	112	12	473	79	101	122
Water Soluble Swallow	12	34	986	99	24	273	69	85	108

* Mean patient weight range 75-85 kg.

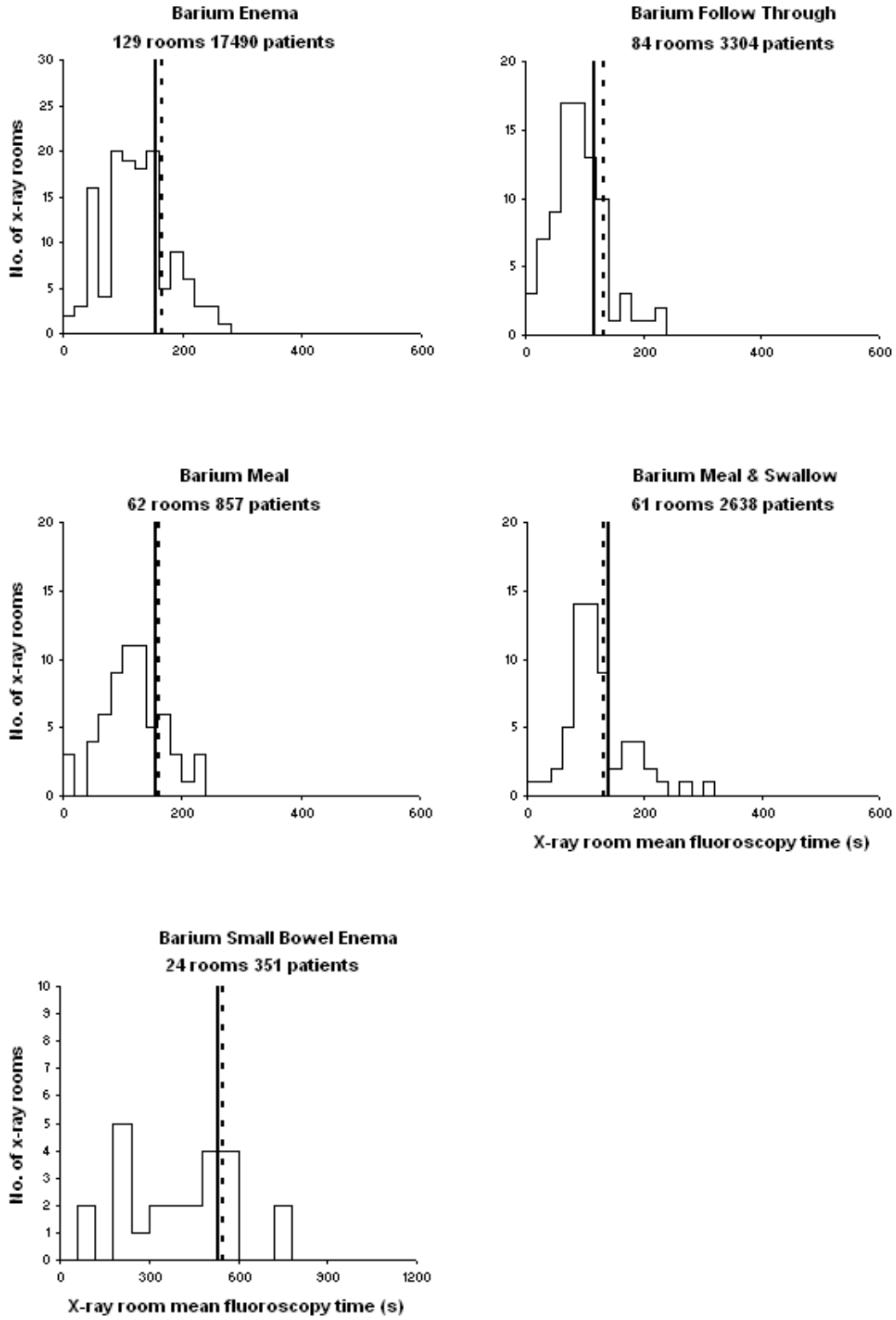


FIGURE 5 Distribution of X-ray room mean fluoroscopy time per examination (adults)

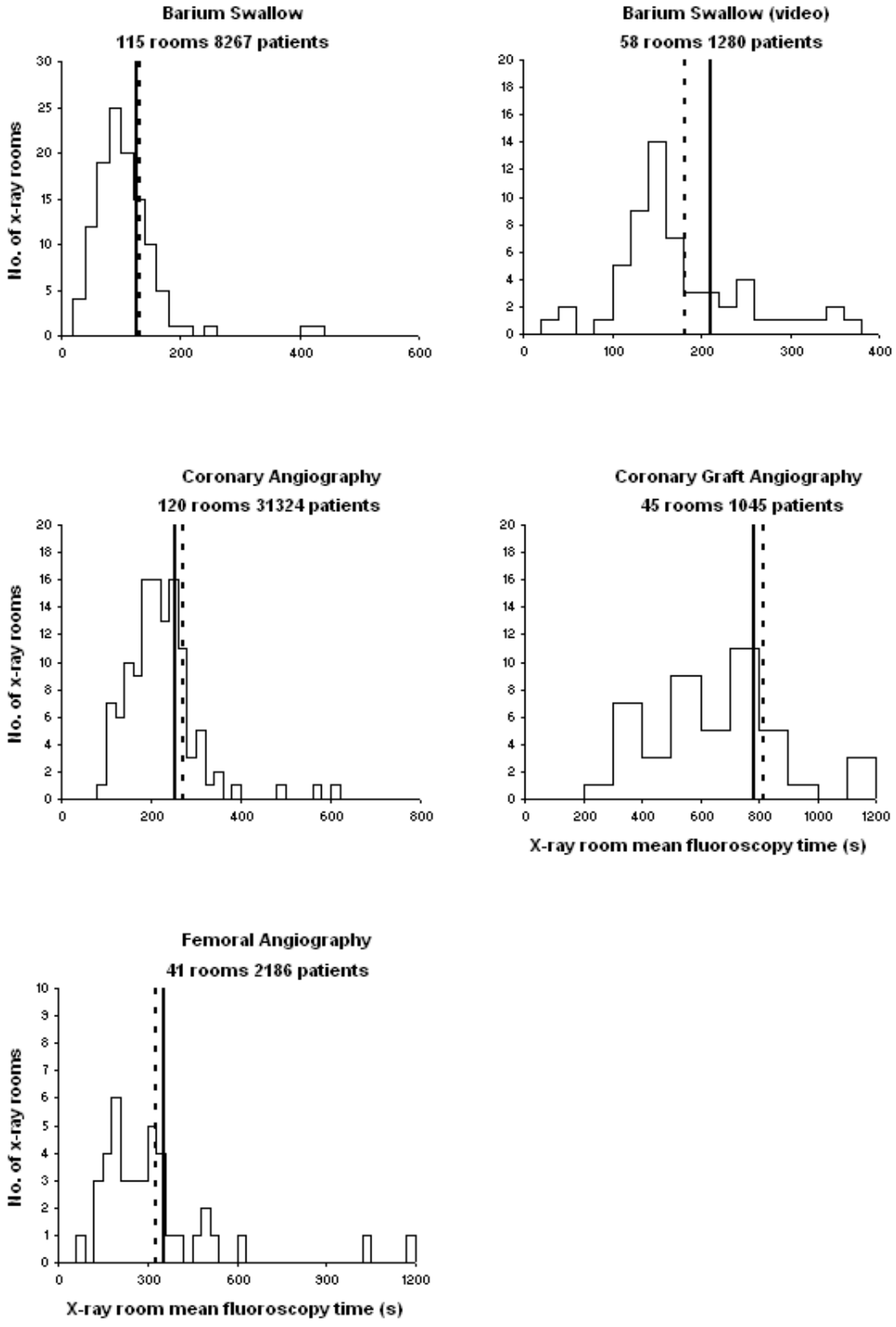


FIGURE 5 (continued)

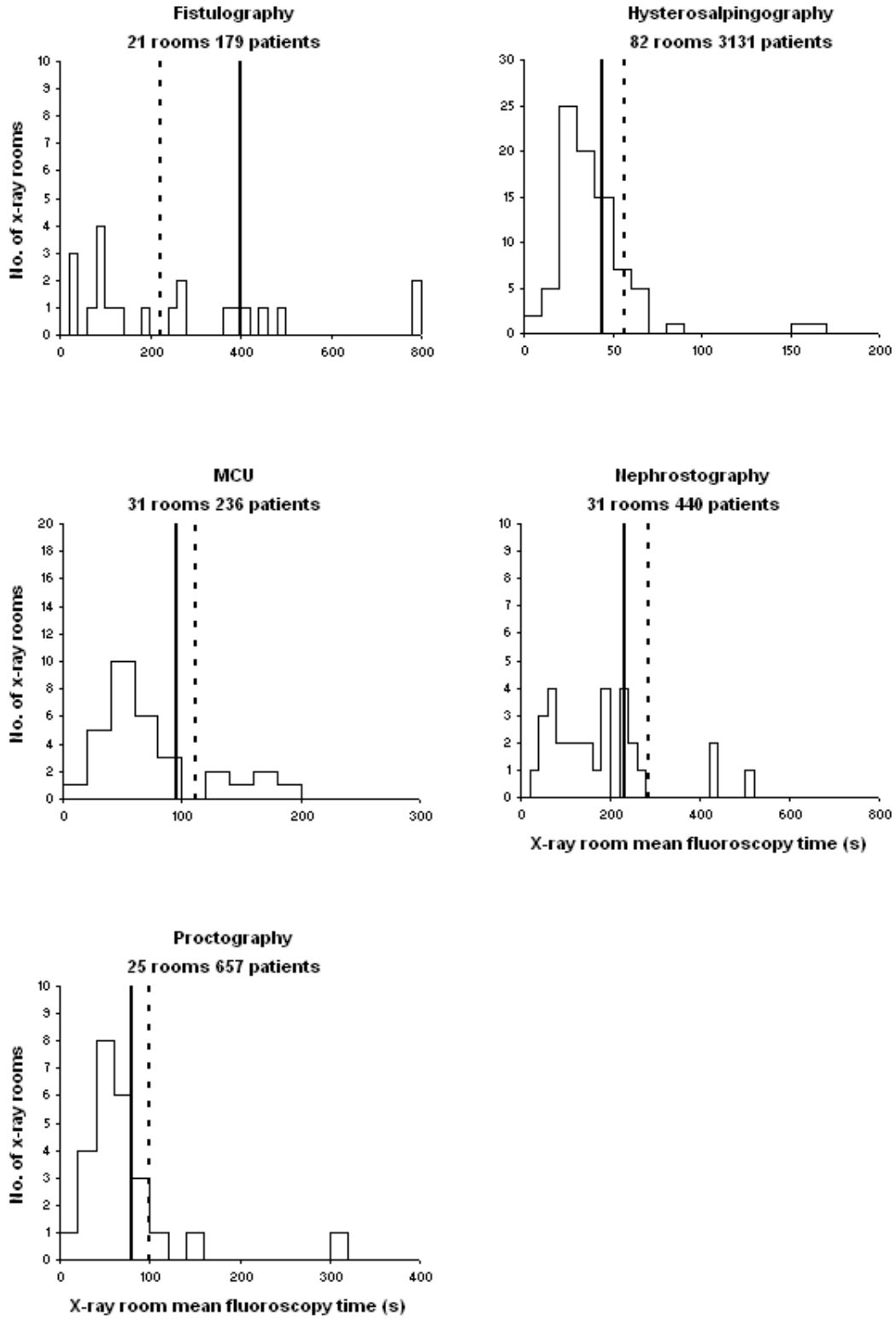


FIGURE 5 (continued)

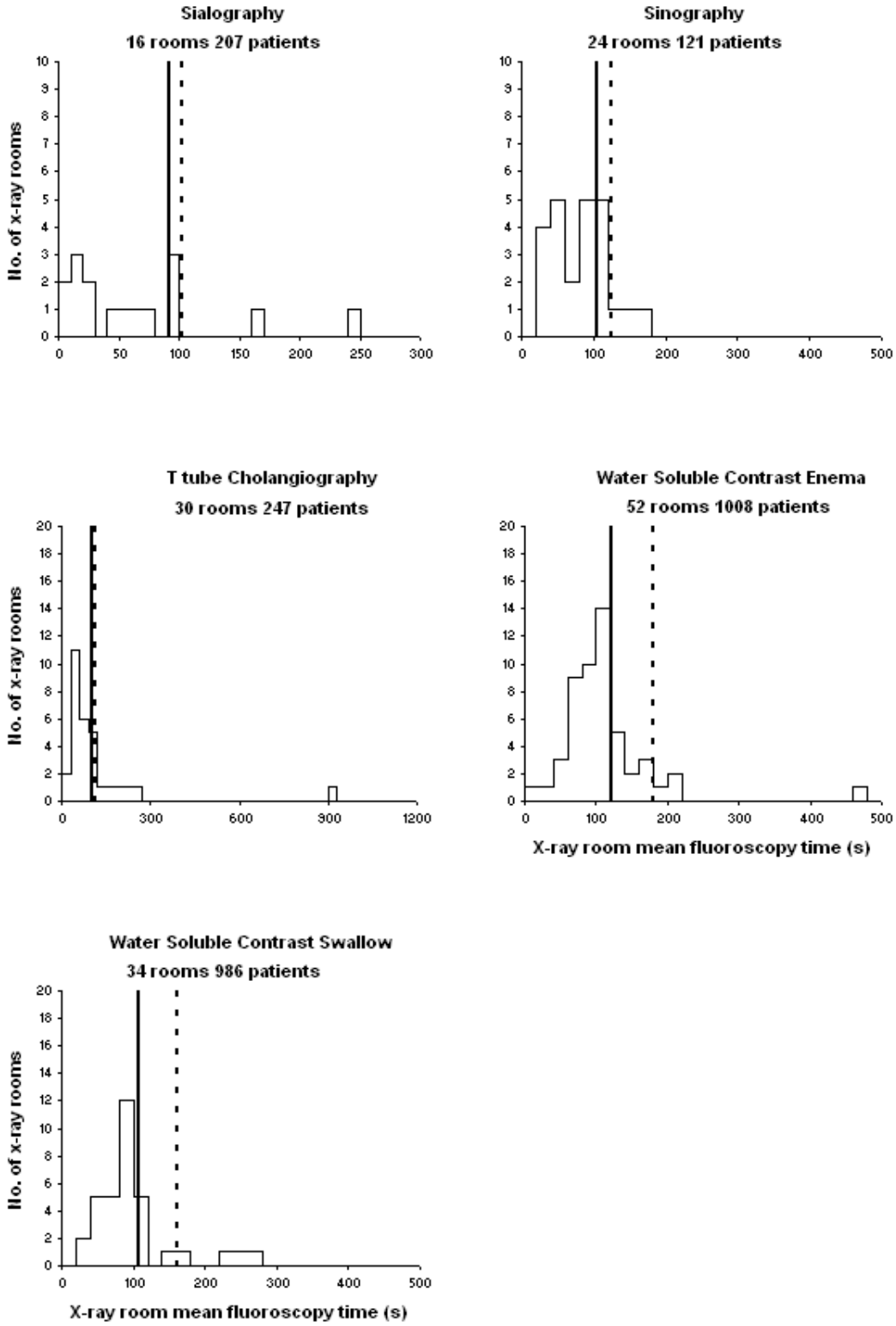


FIGURE 5 (continued)

4.2 Interventional procedures on adults

4.2.1 DAP per interventional procedure

Table 11 shows the distribution of room mean DAP values for interventional procedures with data for at least 10 hospitals, 20 rooms, and 100 patients. A brief description of each procedure is given in a glossary in Appendix C. *ERCPs* were again mainly submitted to the NPDD as a mix of diagnostic and interventional procedures. There were insufficient purely interventional *ERCPs* to be included in Table 11. There were also insufficient *Oesophageal Dilations* to include in this table. As was the case for *Coronary Angiography*, the mean weight for patients for *PTCAs* was above the normal selection range (65-75 kg). A range of 75-85 kg was therefore used for this procedure in order to maximise the sample of patients.

TABLE 11 Interventional procedures: mean dose-area product per room (adults)

Procedure	Number			Room mean DAP distribution (Gy.cm^2)					
	Hospitals	Rooms	Patients	Mean	Min.	Max.	1st Quartile	Median	3rd Quartile
Biliary Intervention	10	22	279	33	6	111	16	32	43
Facet Joint Injection	20	30	2720	4	0.2	16	1.4	3.1	6
Hickman Line Insertion	21	37	829	2	0.1	10	0.5	1	3
Nephrostomy	24	31	464	8	0.5	24	3	5	13
Oesophageal Stent	15	24	199	13	3	76	6	7	13
Pacemaker (permanent)	31	78	5062	7	0.2	34	2	4	7
PTCA 1 stent *	14	39	5805	34	12	81	21	24	40

* Mean patient weight range 75-85 kg.

