Doses to Patients from Radiographic and Fluoroscopic X-ray Imaging Procedures in the UK – 2005 Review

D Hart, M C Hillier and B F Wall

ABSTRACT

In 1992 the National Radiological Protection Board established a National Patient Dose Database 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. This report is the third in a series of five-yearly reviews of the database, and analyses the information collected during the period January 2001 to February 2006. It includes the results of 23,000 entrance surface dose (ESD) measurements and 57,000 dose-area product (DAP) measurements for single radiographs, and 208,000 DAP measurements and 187,000 records of the fluoroscopy time for complete examinations, collected from 316 hospitals throughout the UK. Information on the patient dose distributions and exposure conditions for over 40 types of x-ray imaging procedure on adults and 3 types of medical x-ray examination on children is presented. The influence of film-screen and digital imaging equipment on patient doses has been analysed. For the first time in this series of reviews patient dose data has been collected for dental x-ray examinations. National reference doses, based on the rounded third quartile values of the dose distributions, are presented for 30 types of diagnostic x-ray examination on adults, for 8 types of interventional procedure on adults and for 4 types of x-ray examination on children. The reference doses are on average about 16% lower than corresponding values in the previous (2000) 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 Radiation Protection Division of the Health Protection Agency gratefully acknowledges the co-operation of hospital physicists and radiology department staff in supplying patient dose data. The continued provision of data to the National Patient Dose Database will be essential in order to monitor the progress of patient dose reduction measures in the UK and to extend and revise national reference doses in the future.

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

Approval: July 2007
Publication: August 2007
£20.00
ISBN 978-0-85951-600-6

EXECUTIVE SUMMARY

The exposure of patients to ionising radiation for diagnostic purposes contributes 90% of the total exposure of the UK population to man-made radiation, and amounts to 15% of exposure to all sources (natural and artificial). However, such exposures for medical purposes are not distributed uniformly in the population. The lifetime medical exposure for some individuals will be greater than their exposure to natural background radiation, and may result in a significant cancer risk that should be weighed against the benefits from the improved diagnosis afforded by the medical exposure.

The Ionising Radiation (Medical Exposure) Regulations 2000 require that doses from diagnostic medical exposures shall be kept as low as reasonably practicable consistent with the intended purpose. The employer is responsible for establishing diagnostic reference levels, for undertaking appropriate reviews whenever these are consistently exceeded, and for ensuring that corrective action is taken where appropriate. The Department of Health has recognised the reviews of the National Patient Dose Database as a major source for national diagnostic reference levels.

This report is the third in a series of five-yearly reviews of the National Patient Dose Database that is maintained by the Radiation Protection Division of 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 NHS 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 is 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 from January 2001 to February 2006, which amounts to nearly 300,000 dose measurements contributed by 316 hospitals and about 3000 dental practices. We have studied the distribution of radiation doses used by different hospitals and dental practices around the UK for over 40 types of x-ray examination. We provide national reference doses for 38 types of x-ray procedure on adults and 4 types of x-ray examination on children. The purpose of these reference doses is to give an indication of unusually high doses on a national scale, against which hospitals and clinics can check their own performance. The reference doses are pragmatically set at the 75th percentile value of the observed dose distributions. National reference doses should be taken into account when setting local diagnostic reference levels.

We have found that doses have continued to follow a downward trend since the first review. Currently, an important issue is to ensure that the replacement of film-screen imaging equipment with digital systems does not result in an increase in patient doses. There will therefore be a continuing need to monitor patient doses, not least because it is a regulatory requirement arising from the Ionising Radiation (Medical Exposure)

Regulations 2000. The continued provision of data to the National Patient Dose Database will be essential in order to check on dose trends and to revise national reference doses in the future. Please send data to david.hart@hpa.org.uk.

CONTENTS

1 INTRODUCTION

The National Radiological Protection Board (NRPB) established a National Patient Dose Database (NPDD) in 1992 after the publication of a National Protocol for Patient Dose Measurements in Diagnostic Radiology (IPSM, 1992). The NPDD was intended to collate the measurements of radiation doses to patients from common x-ray examinations carried out in hospitals throughout the UK, apart from CT examinations for which special dosimetry techniques are required that were not discussed in the National Protocol. NRPB has conducted reviews of the NPDD every 5 years in which the observed distributions of patient doses for common radiographic and fluoroscopic x-ray procedures are described and national reference doses are recommended.