Table 12 shows the mean and range for the patient characteristics and exposure parameters from the selected dataset for the procedures listed in Table 11. The final column of Table 12 shows the number of digital spot images per procedure. As in Table 9, there is a wide range in fluoroscopy times; the room mean fluoroscopy times given in Table 13 are probably more reliable.

TABLE 12 Interventional procedures (dose area product data): mean patient characteristics and exposure parameters (adults)

Examination	Patient age (years)	Patient weight (kg)	Radiographic tube voltage (kV)	Fluoroscopy time (seconds)	No. of images per exam
Biliary Intervention	71 (24-99)	69 (41-110)	80 (60-120)	704 (12-4032)	6 (1-51)
Facet Joint Injection	53 (18-96)	72 (41-115)	90 (50-120)	88 (0.1-3600)	3 (1-20)
Hickman Line Insertion	60 (18-88)	72 (41-120)	77 (50-100)	61 (1-1404)	2 (1-35)
Nephrostomy	68 (16-90)	70 (51-89)	87 (70-120)	237 (1-3000)	4 (1-14)
Oesophageal Stent	71 (32-90)	69 (45-95)	84 (50-120)	256 (6-1310)	6 (1-42)
Pacemaker (permanent)	75 (17-101)	73 (32-155)	71 (50-100)	321 (1-6180)	18 (1-1014)
PTCA 1 stent *	62 (18-94)	81 (33-161)	70 (50-120)	606 (6-8640)	983 (1-3783)

* Mean patient weight range 75-85 kg.

Note: the range from minimum to maximum is given in brackets.

Figure 6 shows histograms of X-ray room mean DAP values for those interventional procedures listed in Table 11. These histograms are again drawn from the selected dataset and the same information is given for each histogram as in Figure 2. The solid vertical line indicates the third quartile of the current data. The dotted vertical line indicates the third quartile of the corresponding 2005 data.

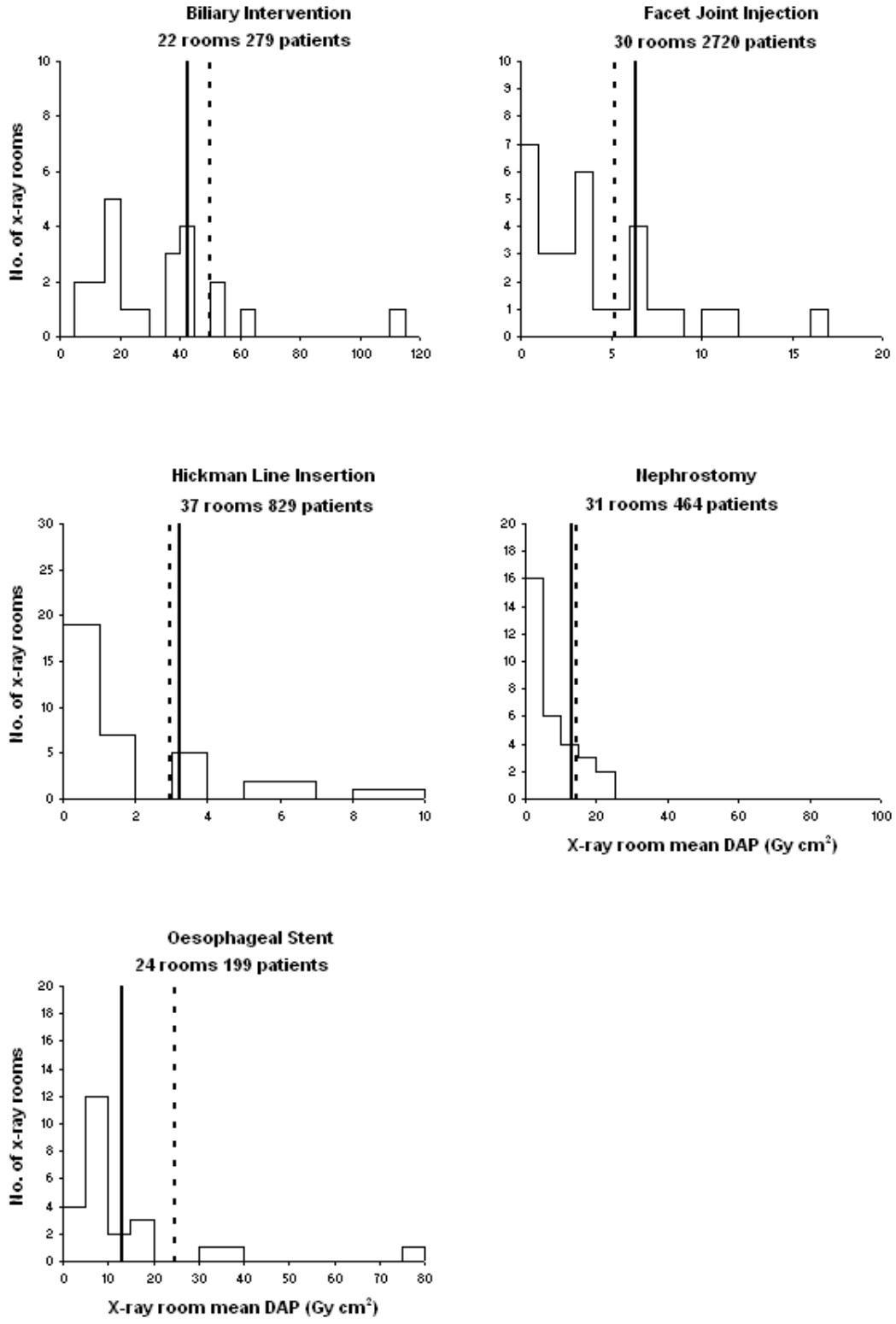


FIGURE 6 Distribution of X-ray room mean dose-area product per procedure (adults)

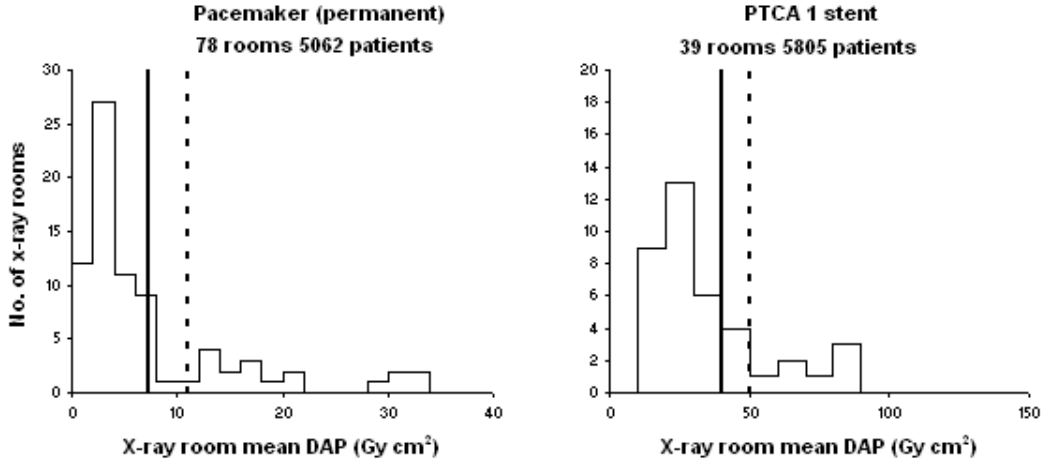


FIGURE 6 (continued)

4.2.2 Fluoroscopy time per interventional procedure

Table 13 shows key parameters for the distribution of mean fluoroscopy time per room for the same procedures as listed in Table 11. The fluoroscopy times shown in Table 13 differ from those in Table 12 because the former are based on room mean data and the latter on individual patient data.

TABLE 13 Interventional procedures: mean fluoroscopy time per room (adults)

Procedure	Number			Room mean fluoroscopy time distribution (seconds)					
	Hospitals	Rooms	Patients	Mean	Min.	Max.	1st Quartile	Median	3rd Quartile
Biliary Intervention	9	21	276	687	147	1116	536	703	849
Facet Joint Injection	17	28	2641	61	4	118	35	58	84
Hickman Line Insertion	18	34	696	75	4	510	29	51	87
Nephrostomy	20	25	332	399	57	1630	118	191	404
Oesophageal Stent	12	21	165	249	51	696	163	248	298
Pacemaker (permanent)	24	63	4475	307	103	670	227	295	358
PTCA 1 stent *	10	35	5444	516	84	882	336	565	675

* Mean patient weight range 75-85 kg.

Figure 7 shows histograms of the distribution of X-ray room mean fluoroscopy time per procedure. The solid vertical line indicates the third quartile of the current distribution. The dotted vertical line indicates the third quartile of the corresponding 2005 data.

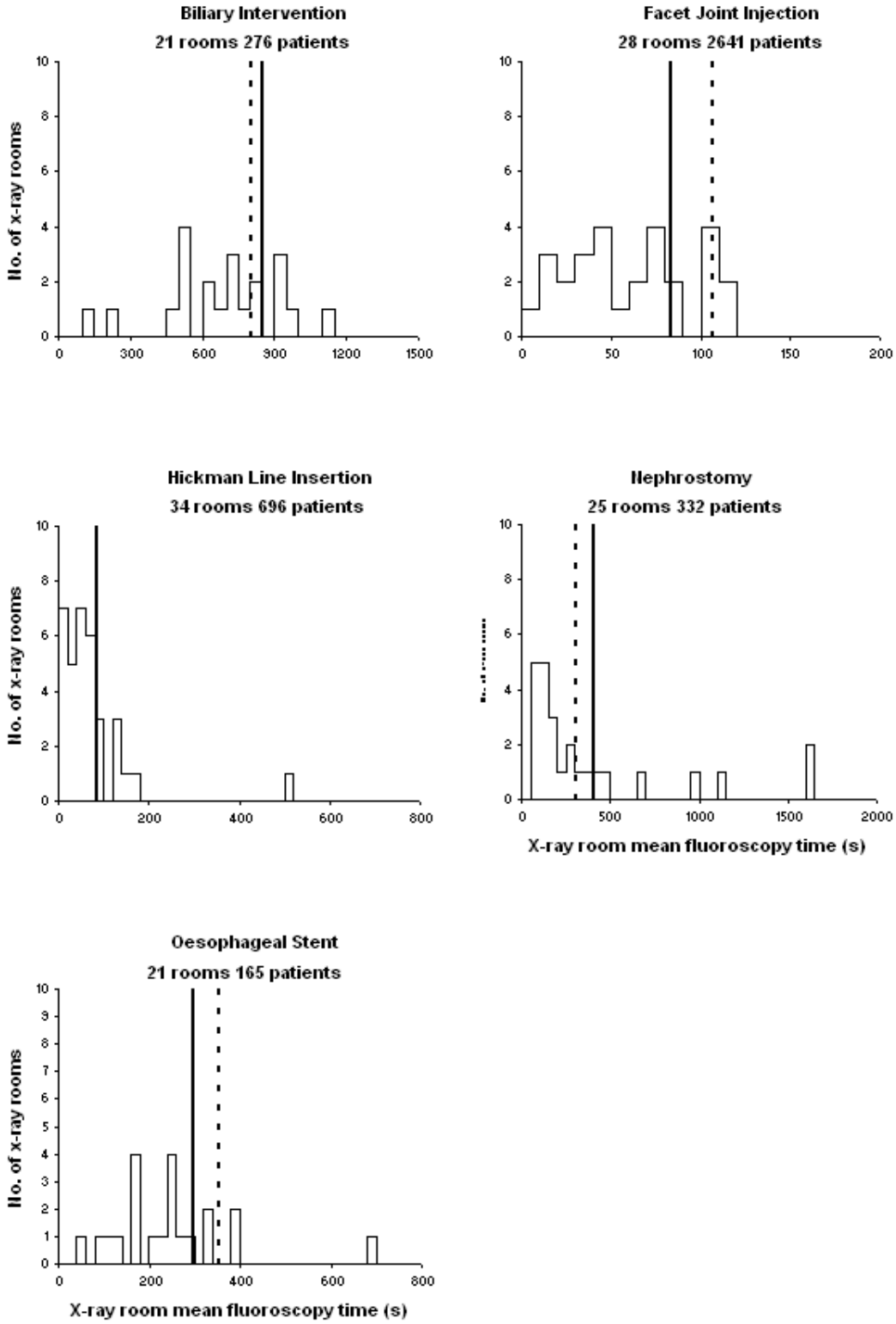


FIGURE 7 Distribution of X-ray room mean fluoroscopy time per procedure (adults)

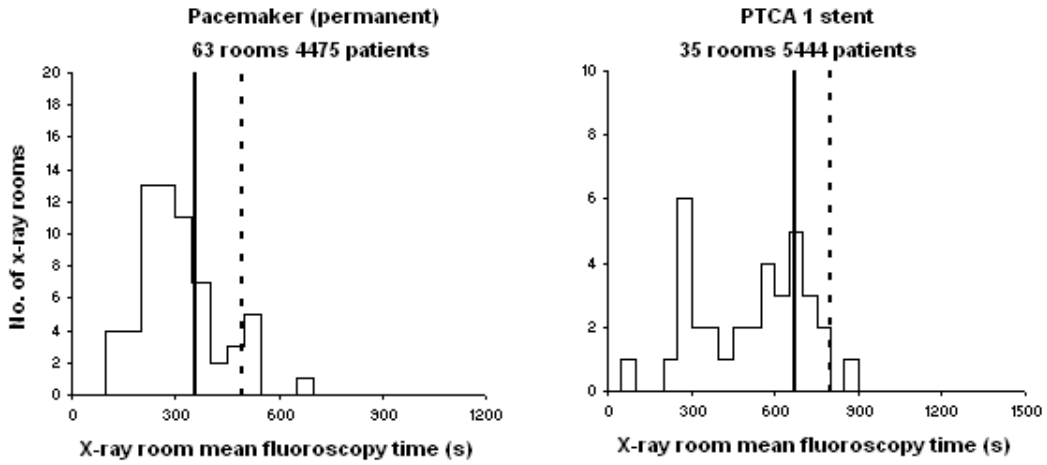


FIGURE 7 (continued)

4.3 More limited data on other examinations and procedures on adults

Table 14 shows a summary of data for 36 other examinations or procedures for which the sample size was too small to include them in Tables 8 or 11, but for which information was supplied for at least 5 hospitals, 5 rooms and 30 patients. Although the sample sizes in Table 14 are insufficient to be truly representative of national practice, the information may be useful in providing a rough indication of typical practice and patient doses for these types of examination. See the glossary in Appendix C for a brief explanation of what is involved in these examinations and procedures.

AICD refers to the insertion of *Automatic Implantable Cardioverter Defibrillators*, for which the mean DAP is identical to that for permanent pacemakers. The insertion of biventricular pacemakers involves a larger DAP and a longer fluoroscopy time (by a factor of more than 4 in each case) than for ordinary pacemakers, whether permanent or temporary. *Embolisation of Uterine Fibroids* and *Mesenteric Angiography* give the highest mean DAPs of any procedures in Table 14. The mean fluoroscopy time for *Embolisation of Uterine Fibroids* is the longest presented in this review at 1,715 seconds. *Mesenteric Angiography* is often carried out as an emergency, and may often involve interventional activity, such as dissolving a blood clot, angioplasty or stenting. This explains the high doses from *Mesenteric Angiography*. *Percutaneous Endoscopic Gastrostomy* provides a lower mean DAP than *Radiologically Inserted Gastrostomy*, though there is not much difference in the mean fluoroscopy times for these 2 procedures. *Percutaneous Transhepatic Cholangiography* has a mean DAP of 45 Gy cm^2 in Table 14, compared with 25 Gy cm^2 in the 2005 review (Hart et al, 2007); the sample size for the current review is 2 to 3 times bigger, so these latest data are probably more reliable. *Urodynamics* seems to be the preferred term nowadays for *Bladder Pressure Studies*, so it is used in this Table. There is little difference between the DAP and fluoroscopy time for *Urodynamics* in this review and for *Bladder Pressure Studies* in the 2005 review. Data were supplied for at least 5 hospitals, 5 rooms and 30 patients for examinations of the ankle, elbow, knee, and wrist: all of these had a mean DAP of 0.1 Gy cm^2. Such a sample size was also supplied for examinations of the shoulder, which had a mean DAP of 0.2 Gy cm^2.

Not shown in Table 14 is information on *TIPS (transjugular intrahepatic portosystemic shunt)* which is still an infrequent procedure. About 100 were performed in the UK in 1998 and about 700 in 2008 (Hart and Wall, 2002b; Hart et al, 2010). Data were provided in relation to *TIPS* from just one room and 15 patients. The mean dose was 205 Gy cm^2 and the mean fluoroscopy time was 1,700 seconds. These latest data are fairly similar to the combined data from the 2000 and 2005 reviews for a total of 23 patients from 11 rooms at 4 hospitals. For that combined dataset, the room mean DAP for *TIPS* was 242 Gy cm^2 and the mean fluoroscopy time was 2,264 seconds.

TIPS is not alone in having a mean dose of more than 200 Gy cm^2. Three other procedures give doses in that region: embolisation of the iliac artery; embolisation of the mesenteric artery; and stenting of an abdominal aortic aneurysm. Although the data received were insufficient for any of these procedures to appear in Table 14, such relatively large doses were evident in this and the previous review, giving some confidence that they are probably typical.

TABLE 14 : Summary of data on other examinations and interventional procedures (adults)

Examination/procedure	Number			Mean of room mean DAP ($Gy\ cm^2$)	Mean of room mean fluoro. time (seconds)	Mean tube voltage (kV)
	Hospitals	Rooms	Patients			
AICD	6	9	222	7	235	
Angiography (Cerebral)	5	8	913	69	772	85
Angiography (Mesenteric)	8	11	118	151	1009	74
Angiography (Renal)	6	7	64	48	361	71
Angioplasty (Femoral)	6	7	149	49	588	
Angioplasty (Iliac)	8	9	225	52	401	
Aortography (Arch)	9	13	179	21	249	70
Arthrography (Hip)	8	10	82	1.4	55	
Dacryocystogram	6	12	180	2.4	63	
Electrophysiology	6	11	399	11	1019	72
Embolisation (Uterine fibroid)	10	11	273	120	1715	
Embolisation (Varicocele)	8	8	71	20	625	70
ERCP (Diagnostic)	9	14	362	4	154	73
ERCP (Interventional)	7	16	820	10	263	70
Filter (Inferior Vena Cava)	10	18	198	21	214	71
Hip	6	14	1713	4	46	71
Naso-gastric feeding tube	11	19	198	7	270	71
Oesophageal dilation	6	10	55	7	233	71
Pacemaker (Biventricular)	8	14	332	30	1472	
Pacemaker (Temporary)	8	16	234	4.5	191	70
Patent Foramen Ovale closure	5	5	90	15	664	
Pelvis	9	27	1761	3	32	70
Percutaneous Endoscopic Gastrostomy	8	13	69	4	138	71
Percutaneous Transhepatic Cholangiography	12	19	246	45	891	69
PTCA 2 stents*	9	19	815	52	653	
Radio Frequency cardiac catheter ablation*	9	21	2510	23	1348	70
Radiologically Inserted Gastrostomy	5	6	65	8	165	70
Retrograde pyelography	7	8	34	5	82	74
Right Heart Catheterisation*	6	7	99	27	270	81
Stent (Biliary)	8	11	97	37	671	70
Stent (Bowel)	5	10	51	36	691	75
Stent (Iliac artery)	5	5	77	52	722	70
Stent (Superior Vena Cava)	7	8	39	21	338	71
Stent (Ureteric)	12	19	206	14	525	75
Thoracic spine	7	22	1238	3		
Urodynamics	10	14	803	4	47	77

* Mean patient weight range 75-85 kg.

4.4 Medical X-ray examinations on children

We have previously recommended national reference doses for 3 paediatric examinations: *Micturating Cystourethrography (MCU)*, *Barium Meal* and *Barium Swallow* (Hart et al, 2002a; Hart et al, 2007). We applied the methods described in NRPB-R318 (Hart et al, 2000) to the paediatric data in the NPDD for which either the patient thickness or both the height and weight were available. This enabled us to adjust the measurements of DAP per examination made on children of known size to values appropriate for children of the nearest standard size. Five standard sizes are available corresponding to newborn babies and 1, 5, 10 and 15 year old children.

For this review, a special effort was made to gather sufficient data to provide additional reference doses for paediatric radiographs, e.g. Abdomen AP, Chest AP/PA. 16 UK hospitals specialising in children were contacted, with the approval of the British Society of Paediatric Radiology, to request data on patient sizes and doses for common radiographs, as well as for the 3 examinations with reference doses. Unfortunately, whereas several hospitals did supply information on radiographs, in total there were insufficient data to establish reference doses. The overwhelming majority of the paediatric data submitted with size information gave only height and weight, so this method was used to adjust the doses. It appears likely that measurement of patient thickness is a less practical option in X-ray departments.

However, there was, as for the 2005 review, sufficient height and weight information to derive once again reference doses for *MCU*, *Barium Meal* and *Barium Swallow*. There were also a significant amount of data for *Barium Video Swallows* and for complete examinations of the pelvis, but insufficient to derive reference doses (there were considerably less than 20 rooms for all patient sizes).

The main parameters for the distributions of room mean doses (in Gy cm^2) for these examinations, after they had been adjusted for patient size, are shown in Table 15. There were about the same number of rooms and patients for *MCU* and *Barium Meal* examinations in this review compared with the 2005 review. There were, however, fewer patients and rooms for *Barium Swallow* in this review than were available for the 2005 review.

The means of the room dose distributions are mostly less than they were for the 2005 review, while the change is more distinct for the third quartiles, all being less than they were for the 2005 review, and mostly less than half. While these reductions are considerable, the current doses are still not as low as those demonstrated by Great Ormond Street Hospital for Sick Children (Hiorns et al, 2006), which are factors of 2 to 5 lower than the mean paediatric doses in this review.

A distinct upward trend in the mean and quartile values as the standard age (and size) increases, can be seen for all three examinations. However, as in the last review, there are fairly small differences between the mean and quartile values of the doses adjusted to the 1 year old and 5 year old standard patient. The mean values of the doses adjusted to the standard new-born baby size are about a factor of two lower than those for the 1 year old and 5 year old.

TABLE 15 Analysis of paediatric data

Exam	Standard age (years)	No. of rooms	Adjusted room DAP/examination (Gy cm^2)*					
			Min.	1st quartile	Median	Mean	3rd quartile	Max.
MCU (1776 patients)	0	44	0.0005	0.02	0.04	0.19	0.12	3.95
	1	61	0.003	0.1	0.17	0.57	0.32	16.7
	5	45	0.016	0.1	0.18	0.65	0.34	10.1
	10	26	0.008	0.18	0.32	0.43	0.44	1.4
	15	23	0.003	0.11	0.36	1.69	0.89	13.2
Barium meal (370 patients)	0	18	0.014	0.04	0.07	0.14	0.13	0.87
	1	22	0.06	0.1	0.13	0.32	0.21	1.94
	5	20	0.004	0.1	0.18	0.4	0.24	2.7
	10	17	0.03	0.13	0.4	0.54	0.65	1.8
	15	12	0.18	0.39	1.1	1.36	2.0	4.0
Barium swallow (190 patients)	0	12	0.009	0.03	0.05	0.27	0.21	1.5
	1	26	0.05	0.12	0.22	0.31	0.39	1.2
	5	28	0.08	0.19	0.26	0.88	0.46	12.8
	10	22	0.19	0.55	0.84	1.47	1.8	6.2
	15	21	0.19	0.45	1.7	2.79	3.0	17.4

* Adjusted to nearest standard size.

4.5 Dental X-ray examinations on adults and children

4.5.1 Intra-oral mandibular molar radiographs

Table 16 shows some key parameters for the distributions of the patient entrance dose (PED) for an intra-oral mandibular molar radiograph measured for the typical exposure conditions used on each X-ray set for an adult and a child patient, respectively. PEDs for child exposure conditions were not available from HPA DXPS, hence the smaller sample of X-ray sets providing these particular data. The mean PED for both adults and children has dropped substantially below the corresponding data for 2005 (which were 1.85 mGy and 1.15 mGy respectively).

TABLE 16 Intra-oral radiographs: distribution of patient entrance dose

Exposure conditions	No. of X-ray sets	Patient entrance dose (mGy)					
		Mean	Min.	Max.	1st Quartile	Median	3rd Quartile
Adult	9327	1.37	0.1	11.4	0.9	1.2	1.7
Child	405	0.63	0.04	1.9	0.4	0.55	0.7

The data from DXPS alone (6,109 values) had a mean adult PED of 1.5 mGy, while the mean adult PED for the data supplied by hospital physicists was 1.2 mGy.

Figure 8 shows histograms of the distributions described in Table 16. The vertical line indicates the third quartile of each distribution for 2010. The dotted line shows the third quartile for the 2005 review.

Table 17 shows the mean exposure parameters for the adult radiographs listed in Table 16. No data were received on exposure parameters for children. The adult mean exposure time for 2010 is about two-thirds the value from the 2005 review.

TABLE 17 Intra-oral radiographs: exposure parameters

Exposure conditions	Mean exposure time (sec)	Mean kV	Mean filtration (mm Al)
Adult	0.25 (0.02-1.2)	68 (50-81)	2.7 (1.5 – 5.6)

The range from minimum to maximum is given in brackets.

Table 18 shows the distribution in the type of detector used for the adult radiographs. It can be seen that D speed film is used much less than it was for the 2005 review. In 2005, 24% of detectors were D speed film, whereas currently only 6% are D speed film. E or F speed films are now used for the majority of detectors (63%). Digital detectors (CR or DDR) are now used for a substantial minority (25%) of systems; in 2005, this fraction was about 15%. Patient entrance dose shows a reduction from C through D to E and F speed, but the lowest dose is given by digital detectors (typically 1.15 mGy).

TABLE 18 Intra-oral radiographs: mean dose and type of detector used for adults

Detector	PED (mGy)	Number	% of specified detectors
C film	2.8	11	0.1
D film	2.0	579	6
E film	1.5	2825	30
E/F film	1.2	446	5
F film	1.4	2577	28
Digital (CR/DDR)	1.15	2346	25
Unknown	1.3	543	6
TOTAL		9327	100

CR = computed radiography (photostimulable phosphor); DDR = direct digital radiography.

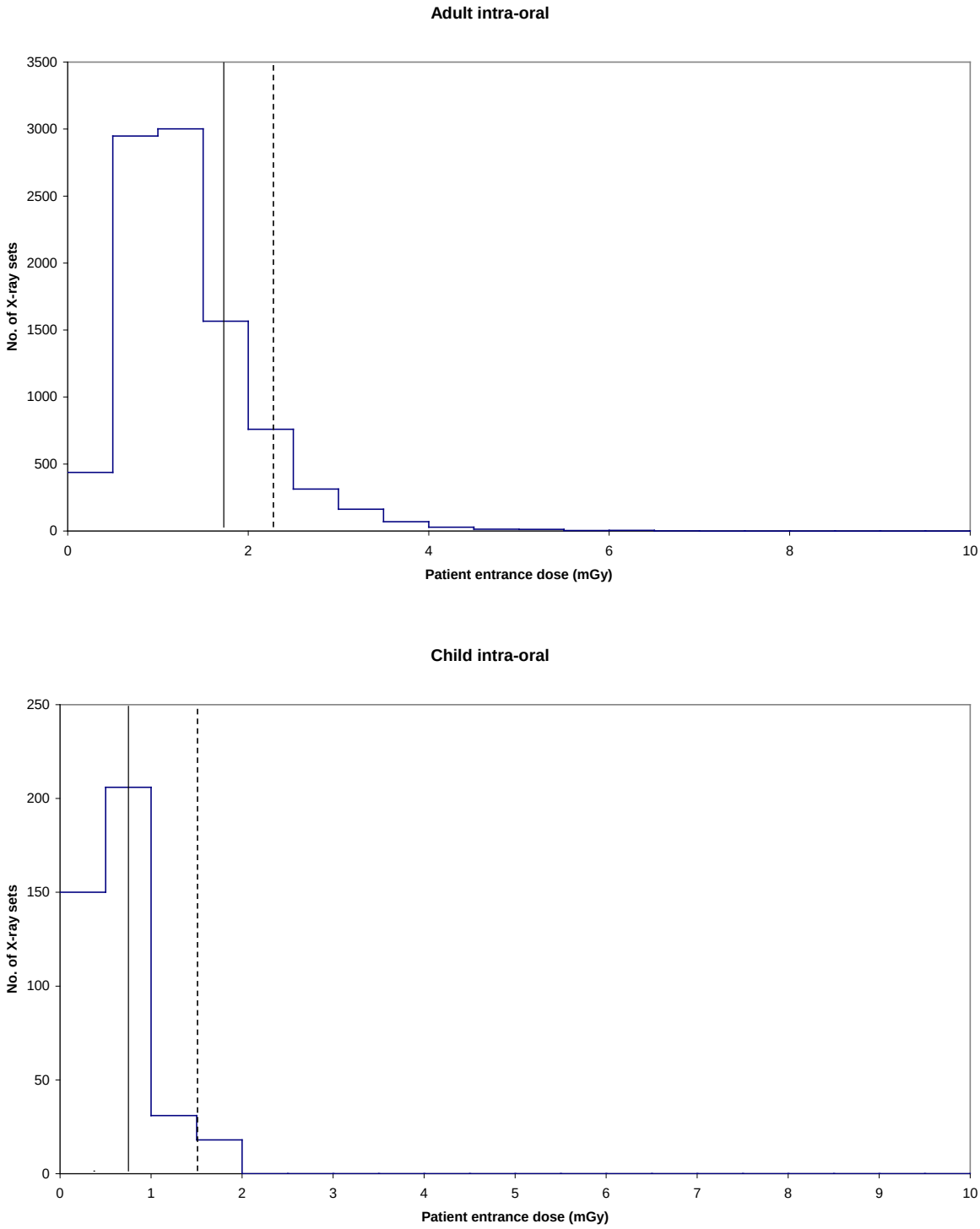


FIGURE 8 Distribution of patient entrance dose for intra-oral radiographs

4.5.2 Panoramic radiographs

Table 19 shows some key parameters for the distributions of DWP and DAP for panoramic radiographs measured for the typical exposure conditions used on each panoramic X-ray set for an adult and child patient, respectively. Dose measurements for child exposure settings were not available from DXPS, hence the much smaller sample of panoramic sets providing these particular data.

TABLE 19 Panoramic radiographs

Exposure conditions	No. of sets measured	Dose-width product (mGy mm)					
		Mean	Min.	Max.	1st Quartile	Median	3rd Quartile
Adult	1565	63	1.7	221	48	60	74
Child	89	43	1.4	85	33	39	49
		Dose-area product (mGy cm^2)					
Adult	2014	80	2.3	288	61	77	93
Child	81	56	1.9	96	44	54	67

The mean adult DWP has increased by 20% over the 2005 value. The mean adult DAP has increased by 14%. These increases are probably mainly due to a change in the DXPS beam width measurement method, which now evaluates beam widths as, on average, 30% larger than was the case for the 2005 review (Holroyd, 2012). The differences between the 2 datasets are consistent with this explanation. The data from DXPS alone (1,389 values) had a mean adult DWP of 64 mGy mm, while the mean adult DWP for the data supplied by hospital physicists was 55 mGy mm. The data from DXPS alone had a mean adult DAP of 82 mGy cm^2, while the mean adult DAP for the data supplied by hospital physicists was 76 mGy cm^2. All the DXPS DAP values were obtained by multiplying the DWP by the measured height of the X-ray beam, while 28% of the DAP values from the hospital physicists were obtained by this method and 72% were measured directly with a DAP meter.

The mean DWP and DAP for children have decreased by 20% since the 2005 review. Since the sample size for 2010 is twice as large as for 2005, the more recent data are probably more reliable.

Figures 9 and 10 show histograms of the adult and child dose distributions described in Table 19. The vertical line indicates the third quartile of each distribution. The dotted line shows the third quartile for the 2005 review. The scales have been chosen to match that used for the same diagrams in the 2005 review.

Table 20 shows the mean exposure parameters for the radiographs listed in Table 19. As was the case for the 2005 review, exposure times for the small number of child measurements appear to be similar to those for adults, but the mean tube voltage tends to be slightly lower while the tube filtration remains the same.

TABLE 20 Panoramic radiographs: exposure parameters

Exposure conditions	Mean exposure time (sec)	Mean tube voltage (kV)	Mean tube filtration (mm Al)
Adult	16 (9-24)	71 (57-108)	3.5 (2.3 - 5)
Child	15 (8-19)	66 (60-75)	3.5 (2.3 – 5)

The range from minimum to maximum is given in brackets.

Generic information on the detector (e.g. film, CR/digital) was supplied for 94% of the systems surveyed. This allowed the following comparison of adult doses:

TABLE 21 Panoramic radiographs: mean dose and type of detector used for adults

Detector	Records	DWP (mGy mm)	DAP (mGy cm^2)
Film	1208	63	81
CR/DDR	678	63	80

There appears to be very little difference in doses between the 2 types of system.