In 2000 the Ionising Radiation (Medical Exposure) Regulations (Department of Health, 2000) provided a new impetus for patient dose assessment and introduced a legal framework for the establishment of reference doses or 'diagnostic reference levels' (DRLs) as they are referred to in the regulations. Subsequently, guidance on the establishment and use of diagnostic reference levels for medical and dental x-ray examinations has been provided by a joint working party of relevant professional bodies and published as IPEM Report 88 (IPEM, 2004). As explained in that guidance, national DRLs established to comply with the requirement of IR(ME)R need to be formally adopted by the Department of Health (DH). However, it is recognised by DH that the national reference doses recommended in the regular reviews of the NPDD will provide a major source of information when it is considering the adoption of new national DRLs. Indeed, in April 2007, DH published guidance on its website (Department of Health, 2007) formally adopting the national reference doses recommended in the 2000 review of the NPDD as national DRLs for radiographic and fluoroscopic x-ray examinations in compliance with IR(ME)R.

The NRPB merged into the Health Protection Agency in April 2005, and now forms its Radiation Protection Division (RPD). RPD continues to maintain the NPDD and will continue to publish reviews approximately every five years. Two previous reviews of the data have been published for each of the five-year periods preceding 1995 and 2000 (Hart, 1996 and Hart, 2002). This current report continues the review process by analysing the data collected during the latest five-year period from January 2001 to February 2006.

For the first time, radiation doses from dental x-ray examinations have been included in this review. These common examinations are mostly carried out in dental practices where there is only remote access to medical physics or radiation protection expertise. It is therefore more difficult for the dentist to be confident that the dose to the patient is as low as reasonably practicable. National reference doses can be an important aid to optimisation in these circumstances, so it is intended that national reference doses for dental x-ray examinations will be included in this and future reviews of the NPDD.

Patient radiation doses from CT examinations are not included in this report. Such information is stored in a separate database, also maintained by RPD, called PREDICT (Patient Radiation Exposure and Dose in CT), and analysed in a separate series of reports. The latest review of the PREDICT database includes national reference doses

for 8 common types of CT examinations and was performed for the year 2003 (Shrimpton, 2005). These reference doses have also been formally adopted by DH as national DRLs in compliance with IR(ME)R (DH, 2007).

After briefly describing the methods used for collecting and analysing the data, this report goes on to review the following aspects of the NPDD:

i) The representativeness of the data sample

ii) Dose distributions for different types of procedure

iii) Influence of equipment or techniques on doses

iv) Trends in doses with time

v) National reference doses.

2 METHODS

2.1 Obtaining the data

Data were obtained through three 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) (97%).

2) From dental practices throughout the UK for the period 2002-2004, supplied by the Dental X-ray Protection Service of the RPD (2%)

3) From the HPA's Patient Dosimetry Service that uses thermoluminescent dosemeters [TLDs] to measure entrance surface doses for simple radiographic examinations at a small sample of hospitals (1%).

The bulk of the total number of dose measurements (97%) came from the first route. More than two-thirds of the dental dose measurements came from the DXPS, the remainder being supplied by 7 medical physicists. HPA's Patient Dosimetry Service provided only 1% of the dose measurements and demand had dropped so low by the end of the review period that the service was closed down in March 2007.

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 and either the dose-area product or dose-width product for panoramic radiographs (IPEM, 2004; Gulson, 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/radiation/understand/radiation_topics/medical/diagnostic_radiology/npdd/npdd.htm .

Data were accepted in virtually any format, both on paper and as computer files. Most were sent by e-mail or on computer disc 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.

The reliability of the dental dose measurements supplied to us by the Dental X-ray Protection Service of the RPD is discussed in the section on assessment methods in Gulson, 2007.

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, 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 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, separate fields are used for adult and child doses, and the associated exposure parameters. Other information stored includes the practice name and address; 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 recommends that measurements should be made on at least ten adults of either sex when obtaining an estimate of the typical dose to an average adult patient for comparison of local performance in a particular room of the x-ray department 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 followed these suggestions when submitting data to the NPDD, so we had to decide how to select the appropriate data for inclusion in the analyses presented in this review.