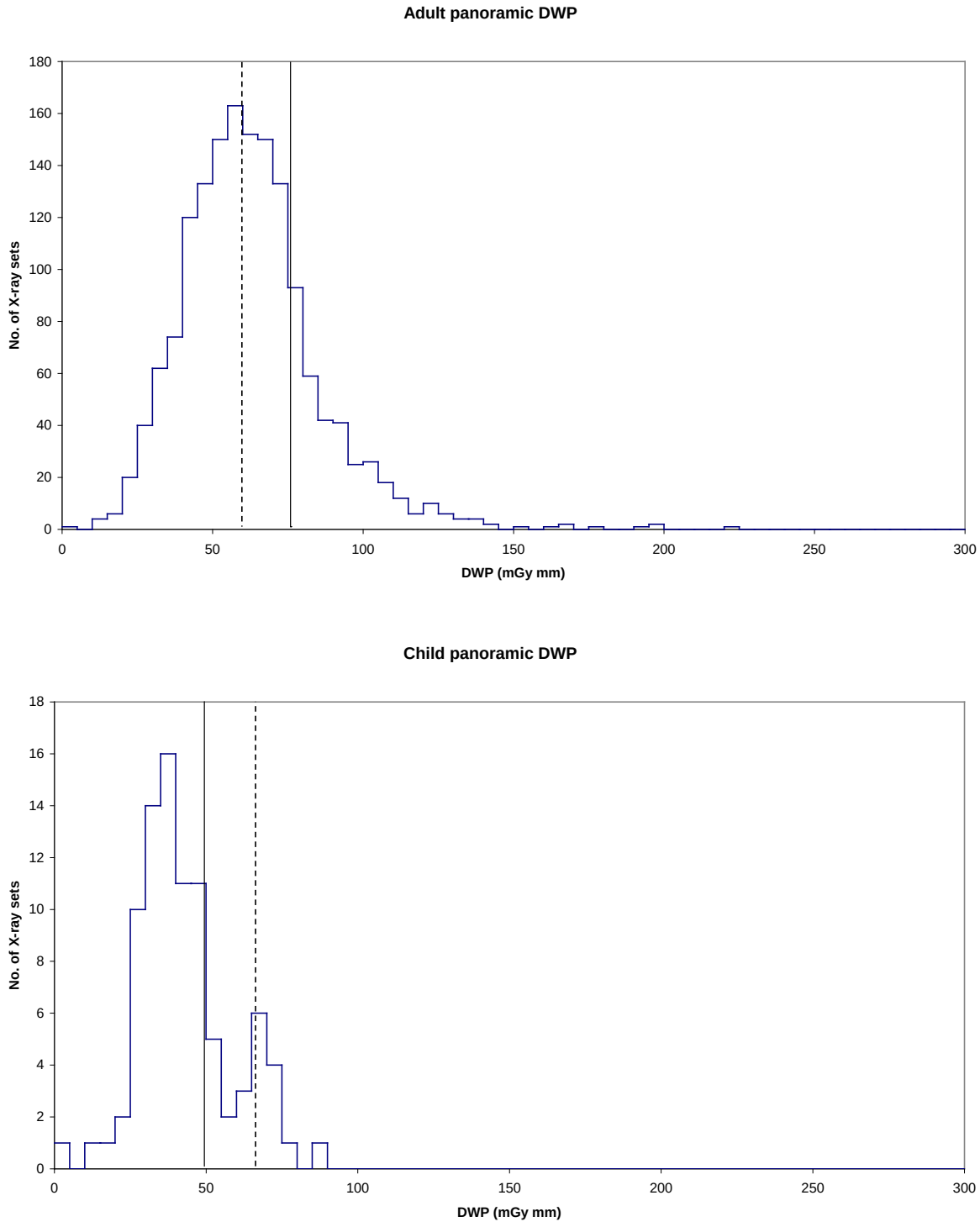


FIGURE 9 Distribution of dose-width product for panoramic radiographs

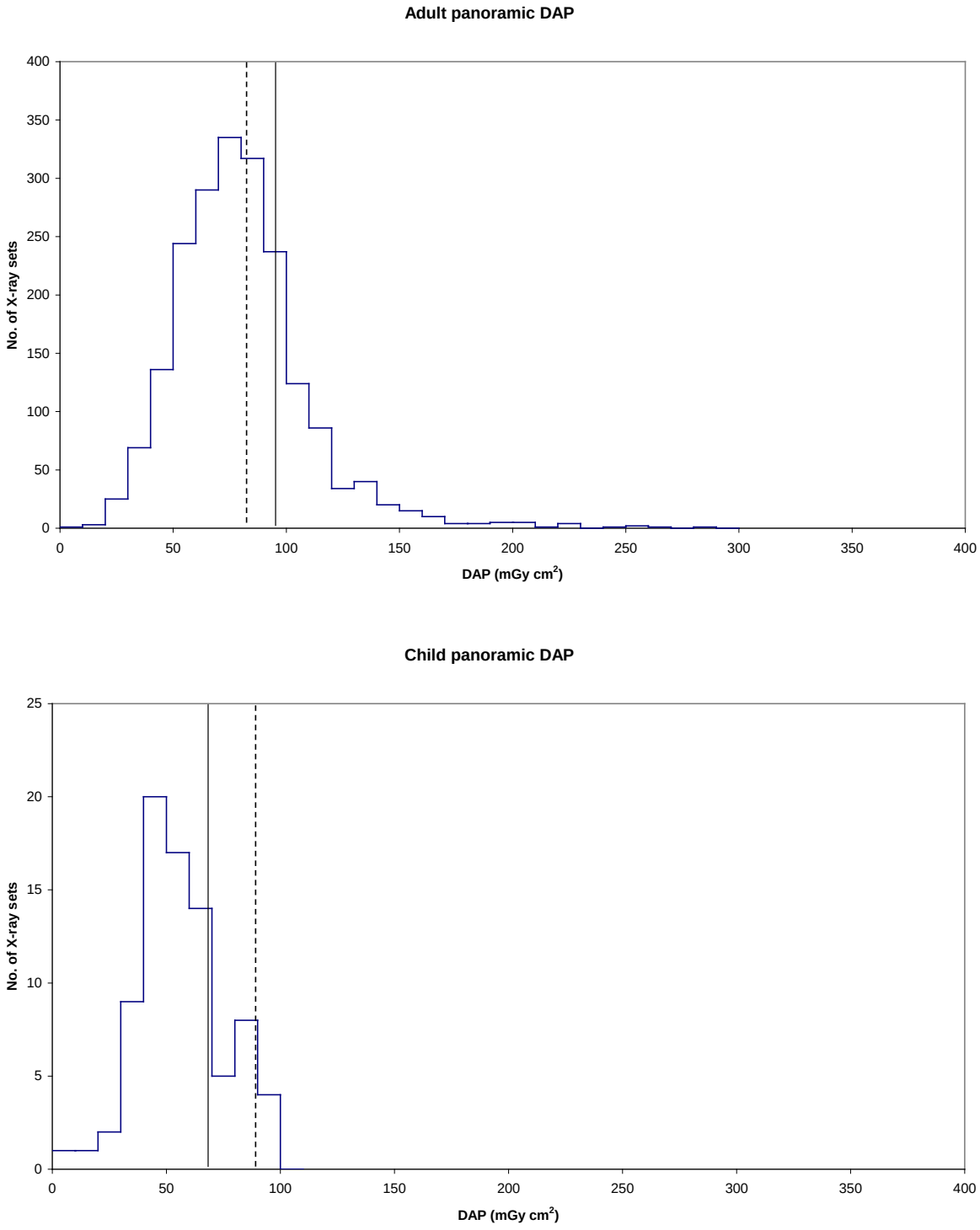


FIGURE 10 Distribution of dose-area product for panoramic radiographs

5 INFLUENCE OF IMAGING EQUIPMENT ON PATIENT DOSE

For over 100 years, radiographic film was used to record X-ray images. But digital detectors (mainly computed radiography and flat panel detectors) have several advantages over film-screen systems, including wide exposure latitude, post-processing, and electronic transfer and archiving (Carter and Veale, 2009). So in recent years, digital systems have largely replaced film-screen systems in hospitals.

Computed radiography (CR) was made commercially available in the UK from 1989 onward. It uses photo-stimulable phosphor plates. These directly replace film in standard cassettes, so existing X-ray equipment could be digitised without any significant modifications. However, CR has the disadvantage of requiring manual handling of the plates to enable read-out with a laser. This takes a roughly similar time to the processing of conventional film. CR phosphor plates generally use barium fluorohalides with a k-edge of 37 keV, while the screens in film-screen systems are generally based on gadolinium with a k-edge of 50 keV. This means that CR does not have as good a response to higher energy X-rays as film-screen. It has been recommended (Honey et al, 2005) that a tube voltage of 75 to 90 kV is best for CR, allowing image quality to be maintained while minimising effective dose.

Flat panel detectors (FPD) started becoming commercially available in the UK in the year 2000. These convert X-ray energy into electrical signals (either directly or indirectly) giving almost instant access to digital images. Such systems have the potential to substantially reduce patient dose. They use either amorphous silicon or amorphous selenium, together with a thin film transistor array to produce an electronic signal. Both systems are compact, and can be used for radiography and fluoroscopy. CR and FPD are the two main digital systems being used in clinical departments in the UK. Other types of digital system based on charge-coupled devices (CCD) or selenium cylinders have a very small share of the market (Centre for Evidence-based Purchasing, 2008).

A new agency, NHS Connecting for Health, was formed on 1 April 2005 to deliver a national programme of IT for the NHS in England. A part of this IT programme involved the implementation of a national 'Picture Archiving and Communication System' (PACS). PACS has the benefit of providing a film-less diagnostic imaging system. This could: save the costs of film-processing; release valuable space used for film storage; provide images almost instantly; and allow the image to be examined simultaneously in more than one location. In order to establish a national PACS, it was necessary to digitise X-ray imaging systems. The simplest way to do this was to use CR instead of film. As a result, CR was introduced into many more hospitals across England during the period 2005 to 2010, and a similar development occurred in Scotland. For the 1995 review, all the hospital radiology rooms that were sampled used film-screen systems. For the 2000 review, 98% of radiology rooms used film, and only 2% used CR. For the 2005 review, 55% of rooms used film, 40% used CR and 5% used FPD. In this review 3% of rooms used film, 65% used CR and 32% used FPD.

Table 22 shows a comparison of the NPDD mean ESD/radiograph using CR, FPD and film-screen systems, and using the standard selection procedure as described in

Section 2.4.1. Radiographs were chosen that had a significant quantity of data across all 3 modalities. This would, ideally, have consisted of 10 hospitals, 20 rooms and 100 patients, but this was not always possible. Indeed, film-screen systems are used so little now, that there were insufficient data even for common radiographs such as *Abdomen AP* and *Knee AP/LAT*. The mean ESD for FPD is less than that for CR in 7 of the 9 radiographs. The mean ESD for FPD is less than that for FS in 3 of the 4 cases. The mean ESD for FS is less than that for CR in 3 of the 4 cases. However, only 4 of these 17 cases are significant at the 98% confidence level, using a student's T-test. The significant cases are the 2 comparisons with the low FS dose for *Chest PA*, and the 2 comparisons with the low FPD dose for *Lumbar Spine Lateral*.

TABLE 22 Mean of room mean ESDs per radiograph (mGy) for adults

Radiograph	Modality	Hospitals	Rooms	Patients	ESD
Abdomen AP	CR	54	138	9614	3.6
	FPD	7	13	922	3.1
Chest PA	CR	70	229	34924	0.13
	FPD	16	24	6251	0.11
	FS	10	10	96	0.06
Knee AP	CR	14	31	2120	0.27
	FPD	4	7	635	0.24
Knee LAT	CR	10	23	1448	0.36
	FPD	4	7	1003	0.27
Lumbar Spine AP	CR	58	150	3496	4.6
	FPD	7	12	807	4.0
	FS	13	15	173	4.2
Lumbar Spine LAT	CR	60	147	3765	8.0
	FPD	7	12	848	6.2
	FS	12	14	163	9.1
Pelvis AP	CR	66	168	5843	3.2
	FPD	8	12	2595	2.9
	FS	10	12	142	3.1
Thoracic Spine AP	CR	32	89	1130	2.9
	FPD	5	8	260	3.1
Thoracic Spine LAT	CR	34	90	1237	5.1
	FPD	5	8	284	5.3

CR = computed radiography; FPD = flat panel detector; FS = film-screen.

Table 23 shows a comparison of the mean DAP/radiograph using CR, FPD and film-screen systems on a similar basis to Table 22. The mean DAP for FPD is less than that for CR in 10 of the 11 cases. The mean DAP for FPD is less than that for FS in 3 out of 5 cases, and the same in a further case. The mean DAP for FS is less than that for CR in 3 of the 5 cases, and the same in a further case. Again, only 4 of these 21 cases are significant at the 98% confidence level. These all involve a lower dose for FPD than for CR: *Cervical Spine AP*, *Chest PA*, *Pelvis AP* and *Thoracic Spine AP*. The general

picture in Tables 22 and 23 is therefore that the doses from all 3 modalities are typically quite similar, often within margins of 10-20%. However FPD would appear marginally to be the better digital system for achieving reduced dose. In the few cases where a comparison can be made, CR appears to be marginally worse than film for dose reduction.

TABLE 23 Mean of room mean DAPs per radiograph (Gy cm^2) for adults

Radiograph	Modality	Hospitals	Rooms	Patients	DAP
Abdomen AP	CR	45	89	9252	2.1
	FPD	53	86	9551	2.0
	FS	3	4	195	2.5
Cervical spine AP	CR	13	20	378	0.14
	FPD	8	20	287	0.07
Cervical spine LAT	CR	15	22	440	0.17
	FPD	8	21	381	0.13
Chest AP	CR	15	21	2243	0.12
	FPD	9	16	1718	0.11
Chest PA	CR	117	239	59992	0.09
	FPD	100	189	81046	0.08
	FS	10	11	1015	0.08
Knee AP	CR	4	11	192	0.08
	FPD	16	23	169	0.09
Lumbar Spine AP	CR	64	105	2712	1.4
	FPD	62	97	2357	1.3
	FS	8	8	294	1.4
Lumbar Spine LAT	CR	77	135	3653	2.2
	FPD	66	104	2621	2.1
	FS	9	9	299	2.0
Pelvis AP	CR	82	146	10761	2.1
	FPD	83	132	13137	1.6
	FS	7	8	260	1.8
Thoracic Spine AP	CR	31	42	605	0.8
	FPD	23	39	823	0.6
Thoracic Spine LAT	CR	32	43	655	1.6
	FPD	27	48	989	1.2

CR = computed radiography; FPD = flat panel detector; FS = film-screen

For the 2005 review, it was found that most flat panel detectors in the review were used in cardiac catheterisation laboratories. It was also found that, disappointingly, FPDs mostly appeared to give a higher dose than non-digital systems. Table 24 shows a comparison between the mean DAPs for some cardiac procedures that have good quantities of data in both this review and the 2005 review. It can be seen that the doses for all 4 procedures have decreased in the 2010 review, and in 3 cases have reduced to less than half the doses for the 2005 review. This may be an indication that FPDs are now being used to fulfil more closely their potential to reduce dose.

TABLE 24 Mean of room mean DAPs per procedure using flat panel detectors (Gy cm^2) for adults *

Procedure	Review	Hospitals	Rooms	Patients	DAP
Coronary angiography	2010	9	21	5510	23
	2005	10	14	2390	28
Coronary bypass graft angiography	2010	2	11	289	26
	2005	2	2	47	66
PTCA 1 stent	2010	5	14	784	30
	2005	2	3	171	67
PTCA 2 stent	2010	3	11	280	37
	2005	1	2	110	83

* Mean patient weight range 75-85 kg.

6 DISCUSSION

6.1 Trends in patient doses with time

Previous reviews of the National Patient Dose Database showed a continuing downward trend in mean doses to adult patients for the overwhelming majority of the common radiographs and diagnostic examinations carried out in hospitals. Has the changeover to digital systems affected the pattern of dose reduction found in previous reviews? Table 25 gives an indication of what has happened, based on the average percentage reduction between reviews in the mean or the third quartile of room mean doses for radiographs and examinations on adults with substantial quantities of data (excluding dental examinations).

TABLE 25 Average percentage dose reduction between reviews

Dose parameter	1995-2000	2000-2005	2005-2010
Mean	16	16	5
Third quartile	20	16	10

There has again been a dose reduction between 2005 and 2010, but it has been the smallest reduction so far, for both mean and third quartile doses.

Figure 11 shows the trends in the mean value of the room mean ESDs between the mid-1980s survey (Shrimpton et al, 1986), the 1995, 2000, 2005 and 2010 reviews, for eight common radiographs. Data for five of the radiographs show a slight increase in dose for the 2010 review. Only one of the dose changes depicted for 2005 to 2010 is significant at the 98% confidence level: that is the ESD reduction for *Lumbar Spine Lateral*. Mean ESD values for chest radiographs (AP, PA, LAT) are too small to show clearly on the same bar chart, but they showed an increase in dose from the 2005 to the 2010 review. However, none of these increases were significant at the 98% confidence level.

Figure 12 shows the trends in the mean value of the room mean DAPs between the 2000, 2005 and 2010 reviews for the five types of radiograph where we have sufficient data. These do show a general downward trend in 2010, though *Chest PA* remains at the same value. However, none of these decreases were significant at the 98% confidence level.

Figure 13 shows the trends in the mean value of the room mean DAPs for the five types of examination where we have sufficient data going back to at least 1995. Data for four of the examinations show a decrease in dose in 2010, though this is slight in the case of IVUs. Data for *Barium Swallow* show a small increase in mean dose. Only the dose reduction for *Barium Follow Through* is significant at the 98% confidence level.

Figure 14 shows the trends in the mean value of the room mean DAPs for seven interventional procedures. Between the 2005 and the 2010 reviews, the mean DAP/procedure has increased slightly for *Facet Joint Injections*, stayed the same for

Hickman Line Insertions, but has decreased for all the rest. However, none of these changes were significant at the 98% confidence level.

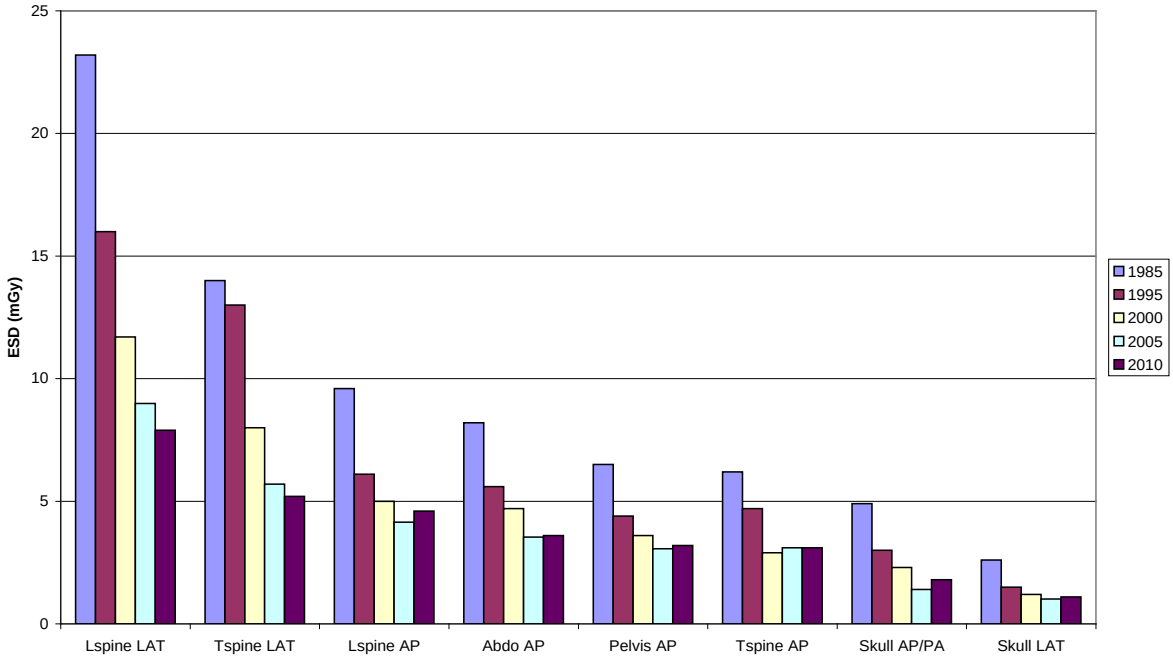


FIGURE 11 Mean room entrance surface dose per radiograph (adults)

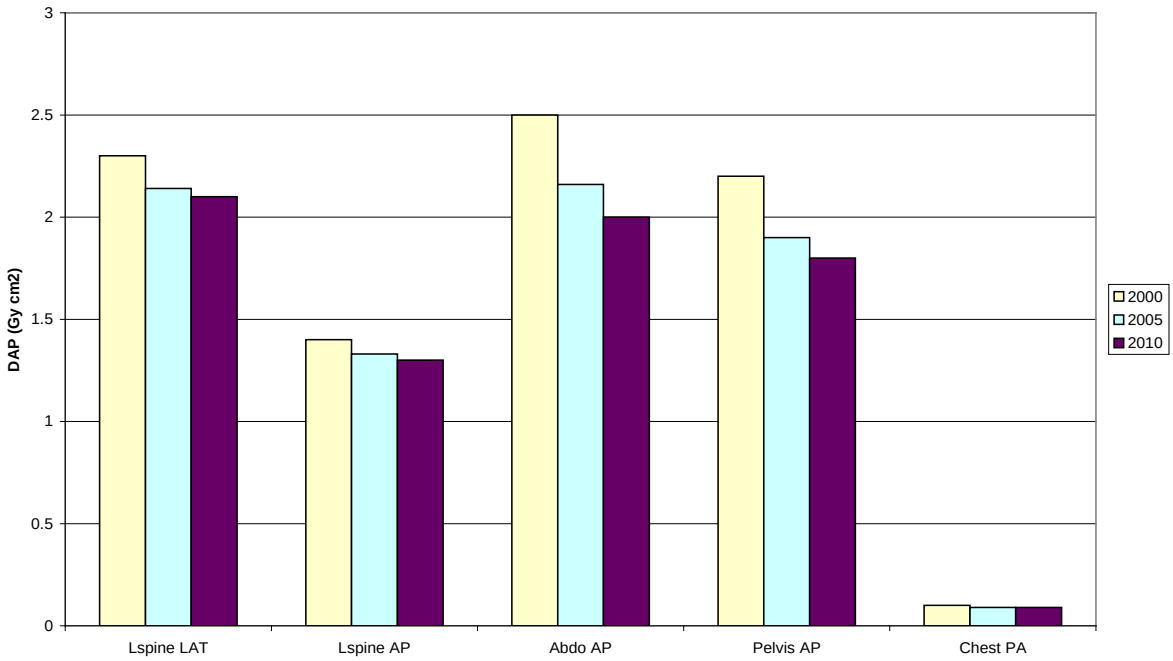


FIGURE 12 Mean room dose-area product per radiograph (adults)

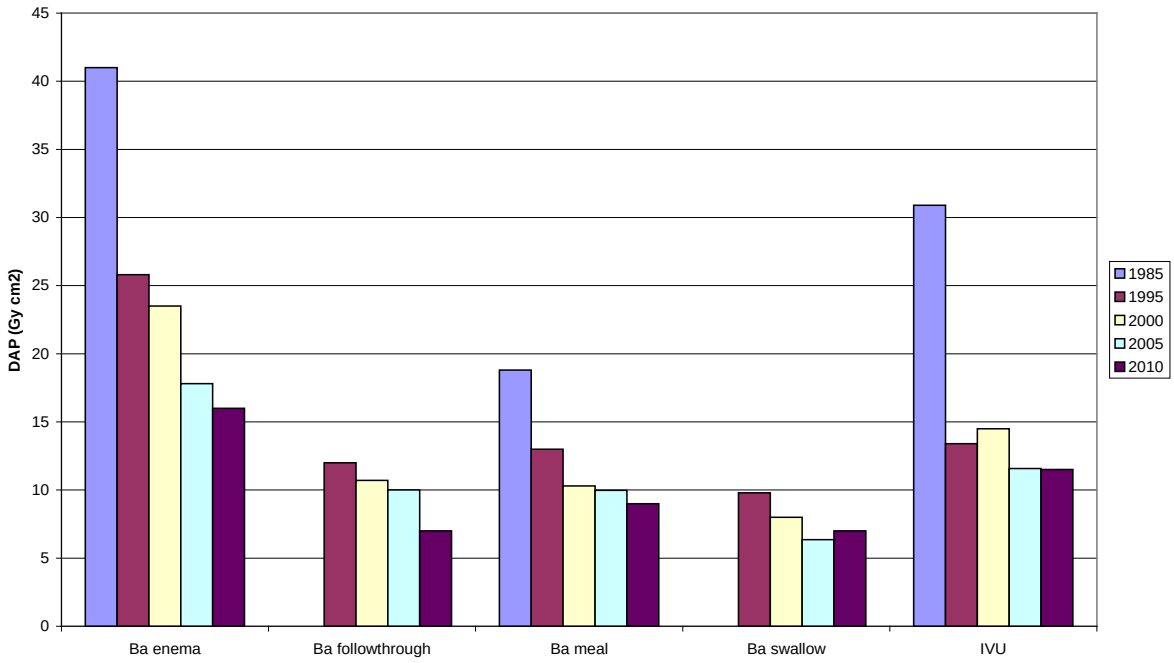


FIGURE 13 Mean room dose-area product per examination (adults)

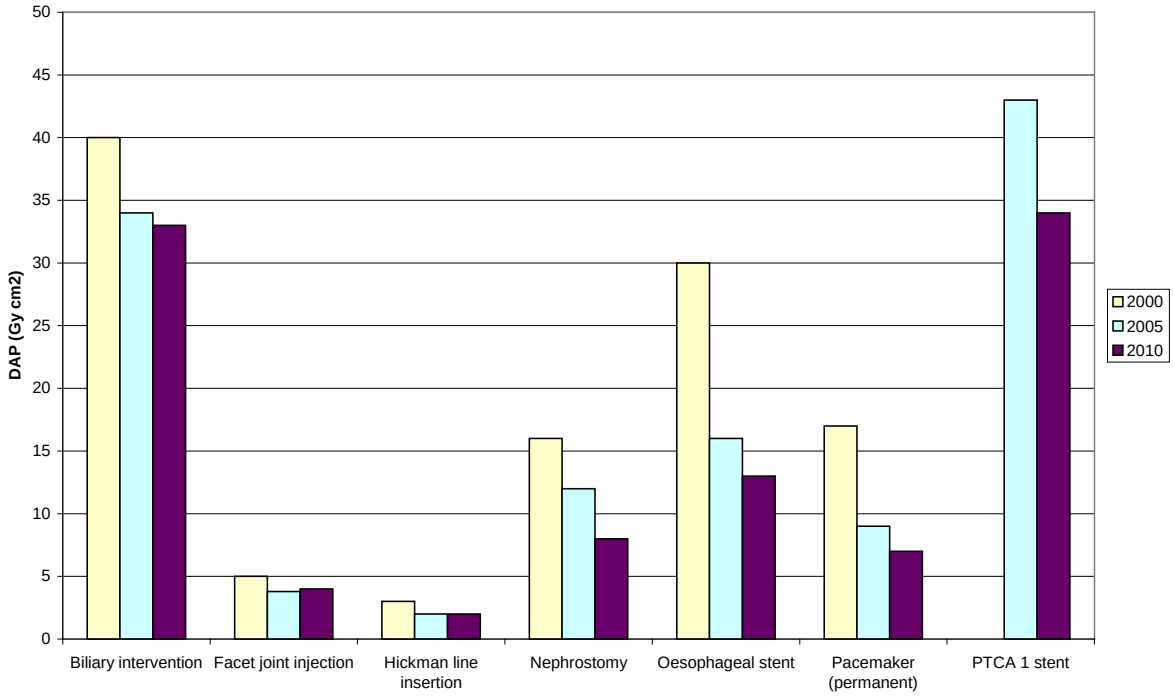


FIGURE 14 Mean room dose-area product per interventional procedure (adults)

Third quartile values of doses for typical adult patients from the current 2010 review, rounded to no more than 2 significant figures, are compared with earlier values in Table 26 (when there are data for more than 2 reviews). There has been a continuing reduction in the third quartile values with time for most types of radiograph and examination. In general, the third quartiles have more than halved in the 25 years since the survey of the mid-1980s. The current third quartiles are on average 10% lower than the third quartiles for the 2005 review.

The third quartiles have increased for 3 radiographs out of 15 when comparing the 2010 values to the values for 2005. Similarly, the third quartiles have increased for 3 examinations/procedures out of 17 when comparing the 2010 values to the values for 2005. The number of increased third quartiles between the 2000 and 2005 reviews was 1 radiograph and 3 examinations/procedures. The changes in this review are therefore not radically different to those for the previous review.

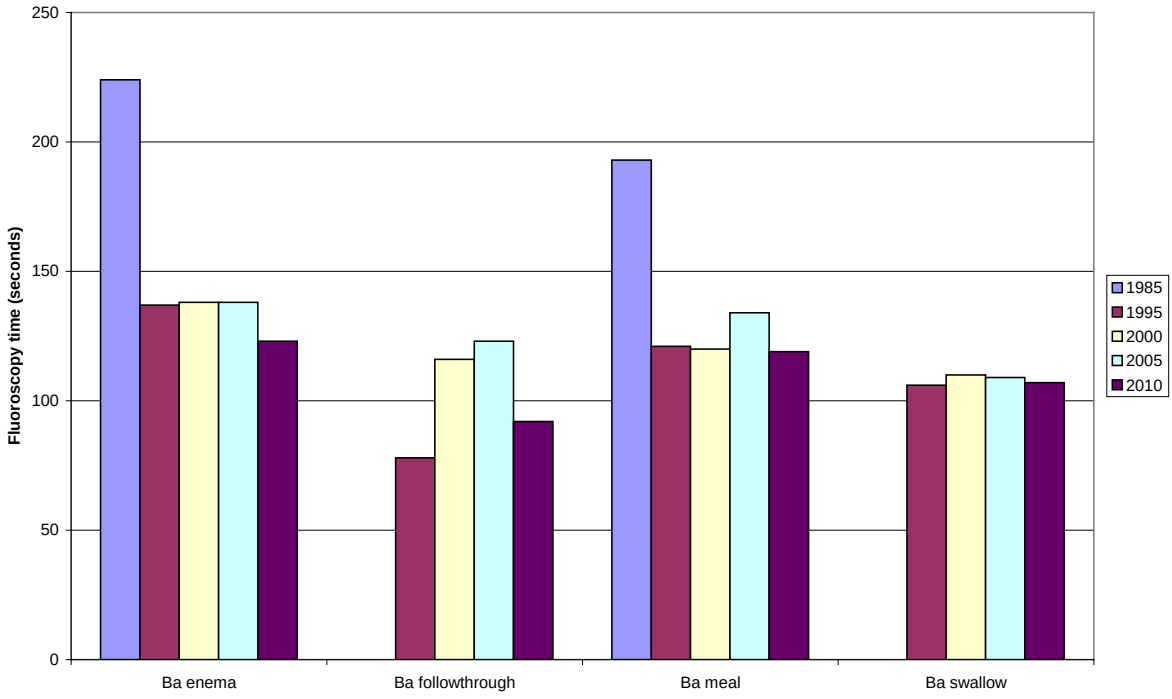


FIGURE 15 Mean room fluoroscopy time per examination (adults)

Figure 15 shows the trends in the mean value of the room mean fluoroscopy times for some barium studies. There is no clear trend for these values, but two of the reductions in fluoroscopy time from 2005 to 2010 are significant at the 98% confidence level: for *Barium Enema* and *Barium Follow Through*. The third quartiles of fluoroscopy time are listed in Table 10 for 17 examinations which appear in both the 2010 and 2005 reviews. For 14 of these examinations, the third quartile values are now lower than they were in the 2005 review. For 3 examinations, the third quartiles are higher than they were in the 2005 review.

TABLE 26 Rounded third quartile values for adult patients from the current and previous reviews of national patient dose data

Category	Rounded room third quartile values				
	Mid-1980s Survey	1995 review	2000 review	2005 review	2010 review
Radiographs	ESD per radiograph (mGy)				
Abdomen AP	10	7	6	4	4.4
Chest LAT	1.5	0.7	1	0.6	0.5
Chest PA	0.3	0.2	0.2	0.15	0.15
Lumbar spine AP	10	7	6	5	5.7
Lumbar spine LAT	30	20	14	11	10
Pelvis AP	10	5	4	4	3.9
Skull AP/PA	5	4	3	2	1.8
Skull LAT	3	2	1.6	1.3	1.1
Thoracic spine AP	7	5	3.5	4	3.5
Thoracic spine LAT	20	16	10	7	7
Radiographs	DAP per radiograph (Gy cm^2)				
Abdomen AP			3	2.6	2.5
Chest PA			0.12	0.11	0.1
Lumbar spine AP			1.6	1.6	1.5
Lumbar spine LAT			3	2.5	2.5
Pelvis AP			3	2.1	2.2
Diagnostic exams	DAP per examination or procedure (Gy cm^2)				
Barium enema	60	32	31	24	21
Barium follow through		15	14	12	8
Barium meal	25	17	13	14	12
Barium small bowel enema			50	40	23
Barium swallow		12	11	8	7.5
Coronary angiography*			36	29	31
Femoral angiography			33	36	56
Hysterosalpingography			4	3	2
IVU	40	23	16	14	14
MCU			17	12	7
Nephrostography			13	12	9
Sialography			1.6	2	2.8
T-tube cholangiography			10	8	5
Interventional procedures	DAP per procedure (Gy cm^2)				
Biliary intervention			54	50	43
Hickman Line			4	3	3
Nephrostomy			19	14	13
Pacemaker			27	11	7

* Mean patient weight range 75-85 kg.