For the 2000 review (Hart, 2002), we examined a range of selection procedures to see how much each one reduced the sample sizes, and whether they significantly affected key parameters of the room mean dose distribution. Nineteen selection procedures

were analysed, ranging from taking all the data, to the strict application of all the National Protocol recommendations, and their results were compared. The selection procedure that was chosen was to use data where the mean patient weight for a room was in the range 65 to 75 kg, or if the patient weights were unknown where there was a minimum of 10 patients per room. This made maximum use of the data that had been supplied without significantly biasing key parameters of the dose distribution. The same selection procedure is used for this report.

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 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 4% of all the dose measurements in the database for this review relate to children.

For medical x-ray examinations, a method has been developed (Hart, 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. 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, 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 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. Measurements on over 6000 intra-oral x-ray sets and about 2000 panoramic x-ray sets from all over the UK are available for this review, which are more than sufficient to provide a good guide to national practice.

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, 231 in England, 18 in Northern Ireland, 55 in Scotland, and 12 in Wales is given in Appendix A. Throughout this report, infirmaries, radiology practices, clinics, and health centres, are included within the term ‘hospitals’. The total number of hospitals (316) is estimated to cover at least 23% of all hospitals and clinics with diagnostic x-ray facilities in the UK. Of this total, 262 hospitals were in the NHS (including Cambridge Military Hospital which operates as a part of Frimley Park Hospitals NHS Trust) and 54 were in the independent sector. Thus 17% of the hospitals in this review were in the independent sector, while independent hospitals actually comprise about 20% of the numbers of all hospitals with radiology departments in the UK (Informa Healthcare, 2003).

Figure 1 shows a map of the location of all the identifiable hospitals that supplied data for the 2005 review. The hospitals are well spread across the UK and can be seen to be distributed roughly in accordance with population density.

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 examination and room specific dose measurements in the database. The results are shown in Table 1. The radiology workload statistics for England for the financial year 2003/04 were taken from KH12 return data published by the Department of Health (2005). 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	27	22	46
England – Midlands & East	22	21	22
England – South	20	15	6
England – London	15	10	12
Scotland	8	21	10
Wales	5	5	2
Northern Ireland	3	6	2
	100	100	100

In terms of dose measurements, it can be seen that the south of England and Wales are somewhat under-represented and the north of England somewhat over-represented in this review, but the other regions are covered reasonably well.