To gauge whether there has been a narrowing in the dose distributions, Table 27 tabulates the inter-quartile range for some common radiographs and examinations. The inter-quartile range is the third quartile minus the first quartile, and it measures the spread of the middle 50% of the data. The maximum inter-quartile range for each examination is coloured red, and the minimum is coloured blue. It can be seen that most of the maxima are in the 1985 and 1995 surveys, while most of the minima are in the 2000 to 2010 reviews. This provides some evidence that the distributions have narrowed.

TABLE 27 Trends in the range between 1st and 3rd quartile doses for some common radiographs and examinations from periodic reviews of the NPDD

Dose/ Exam	1985	1995	2000	2005	2010
ESD (mGy)					
Abdomen AP	3.5	3.6	2.3	1.96	2.0
Chest AP	0.12	0.28	0.05	0.06	0.1
Chest LAT	0.9	0.33	0.68	0.29	0.24
Chest PA	0.1	0.08	0.1	0.07	0.05
Lumbar spine AP	3.8	3.2	2.6	2.18	2.8
Lumbar spine LAT	12.3	9.6	6.4	5.62	4.7
Lumbar spine LSJ	18.1	17	11.3	12.4	
Pelvis AP	2.4	2.4	1.8	1.71	1.7
Skull AP/PA	2.4	1.8	1.4	1.18	0.2
Skull LAT	1.9	0.8	0.9	0.71	0.2
Thoracic spine AP	2.3	2.3	1.3	2.21	1.6
Thoracic spine LAT	4.0	10.3	6.1	4.01	4.4
DAP (Gy cm^2)					
Barium enema	24	16.2	16.4	13.2	13.4
Barium follow		9.4	9	6.24	5
Barium meal	11.2	9.9	6.4	8.15	7.9
Barium swallow		6.4	5.3	4.48	4.5
IVU	13.3	16.4	9.4	5.45	6.6
Venogram		1.9	2.9	4.99	

6.2 National reference doses

In previous reviews and in this one, national reference doses are based on rounded third quartile values of the mean patient doses observed for common X-ray examinations in a nationally representative sample of X-ray rooms. Reference doses set at this level are intended to be an indication of abnormally high doses. When compared with local measurements characterising typical practice in each X-ray department (IPEM, 2004), they serve to identify those X-ray examinations and rooms in most urgent need of investigation and corrective action. They also provide a major source of data supporting the formal setting of national diagnostic reference levels (DRLs) by the Department of Health in compliance with IR(ME)R (Department of Health, 2000), as discussed in the Introduction.

6.2.1 Adult patients

The latest set of recommended national reference doses for individual radiographs on adult patients is shown in Table 28. The number of rooms supplying data for each radiograph is also indicated in the table. The 2010 third quartiles for both ESD and DAP were fairly similar to those in 2005. Reference doses are given as rounded third quartiles. Accordingly, the only ESD reference doses to change are for *Lumbar Spine AP* (up from 5 to 5.7 mGy), *Chest Lateral* (down from 0.6 to 0.5 mGy), *Lumbar Spine Lateral* (down from 11 to 10 mGy), *Skull AP/PA* (down from 2 to 1.8 mGy), *Skull Lateral* (down from 1.3 to 1.1 mGy), and *Thoracic Spine AP* (down from 4 to 3.5 mGy). Six DAP reference doses have changed. Three have gone down slightly, namely *Abdomen AP*, *Chest PA* and *Lumbar spine AP*. Three have gone up slightly, namely *Pelvis AP* and *Thoracic Spine AP* and *Lateral*.

Similarly the latest set of national reference doses for complete diagnostic examinations, in terms of the total DAP and the total fluoroscopy time (expressed in minutes), is shown in Table 29. The number of rooms supplying data for each examination is also indicated in the table. Reference doses are given for an additional 6 types of examination when compared to the 2005 review. The 6 examinations are: *Abdomen*, *Barium Swallow (Video)*, *Chest*, *Coronary Graft Angiography*, *Lumbar Spine* and *Proctography*. As done for the 2005 review, *Water-Soluble Enemas* have been combined with *Barium Enemas* and given the same reference dose in Table 29, since the respective mean DAP and fluoroscopy time values in Tables 8 and 10 are fairly similar for these examinations. The same approach has been followed for *Water-Soluble Swallows* and *Barium Swallows*. It should be remembered that the data for *Coronary Angiography* and *Coronary Graft Angiography* relate to patients with a weight range of 75-85 kg, as discussed in Section 4.3.

Table 28 Recommended national reference doses for individual radiographs on adult patients – 2010 review

Radiograph	ESD per radiograph (mGy)	No. of Rooms	DAP per radiograph (Gy cm^2)	No. of rooms
Abdomen AP	**4**	167	**2.5**	188
Chest AP	**0.2**	53	**0.15**	41
Chest LAT	**0.5**	47		
Chest PA	**0.15**	285	**0.1**	433
Cervical spine AP			**0.15**	40
Cervical spine LAT			**0.15**	44
Knee AP	**0.3**	40		
Knee LAT	**0.3**	32		
Lumbar spine AP	**5.7**	192	**1.5**	206
Lumbar spine LAT	**10**	185	**2.5**	278
Pelvis AP	**4**	204	**2.2**	305
Shoulder AP	**0.5**	34		
Skull AP/PA	**1.8**	21		
Skull LAT	**1.1**	21		
Thoracic spine AP	**3.5**	104	**1.0**	92
Thoracic spine LAT	**7**	104	**1.5**	96

There has been a general reduction in the reference doses for DAP/examination and for fluoroscopy time. Twelve of the DAP reference doses are lower than in 2005, one is the same (*IVU*) and three show an increase (*Coronary Angiography*, *Femoral Angiography* and *Sialography*). Twelve of the reference doses for fluoroscopy time are lower than in 2005, and three show an increase (*Barium Meal & Swallow*, *Femoral Angiography* and *Fistulography*).

The latest set of national reference doses for interventional procedures, in terms of the total DAP and the total fluoroscopy time (expressed in minutes), is shown in Table 30. This would be an identical list to that given in the 2005 review, except that *Oesophageal Dilation* does not appear now, as there are insufficient data. Similarly to diagnostic examinations, there has been a general reduction in the reference doses for interventional procedures. Five of the DAP reference doses are lower than in 2005, one is the same (*Hickman Line Insertion*) and one shows an increase (*Facet Joint Injection*). Five of the reference doses for fluoroscopy time are lower than in 2005, and two show an increase (*Hickman Line Insertion* and *Nephrostomy*).

The national reference doses in Tables 28, 29 and 30 are mostly lower than or equal to the corresponding reference doses for the 2005 review. Out of 62 reference doses that were given in the 2005 review, for which new data are available in the 2010 review, 50 have either decreased or stayed the same.

Table 29 Recommended national reference doses for diagnostic examinations on adult patients – 2010 review

Examination	DAP per exam (Gy cm^2)	No. of Rooms	Fluoroscopy time per exam (mins)	No. of Rooms
Abdomen	**4.4**	42		
Barium (or water soluble) enema	**21**	210	**2.6**	181
Barium follow through	**8.4**	94	**2.0**	84
Barium meal	**12**	74	**2.6**	62
Barium meal & swallow	**10**	62	**2.3**	61
Barium (or water soluble) swallow	**7.5**	166	**2.1**	149
Barium small bowel enema	**23**	26	**8.9**	24
Barium swallow (video)	**3.4**	61	**3.5**	58
Chest	**0.3**	35		
Coronary angiography*	**31**	140	**4.3**	120
Coronary graft angiography*	**47**	49	**13**	45
Femoral angiography	**56**	48	**5.9**	41
Fistulography	**8**	24	**6.7**	21
Hysterosalpingography	**2**	89	**0.7**	82
IVU	**14**	22		
Lumbar spine	**6**	29		
MCU	**7**	33	**1.6**	31
Nephrostography	**9**	36	**3.9**	31
Proctography	**14**	26	**1.3**	25
Sialography	**2.8**	22	**1.5**	16
Sinography	**7**	25	**1.7**	24
T-tube cholangiography	**5**	32	**1.8**	30

* Mean patient weight range 75-85 kg.

Table 30 Recommended national reference doses for interventional procedures on adult patients – 2010 review

Interventional procedure	DAP per exam (Gy cm^2)	No. of Rooms	Fluoroscopy time per exam (mins)	No. of Rooms
Biliary intervention	**43**	22	**14**	21
Facet joint injection	**6**	30	**1.4**	28
Hickman line insertion	**3**	37	**1.5**	34
Nephrostomy	**13**	31	**6.7**	25
Oesophageal stent	**13**	24	**5**	21
Pacemaker (permanent)	**7**	78	**6**	63
PTCA (single stent)*	**40**	39	**11.3**	35

* Mean patient weight range 75-85 kg

6.2.2 Paediatric patients

As discussed in Section 4.4 and shown in Table 15, there are only three examinations on children for which data are available from about 20 or more rooms for each of the five standard sizes. The recommended national paediatric reference doses based on rounded values of the third quartiles of room mean DAP for these three examinations at each standard age corresponding to the standard size are shown in Table 31.

Table 31 Recommended national reference doses for complete examinations on paediatric patients – 2010 review

Examination	Standard age (y)	DAP per examination (Gy cm^2)	No. of rooms	Previous reference doses (Gy cm^2)	
		2010 Review		2005	2000
MCU	0	**0.1**	44	0.3	0.4
	1	**0.3**	61	0.8	1.0
	5	**0.3**	45	0.8	1.0
	10	**0.4**	26	1.5	2.1
	15	**0.9**	23	2.5	4.7
Barium meal	0	**0.1**	18	0.4	0.7
	1	**0.2**	22	1.2	2.0
	5	**0.2**	20	1.2	2.0
	10	**0.7**	17	2.4	4.5
	15	**2.0**	12	6.4	7.2
Barium swallow	0	**0.2**	12	0.4	0.8
	1	**0.4**	26	1.3	1.5
	5	**0.5**	28	1.3	1.5
	10	**1.8**	22	2.9	2.7
	15	**3.0**	21	3.5	4.6

These reference doses are mostly less than one half of the values in the 2005 review, and about a quarter of the values in the 2000 review. Reference doses to 15 year olds for *MCUs*, *Barium Meals*, and *Barium Swallows* are considerably lower (by factors of 2.5 to 8) than those to adults. Separate reference doses for 15 year olds and adults do therefore continue to be necessary.

6.2.3 Dental radiography

Recommended national reference doses for dental radiography were included for the first time in the 2005 review of the National Patient Dose Database (Hart et al, 2007). Reference doses for the 2010 review are shown in Table 32, and are based on the rounded third quartiles of the dose distributions reported in Section 4.5.

Table 32 Recommended national reference doses for dental radiography – 2010 review

Radiograph	PED per radiograph (mGy)	No. of X-ray sets
Intra-oral (adult)	**1.7**	9327
Intra-oral (child)	**0.7**	405
	DAP per radiograph (mGy cm^2)	
Panoramic (adult)	**93**	2014
Panoramic (child)	**67**	81

Due to little difference in the mean and third quartile DWP and DAP values for panoramic radiographs on adult and child patients, separate national reference doses for adults and children were not considered necessary in the 2005 review. However, the data in this review show a clear difference between adults and children for both DWP and DAP. There are more than twice as many data for panoramic radiographs of children in this review than there were in the 2005 review. Therefore separate national reference doses for panoramic dental radiographs are given for adults and children. The panoramic reference dose for adults is therefore higher than for the 2005 review, whereas for children it is lower. The panoramic reference dose is now given only as a DAP value (rather than DWP) because this approach is more consistent with that adopted for medical X-ray examinations (IPEM, 2005), and is more closely related to patient dose.

7 CONCLUSIONS

This review of the data added to the UK National Patient Dose Database during the period January 2006 to December 2010 has shown further reductions in the mean and third quartile values of the distributions of mean patient doses since the 2005 review, though the percentage reduction is less than found for previous reviews. The distributions of patient doses appear to have narrowed over the last 25 years. This series of four five-yearly reviews has witnessed an almost complete change in imaging systems. For the 1995 review, all hospital radiology rooms used film-screen cassettes. For this review, only 3% of rooms used film, all the rest used computed radiography or flat panel detectors. The results of this review give some indication that flat panel detectors are now fulfilling their potential to reduce dose, and suggest that flat panel detectors are typically giving lower radiation doses than either computed radiography or film-screen systems. Switching from film to computed radiography does not appear to be the best long term strategy for lowering doses.

National reference doses for medical procedures, based on rounded third quartile values of the distributions of mean dose, have been recommended and are expressed in terms of entrance surface dose, dose-area product or fluoroscopy time. The reference doses have been derived for standard-sized adults (mean weight 70 kg, apart from *Coronary Angiography* and *PTCA* patients for whom a mean weight of 80 kg was used) and for five standard-sized paediatric patients corresponding to new born babies, 1, 5, 10 and 15 year olds. The current reference doses for adults are on average about 10% lower than the corresponding reference doses for the 2005 review, and have more than halved over the last 20 years. The reference doses for paediatric patients are generally less than half the values given for the 2005 review.

For dental X-ray examinations, national reference doses have been expressed in terms of patient entrance dose for intra-oral radiographs, and dose-area product for panoramic radiographs. National reference doses for intra-oral radiographs are lower than given in the 2005 review. Whereas in the 2005 review a single panoramic reference dose was given for both adults and children, separate national reference doses for panoramic dental radiographs are given for adults and children in this review.

The regular monitoring of patient doses that has been encouraged in the UK since the early 1990s, and is now a regulatory requirement, appears to have had a significant impact on patient protection. However, the variation in the typical dose delivered by different X-ray rooms around the UK for the same examination is still substantial, indicating that there is further scope for patient dose reduction. National reference doses should continue to be useful in identifying further opportunities for improvement in patient protection and supporting the formal setting by the Department of Health of national diagnostic reference levels (DRLs).

The national reference doses recommended in this review are complementary to those previously published for computed tomography in NRPB-W67 (Shrimpton et al, 2005), which are in the process of being updated, following the third UK CT dose survey (Meeson et al, 2011).

Further national reviews of patient dose will be essential to monitor UK trends following continuing advances in radiological practice. However, there is now a timely opportunity to review methods for the collection of new such data in order to exploit fully the increasing availability of information in electronic form from PACS and radiology information (RIS) systems

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.

8 ACKNOWLEDGEMENTS

We wish to thank the following hospital physicists and radiology department staff for supplying patient dose data. Without their help, this report would not have been possible.

Matthew Ager, Rebecca Alkins, Lynn Bateman, Michael Brooks, Liz Chaloner, Catherine Chapman-Jones, Claire-Louise Chapple, Paul Charnock, Patricia Clinch, Val Cook, Ron Corrigall, John Courtney, Therese Crawley, Delphine Darios, Lisa Davenport, Andrew Davis, Rosemary Eaton, Fiona England, Joseph Farwell, Katy Fleckney, Ruby Fong, Jenny Grehan, Andrew Gulson, James Harries, Melanie Hiorns, Phil Hollaway, Sandra Hopkins, Anita Jefferies, John Kotre, Lesley Leavesley, Sharon Maddison, Colin Martin, Clara Marquez-Moreno, Lucy Mather, Anne Miller, Roy Mooney, Mandy Moreton, Giles Morrison, Rosemary Nicholson, Debbie Peet, Matthew Pryor, Stephen Rimmer, Nick Rowles, Alex Sandison, Laura Sawyer, Jon Shafford, Andy Shaw, Jane Shekhdar, Pramjeet Singh, Donna Stretton, David Sutton, Lorna Sweetman, Gill Walton, Hugh Wilkins.

Please accept our apologies if anyone has been inadvertently omitted from this list.

We also wish to thank Barry Wall who initiated this series of reviews. David Hart, the principal author of this report, will be retiring in 2012, so any data for further reviews should be sent to Paul Shrimpton (paul.shrimpton@hpa.org.uk).

9 REFERENCES

Binley's (2009). The Health and Social Care Yearbook 2009-2010. Official Handbook of the Institute of Healthcare Management. Beechwood House Publishing Ltd, Basildon.

Bohmann I (1990). Ermittlung der Durchstrahlungsdurchmesser bei Sauglingen, Kindern und Jugendlichen zur Aufstellung von Belichtungswerten in der Rontgendiagnostik und Abschatzung der Organdosiswerte bei typischen Rontgenuntersuchungen. Munchen, Institut fur Strahlenschutz, GSF-Bericht 16/90.

British Dental Association (2011). www.bda.org.

Carter C and Veale B (2009). Digital Radiography and PACS. Mosby, St Louis, Missouri.

Centre for Evidence-based Purchasing (2008). Direct digital radiography systems for general radiography. Report CEP08040. NHS Purchasing and Supply Agency, London.

Department of Health (2000). The Ionising Radiation (Medical Exposure) Regulations 2000 (together with notes on good practice). http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_4007957.

Department of Health (2007). Guidance on the establishment and use of diagnostic reference levels (DRLs). http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_074067.

Department of Health (2010). Hospital activity statistics: Imaging and radiodiagnostics (KH12) data. http://www.dh.gov.uk/en/Publicationsandstatistics/Statistics/Performancedataandstatistics/HospitalActivityStatistics/DH_077487.

Gulson AD, Knapp TA and Ramsden PG (2007). Doses to patients arising from dental X-ray examinations in the UK, 2002-2004: a review of Dental X-ray Protection Service data. Report HPA-RPD-022. www.hpa.org.uk .

Hart D, Hillier MC and Wall BF (2002a). Doses to patients from medical X-ray examinations in the UK – 2000 review. Report NRPB-W14. www.hpa.org.uk .

Hart D, Hillier MC and Wall BF (2007). Doses to patients from radiographic and fluoroscopic X-ray imaging procedures in the UK - 2005 review. Report HPA-RPD-029. www.hpa.org.uk .

Hart D, Hillier M C, Wall B F, Shrimpton P C and Bungay D (1996). Doses to patients from medical X-ray examinations in the UK – 1995 review. Report NRPB-R289. www.hpa.org.uk .

Hart D and Wall BF (2002b). Radiation exposure of the UK population from medical and dental x-ray examinations. Report NRPB-W4. www.hpa.org.uk .

Hart D, Wall BF, Hillier MC and Shrimpton PC (2010). Frequency and collective dose for medical and dental X-ray examinations in the UK, 2008. Report HPA-CRCE-012. www.hpa.org.uk .

Hart D, Wall BF, Shrimpton PC, Bungay DR and Dance DR (2000). Reference doses and patient size in paediatric radiology. Report NRPB-R318. www.hpa.org.uk .

Hiorns MP, Saini A and Marsden PJ. (2006). A review of current local dose-area product levels for paediatric fluoroscopy in a tertiary referral centre compared with national standards. Why are they so different? *Br J Radiol*, **79**, 326-330.

Holroyd JR (2012). The measurement of X-ray beam size from dental panoramic radiography equipment. Report HPA-CRCE-032. www.hpa.org.uk .

Honey I, MacKenzie A and Evans DS (2005). Investigation of optimum energies for chest imaging using film-screen and computed radiography. *Br J Radiol*, **78**, 422-427.

IPEM (2004). Guidance on the establishment and use of diagnostic reference levels for medical X-ray examinations. Institute of Physics and Engineering in Medicine Report 88. IPEM, York.

IPEM (2005). Recommended standards for the routine performance testing of diagnostic x-ray imaging systems. Institute of Physics and Engineering in Medicine Report 91. IPEM, York.

IPSM (1992). National protocol for patient dose measurements in diagnostic radiology. Dosimetry Working Party of the Institute of Physical Sciences in Medicine. NRPB, Chilton. www.hpa.org.uk

Meeson SM, Shrimpton PC, Maclachlan SA and Golding SJ (2011). Update on radiation exposure from CT: early progress in the third UK CT dose survey. Electronic poster e103. Proceedings of UK Radiological Congress 2011. BJR Congress series 55-56.

Shrimpton PC, Hillier MC, Lewis MA and Dunn M. (2005) Doses from computed tomography examinations in the UK - 2003 review. Report NRPB–W67. www.hpa.org.uk

Shrimpton PC, Wall BF, Jones DG, Fisher ES, Hillier MC, Kendall GM and Harrison RM (1986). A national survey of doses to patients undergoing a selection of routine X-ray examinations in English hospitals. Report NRPB-R200. www.hpa.org.uk

APPENDIX A

Participating Hospitals in 2010 review

HOSPITAL NAME	DOMAIN	TOWN	COUNTRY
Abingdon Community Hospital	N	Abingdon	E
Addenbrooke's Hospital	N	Cambridge	E
Airedale General Hospital	N	Keighley	E
Aldershot Centre for Health	N	Aldershot	E
Alexandra Hospital	P	Cheadle	E
Alltwen Hospital	N	Porthmadog	W
Alton Community Hospital	N	Alton	E
Altrincham General Hospital	N	Altrincham	E
Amersham General Hospital	N	Amersham	E
Arbroath Infirmary	N	Arbroath	S
Arran War Memorial Hospital	N	Isle of Arran	S
Ashford Hospital	N	Ashford	E
Ayr Hospital	N	Ayr	S
Ayrshire Central Hospital	N	Irvine	S
Basingstoke & North Hampshire Hospital	N	Basingstoke	E
Beckenham Hospital	N	Beckenham	E
Bicester Community Hospital	N	Bicester	E
Birmingham Dental Hospital	N	Birmingham	E
Birmingham Heartlands Hospital	N	Birmingham	E
BMI Bath Clinic	P	Bath	E
BMI Esperance Hospital	P	Eastbourne	E
BMI Goring Hall Hospital	P	Goring-by-Sea	E
BMI Hampshire Clinic	P	Basingstoke	E
BMI Mount Alvernia Hospital	P	Guildford	E
BMI Runnymede Hospital	P	Chertsey	E
BMI Shirley Oaks Hospital	P	Croydon	E
Bognor Regis War Memorial Hospital	N	Bognor Regis	E
Bolton Radiology	P	Bolton	E
Borders General Hospital	N	Melrose	S
Botesdale Health Centre	P	Diss	E
Bradford Royal Infirmary	N	Bradford	E
Bridgeton Health Centre	N	Glasgow	S
Bridgnorth & S.Shropshire Infirmary	N	Bridgnorth	E
Bro Ddyfi Community Hospital	N	Machynlleth	W
Bronglais General Hospital	N	Aberystwyth	W
Bryn Beryl Hospital	N	Pwllheli	W
Burnley General Hospital	N	Burnley	E
Campbeltown Hospital	N	Campbeltown	S
Cardigan & District Memorial Hospital	N	Cardigan	W
Castle Hill Hospital	N	Cottingham	E
Caterham Dene Hospital	N	Caterham	E
Chalfont & Gerrard's Cross Hospital	N	Chalfont St Peter	E
Chase Community Hospital	N	Bordon	E
Chesterfield & North Derbyshire Royal Hospital	N	Chesterfield	E

Chippenham Community Hospital	N	Chippenham	E
Chipping Norton War Memorial Hospital	N	Chipping Norton	E
Chorley & South Ribble District Hospital	N	Chorley	E
Christchurch Hospital	N	Christchurch	E
Churchill Hospital	N	Oxford	E
City Hospital Birmingham	N	Birmingham	E
Clacton and District Hospital	N	Clacton-on-sea	E
Clydebank Health Centre	N	Clydebank	S
Coatbridge Health Centre	N	Coatbridge	S
Colchester General Hospital	N	Colchester	E
Colwyn Bay Community Hospital	N	Colwyn Bay	W
Crawley Hospital	N	Crawley	E
Cromer District Hospital	N	Cromer	E
Crosshouse Hospital	N	Kilmarnock	S
Cumberland Centre	N	Plymouth	E
Cumbernauld Central Health Centre	N	Cumbernauld	S
Deeside Community Hospital	N	Aston	W
Denbigh Community Hospititал	N	Denbigh	W
Derriford Hospital	N	Plymouth	E
Devizes Community Hospital	N	Devizes	E
Doddington Hospital	N	March	E
Dorking General Hospital	N	Dorking	E
Downe Hospital	N	Downpatrick	N
Dumbarton Health Centre	N	Dumbarton	S
Dumfries & Galloway Royal Infirmary	N	Dumfries	S
Dunaros Hospital	N	Aros	S
Dunoon/Cowal Hospital	N	Dunoon	S
East Ayrshire Community Hospital	N	Cumnock	S
East Surrey Hospital	N	Redhill	E
Easterhouse Health Centre	N	Glasgow	S
Edenbridge and District War Memorial Hospital	N	Tunbridge	E
Eryri Hospital	N	Caernarfon	W
Essex County Hospital	N	Colchester	E
Fairfield General Hospital	N	Bury	E
Falkirk & District Royal Infirmary	N	Falkirk	S
Farnham Hospital	N	Farnham	E
Felixstowe Community Hospital	N	Felixstowe	E
Fernbrae Private Clinic	P	Dundee	S
Ffestiniog Memorial Hospital	N	Blaenau Ffestiniog	W
Fleet Hospital	N	Fleet	E
Frimley Park Hospital	N	Camberley	E
Frome Community Hospital	N	Frome	E
Fryatt Hospital and Mayflower Medical Centre	N	Harwich	E
Fylde Coast BUPA Hospital	P	Blackpool	E
Galloway Community Hospital	N	Stranraer	S
Gartnavel General Hospital	N	Glasgow	S
Glan Clwyd Hospital	N	Rhyl	W
Glasgow Royal Infirmary	N	Glasgow	S
Global Clinic	P	Norwich	E
Golden Jubilee National Hospital	N	Glasgow	S
Gorbals Health Centre	N	Glasgow	S
Gorseinon Hospital	N	Swansea	W

Gosport War Memorial Hospital	N	Gosport	E
Grange Medical Centre	N	Leeds	E
Great Ormond Street Hospital for Sick Children	N	London	E
Greater Manchester Surgical Centre	P	Manchester	E
Guy's Hospital	N	London	E
Hairmyres Hospital	N	East Kilbride	S
Halstead Hospital	N	Halstead	E
Harbour Hospital	P	Poole	E
Harrogate & District Hospital	N	Harrogate	E
Haslemere Hospital	N	Haslemere	E
Heart Hospital, The	N	London	E
Herts & Essex General Hospital	N	Bishop's Stortford	E
Hinchingbrooke Hospital	N	Huntingdon	E
Horsham Hospital	N	Horsham	E
Horton General Hospital	N	Banbury	E
Hove Polyclinic	N	Hove	E
Hull Royal Infirmary	N	Hull	E
Hurstwood Park Neurological Centre	N	Haywards Heath	E
InHealth Beechwood Hall	P	High Wycombe	E
Inverclyde Royal Hospital	N	Greenock	S
Ipswich Hospital	N	Ipswich	E
James Paget Hospital	N	Great Yarmouth	E
John Radcliffe Hospital	N	Oxford	E
Keighley Health Centre	N	Keighley	E
Kent & Sussex Hospital	N	Tunbridge Wells	E
Kilsyth Health Centre	N	Kilsyth	S
King’s College Hospital	N	London	E
King's Cross Hospital (Dundee)	N	Dundee	S
Lady Margaret Hospital	N	Isle of Cumbrae	S
Lagan Valley Hospital	N	Lisburn	N
Launceston General Hospital	N	Launceston	E
Leeds General Infirmary	N	Leeds	E
Leigh Infirmary	N	Leigh	E
Lightburn Day Hospital	N	Glasgow	S
Links Health Centre	N	Montrose	S
Liskeard Community Hospital	N	Liskeard	E
Llandudno General Hospital	N	Llandudno	W
London Chest Hospital	N	London	E
London Independent Hospital	P	London	E
Lorn & Islands District General Hospital	N	Oban	S
Macclesfield District General Hospital	N	Macclesfield	E
Maidstone Hospital & Community Unit	N	Maidstone	E
Manchester Royal Infirmary	N	Manchester	E
Mansionhouse Unit	N	Glasgow	S
Marlow Cottage Hospital	N	Marlow	E
Melksham Community Hospital	N	Melksham	E
Mid-Argyll Hospital	N	Lochgilphead	S
Milford Hospital	N	Milford, Surrey	E
Mold Community Hospital	N	Mold	W
Monklands Hospital	N	Airdrie	S
Montgomery County Infirmary	N	Newtown	W
Morriston Hospital	N	Swansea	W

Mount Gould Hospital	N	Plymouth	E
Mount Vernon Hospital	N	Northwood	E
Neath Port Talbot Hospital	N	Port Talbot	W
New Tenby Cottage Hospital	N	Tenby	W
Newmarket General Hospital	N	Newmarket	E
Ninewells Hospital	N	Dundee	S
Norfolk & Norwich Hospital	N	Norwich	E
Norfolk House	N	Manchester	E
North Cambridgeshire Hospital	N	Wisbech	E
Northern General Hospital	N	Sheffield	E
Nuffield Orthopaedic Centre	N	Oxford	E
Orchard Hospital	P	Newport (IoW)	E
Ormskirk & District General Hospital	N	Ormskirk	E
Orpington Hospital	N	Orpington	E
Orthopaedics & Spine Specialist Hospital	P	Peterborough	E
Papworth Hospital	N	Cambridge	E
Pembury Hospital	N	Tunbridge Wells	E
Perth Royal Infirmary	N	Perth	S
Petersfield Community Hospital	N	Petersfield	E
Poole Hospital	N	Poole	E
Prince Philip Hospital	N	Llanelli	W
Princess Alexandra Hospital	N	Harlow	E
Princess of Wales Hospital	N	Ely	E
Princess Royal Hospital	N	Haywards Heath	E
Princess Royal Hospital	N	Hull	E
Princess Royal University Hospital	N	Orpington	E
Queen Alexandra Hospital	N	Portsmouth	E
Queen Elizabeth Hospital	N	King's Lynn	E
Queen Elizabeth the Queen Mother Hospital	N	Margate	E
Queen Mary's Hospital for Children	N	Carshalton	E
Queen Victoria Centre	N	Morecambe	E
Queen Victoria Memorial Hospital	N	Herne Bay	E
Ripon and District Community Hospital	N	Ripon	E
Rochdale Infirmary	N	Rochdale	E
Rowley Regis Hospital	N	Warley	E
Royal Albert Edward Infirmary	N	Wigan	E
Royal Alexandra Hospital	N	Paisley	S
Royal Alexandra Hospital	N	Rhyl	W
Royal Alexandra Hospital for Sick Children	N	Brighton	E
Royal Blackburn Hospital	N	Blackburn	E
Royal Bolton Hospital	N	Bolton	E
Royal Bournemouth General Hospital	N	Bournemouth	E
Royal Devon & Exeter Hospital	N	Exeter	E
Royal Hospital for Sick Children	N	Glasgow	S
Royal Lancaster Infirmary	N	Lancaster	E
Royal London Hospital	N	London	E
Royal Manchester Children's Hospital	N	Pendlebury	E
Royal National Hospital for Rheumatic Diseases	N	Bath	E
Royal Oldham Hospital	N	Oldham	E
Royal Preston Hospital	N	Fulwood	E
Royal Surrey County Hospital	N	Guildford	E
Royal Sussex County Hospital	N	Brighton	E

Royal United Hospital	N	Bath	E
Ruthin Cottage Community Hospital	N	Ruthin	W
Saffron Walden Community Hospital	N	Saffron Walden	E
Sandringham Hospital	P	King's Lynn	E
Sandwell District General Hospital	N	West Bromwich	E
Santa Maria Hospital	P	Swansea	W
Sevenoaks Hospital	N	Sevenoaks	E
Shettleston Health Centre	N	Glasgow	S
Singleton Hospital	N	Swansea	W
Skipton General Hospital	N	Skipton	E
South Hams Hospital	N	Kingsbridge	E
South Pembrokeshire Hospital	N	Pembroke Dock	W
Southern General Hospital	N	Glasgow	S
Southlands Hospital	N	Shoreham	E
Southport & Formby District General Hospital	N	Southport	E
Spire Alexandra Hospital	P	Chatham	E
Spire Cambridge Lea Hospital	P	Cambridge	E
Spire Clare Park Hospital	P	Farnham	E
Spire Gatwick Park Hospital	P	Horley	E
Spire Hartswood Hospital	P	Brentwood	E
Spire Norwich Hospital	P	Norwich	E
Spire Portsmouth Hospital	P	Havant	E
Spire Roding Hospital	P	Ilford	E
Spire Southampton Hospital	P	Southampton	E
Spire Tunbridge Wells Hospital	P	Tunbridge Wells	E
St. Bartholomew's Hospital	N	West Smithfield	E
St. Helens Hospital	N	St. Helens	E
St. James's University Hospital	N	Leeds	E
St. Leonard's Hospital	N	Sudbury	E
St. Luke's Hospital	N	Bradford	E
St. Margaret's Hospital	N	Epping	E
St. Mary's Hospital	N	London	E
St. Mary's Hospital	N	Portsmouth	E
St. Peter’s Hospital	N	Chertsey	E
St. Richard’s Hospital	N	Chichester	E
St. Thomas' Hospital	N	London	E
Stepping Hill Hospital	N	Stockport	E
Stirling Royal Infirmary	N	Stirling	S
Stobhill General Hospital	N	Glasgow	S
Stoke Mandeville Hospital	N	Aylesbury	E
Stonehouse Hospital	N	Larkhill	S
Stracathro Hospital	N	Brechin	S
Swaffham Community Hospital	N	Swaffham	E
Swanage Hospital	N	Swanage	E
Tameside General Hospital	N	Ashton-under-Lyne	E
Tavistock Hospital	N	Tavistock	E
Thetford Cottage Hospital	N	Thetford	E
Thomas Linacre Outpatients Centre	N	Wigan	E
Trafford General Hospital	N	Davyhulme	E
Trowbridge Community Hospital	N	Trowbridge	E
Ulster Hospital	N	Belfast	N
University Hospital Aintree	N	Liverpool	E