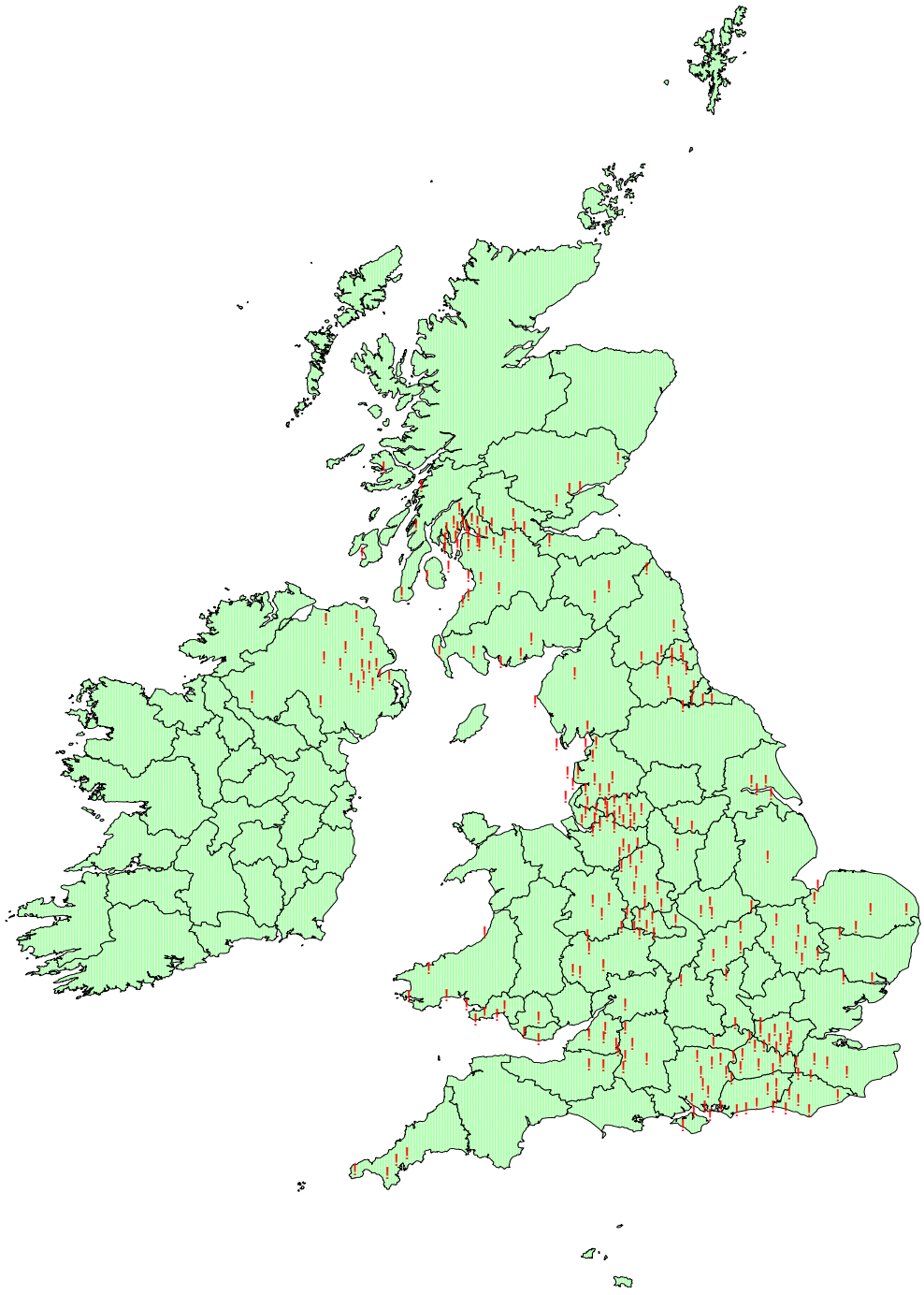


Figure 1 Geographical distribution of hospitals in sample

3.1.2 Distribution by size of hospital

Table 2 shows the percentage of hospitals in the 2005 review of the NPDD and in the UK (excluding psychiatric hospitals but including independent hospitals) as a function of the number of beds. Both sets of data have been taken from the Directory of Hospitals and Trusts 2003/04 (Informa Healthcare, 2003). There is a reasonable match between the two distributions, which is important for this survey, because medical physics support may be more readily available at larger hospitals and this could affect patient doses.

TABLE 2 Percentage of hospitals in the UK and the National Patient Dose Database as a function of the number of beds

	Percentage of hospitals	
Number of beds per hospital	UK	NPDD 2005
0-49	34	25
50-249	33	33
250-499	16	20
500-999	16	21
1000+	1	1

Source: Informa Healthcare 2003

3.1.3 Type and amount of data

During the period January 2001 to February 2006, data were received from 49 individuals working in medical physics or radiology departments throughout the UK, as listed in the Acknowledgements. A total of 23,000 ESD values for single radiographs, 57,000 DAP values for single radiographs, 208,000 DAP values for complete examinations/procedures and 187,000 records of the fluoroscopy time per examination/procedure were supplied between 2001 and 2006. Of these values, the overwhelming majority were supplied for individual patients i.e. more than 20,000 ESD values, 37,000 DAP/radiograph values, 200,000 DAP/examination values, and 183,000 fluoroscopy time per examination values were supplied for individuals. 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 fallen by 18% compared with the previous analysis (Hart, 2002). But the number of DAP values for single radiographs has risen by a factor of four, and the number of DAP values for complete examinations has risen by nearly 50%. These changes are due to the increased availability of DAP meters, and due to the convenience of taking DAP measurements as compared with either the processing of thermo-luminescent dosemeters (TLDs) or the calculation of ESDs from exposure factors. About 13% of the ESD values were measured by TLDs supplied by the HPA Patient Dosimetry Service, 31% were measured by TLDs supplied locally, and 56% were calculated. This is much greater than the 20% of ESDs that were calculated for the 2000 review.

The number of values of fluoroscopy time per examination has increased approximately in line with the number of values of DAP per examination. This is because the majority

of fluoroscopy times were supplied along with a simultaneously measured DAP value for the same examination. The fluoroscopy time is easily measured and usually automatically displayed, and provides a simple indication of the complexity of an examination that will be roughly proportional to the patient dose, as long as fluoroscopy predominates over spot imaging. It can provide a useful alternative reference level for those situations where a DAP meter is not available, as recommended by the Department of Health in its guidance on IRMER (Department of Health, 2000).

Table 3 shows the amount of data provided on 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. About 9% of the dose measurements for individual radiographs were accompanied by a film-screen speed rating, which is a lower response than the 35% seen in the 2000 review, and which in turn was lower than the 58% response in the 1995 review. This is probably partly because there has been a trend toward more radiographic examinations being conducted with computed radiography and other alternatives to film-screen over the last five years. For those rooms where the type of imaging equipment was fully identifiable, 55% used a film-screen combination, 40% used computed radiography (CR), and 5% used a direct digital system in this review, compared with 98% film and 2% CR in the 2000 review.

TABLE 3 Data provision on factors likely to affect patient dose

Factor	Percentage of dose measurements		
	DAP/exam.	ESD/radiograph	DAP/radiograph
Patient weight	69	81	17
Patient height	69	44	9
Patient age	83	12	21
Patient gender	72	25	15
Radiographic kV		97	22
AEC/AERC used	5	28	22
Fluoroscopic kV	3		
Fluoroscopy time	90		
Fluoroscopy pulsed	6		
Last image hold used	3		
Filtration		10	46
Film-screen speed	1	9	9

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

The number of male and female patients in the database was found to be approximately equal. For measurements of DAP/examination, 36% were female, 36% were male, and 28% were unspecified. However, for measurements of ESD and DAP/radiograph the patient gender was mostly unspecified – 9% of patients were female, 8% were male, and all the rest were unspecified.

A detailed breakdown of the numbers of patients, x-ray rooms and hospitals in the database for different types of radiograph, examination or interventional procedure is given in section 4.

3.2 Dental x-ray data

3.2.1 Geographical distribution

Data was supplied by seven medical 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 doses and 77% of the panoramic doses (Gulson, 2007). Five of the medical physicists were located in England, one in Scotland and one in Wales.

Figure 2 shows a map of the geographical distribution of all the identifiable dental clinics that supplied data for this review. The distribution is presented in terms of the number of clinics supplying data for each county of England, Wales, Scotland and Northern Ireland. The numbers are divided into 4 bands, ranging from 1-15 to 54-334, with a quarter of the total of 68 counties in each band. No clinics supplied data from the cross-hatched areas (the Orkney Isles, the Outer Hebrides, and of course the Republic of Ireland) but otherwise every county was sampled, including the Isle of Man, the Isle of Wight, Guernsey, Jersey and the Shetland Isles. Only the Shetland Isles had just one clinic in its sample, the Isle of Man had three, and all other counties/islands had greater numbers. 334 clinics sent data from Greater London.

3.2.2 Types and amount of data

Data were supplied for two types of radiograph:

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

b) a 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, 2007).

Dose measurements for panoramic radiographs are made in terms of either dose-width product or of 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. Most of the DAP measurements reported in this review were derived from a DWP and height measurement. In future, DAP is likely to be the preferred quantity for panoramic doses (IPEM, 2004; Gulson, 2007).

The complete intra-oral dataset covered 2908 dental clinics, and over 6000 measurements of the patient entrance dose. The complete panoramic radiograph

dataset covered 2138 dental clinics, more than 2200 measurements of dose-width product, and nearly 2000 measurements of dose-area product. There are approximately 11,000 general dental practices in the UK (British Dental Association, 2006). The clinics sampled in this survey therefore represent about 25% of the total.