University Hospital Lewisham	N	London	E
Vale of Leven Hospital	N	Alexandria	S
Victoria Hospital	N	Lewes	E
Victoria Hospital	N	Rothesay	S
Victoria Hospital	N	Wimbourne	E
Victoria Infirmary	N	Glasgow	S
Victoria Infirmary	N	Helensburgh	S
Walton Community Hospital	N	Walton-on-Thames	E
Warminster Community Hospital	N	Warminster	E
Warrington Hospital	N	Warrington	E
West Suffolk Hospital	N	Bury-St-Edmunds	E
West Wales General Hospital	N	Carmarthen	W
Western Infirmary	N	Glasgow	S
Westmorland General Hospital	N	Kendal	E
Weybridge Community Hospital	N	Weybridge	E
Wharfedale General Hospital	N	Otley	E
Whipps Cross Hospital	N	Leytonstone	E
Whiston Hospital	N	Prescot	E
Whitehills Health Centre	N	Forfar	S
William Harvey Hospital	N	Ashford	E
Wishaw General Hospital	N	Wishaw	S
Withybush General Hospital	N	Haverfordwest	W
Woking Community Hospital	N	Woking	E
Worthing Hospital	N	Worthing	E
Wrexham Maelor Hospital	N	Wrexham	W
Wycombe General Hospital	N	High Wycombe	E
Wythenshawe Hospital	N	Wythenshawe	E
X-ray at 77 Ltd	P	Norwich	E
York District Hospital	N	York	E
Ysbyty Gwynedd	N	Bangor	W
Ysbyty Penrhos Stanley	N	Holyhead	W
Ystradgynlais Community Hospital	N	Ystradgynlais	W

In addition, there were 20 NHS hospitals, 15 private hospitals, and 1 prison, all located in England, which preferred to remain anonymous.

Domain: N=NHS, P=Private.

Country: E=England, N=N.Ireland, S=Scotland, W=Wales.

APPENDIX B

Data Requested for NPDD

(Essential data is highlighted)

Form 1. Dose per radiograph

Date ……		Hospital ……	
		X-ray room ……	
Patient data			
Sex M / F		Weight ……	
Age ……		Height* ……	
		Thickness* ……	
Examination data			
Type of examination ……			
Projection ……			
Data for each radiograph			
Entrance surface dose	…….. mGy	or Dose-area product	…… Gy cm^2
Focus-Film Distance	……. cm	Automatic Exposure Control used?	Yes / No
Tube voltage	……. kV	Film size	……..cm x cm
Exposure setting	…….. mAs	Film of diagnostic quality?	Yes / No
Equipment data			
Generator waveform	……..	Film make and type	……..……
Total tube filtration	…... mm Al	Intensifying screen make and type	……
Antiscatter grid: - ratio	……	Film/screen speed class	……
- strips/cm	……	Cassette with carbon fibre cover	Yes /No
- carbon fibre covers	Yes / No		
- fibre spacers	Yes / No	CR# make and type	……
Table top material	……		
Table top Al equivalence	..…..mm Al	Digital detector (TFT)~ make & type	……..……
		Other detector systems make & type	…… ……

* **For children**, it is essential that either the thickness of the body part being X-rayed **or** both the height and weight of the patient, be provided**.**

CR = computed radiography (photostimulable phosphor)

~ TFT = thin film transistor

This form may be freely photocopied for the purpose of data collection.

(Essential data is highlighted)

Form 2. Dose per examination or procedure

Date …….. Hospital ……

X-ray room ……

Patient data

Sex M / F Weight ……. or small/medium/large

Age …… Height* ……

Examination data

Type of examination …… (including anatomical location)

Total dose-area product ……Gy cm^2 For angioplasties: no. of dilations…..

Degree of difficulty$^+$ Easy/Average/Difficult no. of stents…….

No. of exposures (not necessarily no. of images) using:-

- Screen/film ……
- Computed radiography ……
- Photofluorography (eg. 100 mm camera) ……
- Digital spot imaging (not DSA) ……
- Digital subtraction angiography (DSA) ……
- Rapid film changer (eg. Puck, AOT) ……

Tube voltage range …….. - …….. kV

Fluoroscopy data

Fluoroscopy time ……. Secs Automatic Exposure Rate Control used? Yes / No

Cine time …… Secs Last image hold? Yes / No

Tube voltage range …….. - …….. kV Pulsed fluoro.? Yes / No

Tube current range …….. - …….. mA

Equipment data

Generator waveform …… Film make and type ……

Total tube filtration …… mm Al Intensifying screen make & type ……..

Antiscatter grid: - ratio …… Film/screen speed class ……

- strips/cm …… Cassette with carbon fibre cover Yes /No

- carbon fibre covers Yes / No

- fibre spacers Yes / No CR$^{\#}$ make & type ……

Image intensifier Field of View ……cm

Table top material …… Digital detector (TFT)$^{\sim}$ make & type ……

Table top Al equivalence …… mm Al Other detector systems make & type ……

* **For children**, it is essential that the height and weight of the patient be provided.

$^+$ Delete whichever do not apply; Incomplete examinations should be excluded.

$^{\#}$ CR = computed radiography (photostimulable phosphor).

$^{\sim}$ TFT = thin film transistor

This form may be freely photocopied for the purpose of data collection.

(Essential data is highlighted)

Form 3. Dental: dose per intra-oral mandibular molar radiograph

Date …….. Dental practice ……

Operating parameters for adult/child (delete whichever does not apply)

Tube voltage	……. kV	Beam shape	Circular	Rectangular
Exposure setting	…….. mAs	Beam size	Diameter……cm	……..cm x cm
or …….. mA and	……. s	FSD[1]	…… cm	

Dose measurement

Spacer exit dose[2] …….. mGy

Equipment data

Equipment make	……	Film make	……
Equipment model	……	Film type	……
Total tube filtration	……... mm Al	Film speed class	……
		Digital system make	……
		Digital system model	……

1 Distance between focus and end of spacer cone.

2 Absorbed dose to air (or air kerma) measured at end of spacer cone, without backscatter

(Essential data is highlighted)

Form 4. Dental: dose per panoramic radiograph

Date ……		Dental practice ……	
Operating parameters for adult/child (delete whichever does not apply)			
Tube voltage	…… kV	Exposure setting	…… mAs
		or ……mA and	…… s
Dose measurement			
Dose-area product[1]	…… Gy cm^2	or	
Dose-width product[2]	…… Gy cm	and Height of X-ray beam	…… cm
Equipment data			
Equipment make	……	CR[3] used?	Yes / No
Equipment model	……	CR[3] make	……
Total tube filtration	…… mm Al	CR[3] model	……
Film make	……		
Film type	……	Other digital system used?	Yes / No
Intensifying screen make	……	Make of digital system	……
Intensifying screen model	……	Model of digital system	……
Film/screen speed class	……		
Cassette with carbon fibre cover	Yes /No		

1 Absorbed dose to air (or air kerma) x width of X-ray beam x height of X-ray beam, all measured in the same plane between the X-ray tube and the image receptor, in the absence of a patient.

2 Measured on the patient side of the receiving slot in the cassette carriage faceplate, but without a patient or phantom in the beam. 'Width' is measured horizontally.

3 CR = computed radiography (photostimulable phosphor).

APPENDIX C

Glossary of examinations and interventional procedures

AICD Automatic Implantable Cardioverter Defibrillator, a similar device to a pacemaker.

Angiography An imaging examination of blood vessels using contrast medium.

Angioplasty. The dilation of vascular strictures, usually arterial, during an interventional procedure. Especially used in the coronary arteries (see PTCA).

Aortography Angiography of the aorta, the largest artery carrying blood from the heart.

Arthrography Examination of a joint, involving injection of water soluble contrast medium into it.

Barium enema Examination of the colon with the passage of barium sulphate suspension per rectum as a contrast medium.

Barium follow-through Examination of the small bowel after swallowing barium sulphate suspension as a contrast medium.

Barium meal Examination of the stomach and duodenum after swallowing barium sulphate suspension as a contrast medium.

Barium small bowel enema Examination of the small intestine using barium sulphate suspension introduced via a catheter placed down the oesophagus and into the duodenum.

Barium swallow Examination of the oesophagus after swallowing barium sulphate suspension as a contrast medium.

Barium swallow (video) Video recording of the throat after swallowing barium sulphate suspension as a contrast medium. Mostly performed for speech therapy.

Biliary drainage An interventional procedure used to decompress an obstructed biliary system using external or combined external/internal drainage by means of percutaneously inserted catheters.

Biliary intervention Any percutaneous or endoscopic interventional procedure in the biliary system such as balloon dilation of bile ducts or stone removal.

Biliary stent introduced endoscopically via an ERCP, drainage is internal into the duodenum.

Carotid angiography Angiography of the two great arteries of the neck. Made largely obsolete by ultrasonic Doppler measurement of blood flow.

Cerebral angiography Angiography of the cerebral blood vessels.

Coronary angiography Angiography of the coronary arteries which supply the heart muscle with blood. Usually preceded by left ventricular angiography.

Coronary graft angiography Angiography of a coronary artery bypass graft. The latter is a surgical procedure using a piece of vein or artery from elsewhere in the body to bypass blocked coronary arteries.

Dacryocystogram Investigation of the tear ducts following injection of contrast medium.

Electrophysiology is used to diagnose disorders in heart rhythm. Electrodes are usually passed to the heart via the femoral artery with x-ray imaging guidance.

Embolisation An interventional procedure to block an artery or vein to stop bleeding, or to stop blood supply to a tumour. Often carried out to treat fibroids in the uterus, and to treat varicoceles (enlarged veins in the scrotum).

ERCP Endoscopic retrograde cholangiopancreatography is either a purely diagnostic examination of the biliary tree and pancreatic ducts using water-soluble contrast medium, or an interventional procedure to remove calculi and place stents.

Facet joint injection An interventional procedure for pain control in the spine.

Femoral angiography Investigation of the blood supply to the legs, usually involves some imaging of the lower torso as well as the leg(s).

Filter (Inferior vena cava) An interventional procedure in which a filter is extruded from a catheter into the inferior vena cava, which is one of the main veins discharging into the heart. The filter forms a barrier to the passage of clots to the heart and lungs.

Fistulography A contrast examination of a narrow duct between two internal organs, usually the oesophagus and trachea.

Herniography uses water soluble contrast medium injected below the navel to demonstrate a hernia in the groin.

Hickman Line Insertion An interventional procedure to insert a large bore catheter into the body, usually into the vena cava in the chest, to deliver drugs for chemotherapy, long-term antibiotics etc.

Hysterosalpingography The injection of contrast medium through the cervix to demonstrate the uterus and especially the fallopian tubes.

Interventional procedure Minimally invasive therapeutic procedure using image guidance.

IVU (Intravenous urography) Injection of iodine contrast medium to image kidneys, ureter and bladder. (Also known as IVP, intravenous pyelography).

MCU (Micturating cystourethrography) The urinary bladder is filled with water soluble iodine contrast medium via a catheter. The catheter is removed and fluoroscopic imaging is used during micturition to detect reflux.

Mesenteric angiography Angiography of the mesenteric arteries which supply blood to the intestines.

Naso-gastric feeding tube is inserted down one nostril and into the stomach.

Nephrostography A diagnostic examination of a patient with an external nephrostomy catheter. Contrast medium is injected via the catheter to delineate the urinary collecting system and ureter.

Nephrostomy An interventional procedure for draining the kidney(s) of urine by percutaneous insertion of a catheter. The catheter may be positioned a) externally so that urine exits effectively through an open wound, or b) internally by running the catheter down the ureter to the bladder.

Oesophageal dilation An interventional procedure in which the throat is anaesthetised, and the patient swallows a balloon dilator.

Oesophageal stent An interventional procedure in which a stent is inserted to open a stricture usually caused by cancer of the oesophagus.

Pacemaker The fitting of a cardiac pacemaker involves surgery to implant the generator and interventional radiology to guide the electrode and its lead into position. A single chamber pacemaker paces the right ventricle only, whereas a dual chamber pacemaker also paces one of the atria.

Pacemaker (Biventricular) Can pace both the septal and lateral walls of the left ventricle. Such a device has at least 2 leads, while a single chamber pacemaker has just one.

Pain relief in spine refers to a number of procedures relating to the spine that are concerned with pain relief e.g. spinal nerve root injection.

Patent Foramen Ovale closure A PFO is a small hole in the wall that divides the upper left and upper right chambers (atria) of the heart. It should close at birth, but often does not.

Percutaneous Endoscopic Gastrostomy involves making an opening to introduce food into the stomach. An endoscope is passed through the mouth and into the stomach. PEG tube is passed through the skin of the abdomen through a very small incision. A balloon is blown up on the end of the tube to hold it in place.

Percutaneous transhepatic cholangiography (PTC) Injection of contrast medium into the biliary system by direct puncture of a bile duct. Often involves introduction of a catheter and an interventional procedure such as balloon dilation of the bile duct, removal of gallstones, placement of a stent, or drainage through a catheter.

Pouchography is a contrast study of an ileal pouch which was created when the entire colon was surgically removed.

Proctography is an investigation of an anal-rectal disorder.

PTCA (Percutaneous transluminal coronary angioplasty) A catheter is inserted through the femoral artery and guided fluoroscopically to the coronary arteries for balloon dilation. Often involves stenting also.

Radiofrequency cardiac catheter ablation is a treatment for disturbed heart rhythms. RF energy is used to ablate (get rid of) an accessory pathway for arrhythmia.

Radiologically Inserted Gastrostomy (RIG) or Radiological percutaneous gastrostomy is performed to achieve feeding access in patients with tumours of the head & neck or oesophagus. RIG is an alternative to percutaneous endoscopic gastrostomy.

Renal angiography Angiography, usually of the renal arteries which supply blood to the kidneys, or, rarely, of the renal veins.

Retrograde pyelography An examination of the kidney and ureter using contrast medium. To achieve this, a ureteric catheter is introduced retrogradely through the bladder.

Right Heart Catheterisation Relatively simple angiographic procedure involving the catheterisation of the right hand side of the heart. The catheter is inserted at the neck and guided under fluoroscopic control. When in position haemodynamic studies are performed -- does not usually involve any radiographs.

Sialography Examination of the salivary system using iodine contrast medium injected into a dilated orifice of a salivary gland.

Sinography The injection of water-soluble contrast medium into an abnormal channel leading from an organ, usually in the gastro-intestinal tract, to an abscess on the surface of the body.

Stent A cylindrical object introduced into the body during an interventional procedure to keep open a tubular structure, such as an artery, bile duct, intestine, oesophagus or ureter.

T-tube cholangiography An examination of the biliary system performed post-operatively by injecting contrast medium through a T-tube catheter placed in the common bile duct during surgery.

Urethrography An examination of the male urethra performed by retrograde injection of contrast.

Urodynamics is an alternative term for bladder pressure studies, also known as cystomanometry or cystometrography. A catheter is passed retrogradely into the urinary bladder, which is slowly filled with contrast medium and pressures are measured.

Venography (sometimes called phlebography) A contrast examination of the venous system, usually looking for evidence of deep vein thrombosis in the legs. Occasionally performed on the arms.

Water soluble enema Examination of the colon using iodinated water-soluble contrast medium, performed in preference to a barium enema if there is a risk of leakage from the bowel.

Water soluble swallow Examination of the oesophagus using iodinated water-soluble contrast medium, performed in preference to a barium swallow if there is a risk of leakage from the gastro-intestinal tract.