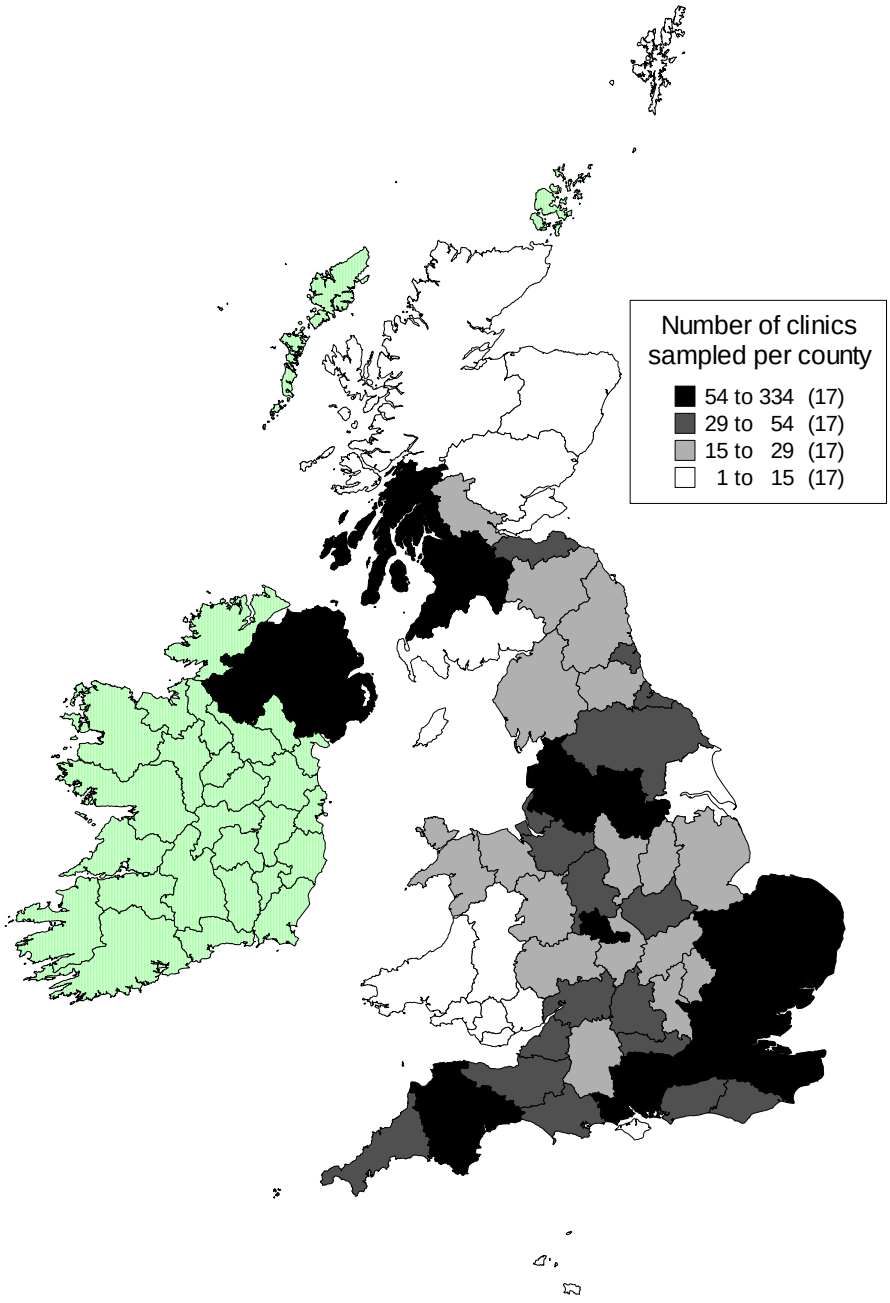


FIGURE 2 Geographical distribution of dental clinics in sample

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 review (Hart, 2002). Chest AP does not meet this criterion but is tabulated because it was included in the analyses for the previous reviews.

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

Radiograph	Number			Room mean ESD distribution (mGy)					
	Hospitals	Rooms	Patients	Mean	Min.	Max.	1st quartile	Median	3rd quartile
Abdomen AP	102	209	1846	3.54	1.03	9.68	2.26	3.29	4.22
Chest AP	6	10	116	0.13	0.05	0.23	0.09	0.13	0.15
Chest LAT	22	39	236	0.44	0.09	1.24	0.26	0.34	0.55
Chest PA	145	311	4685	0.11	0.02	0.56	0.07	0.10	0.14
Lspine AP	126	237	2007	4.15	1.29	10.8	2.88	3.86	5.06
Lspine LAT	124	232	2028	8.99	2.44	32.4	5.58	8.03	11.2
Lspine LSJ	23	27	157	20.2	5.8	50.8	14.2	18.1	26.6
Pelvis AP	127	231	2310	3.06	0.95	12.9	2.02	2.68	3.73
Skull AP/PA	24	42	304	1.41	0.07	3.01	0.86	1.54	2.04
Skull LAT	19	26	193	1.01	0.14	1.68	0.63	1.07	1.34
Tspine AP	42	79	541	3.11	0.48	12.1	1.87	2.84	4.08
Tspine LAT	40	79	494	5.71	0.72	21.9	3.04	4.87	7.05

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 ratio of male to female patients for each radiograph is shown in Table 5 and despite ranging from 1.81 to 0.45 the mean patient weight remains very close to 70 kg for all examinations.

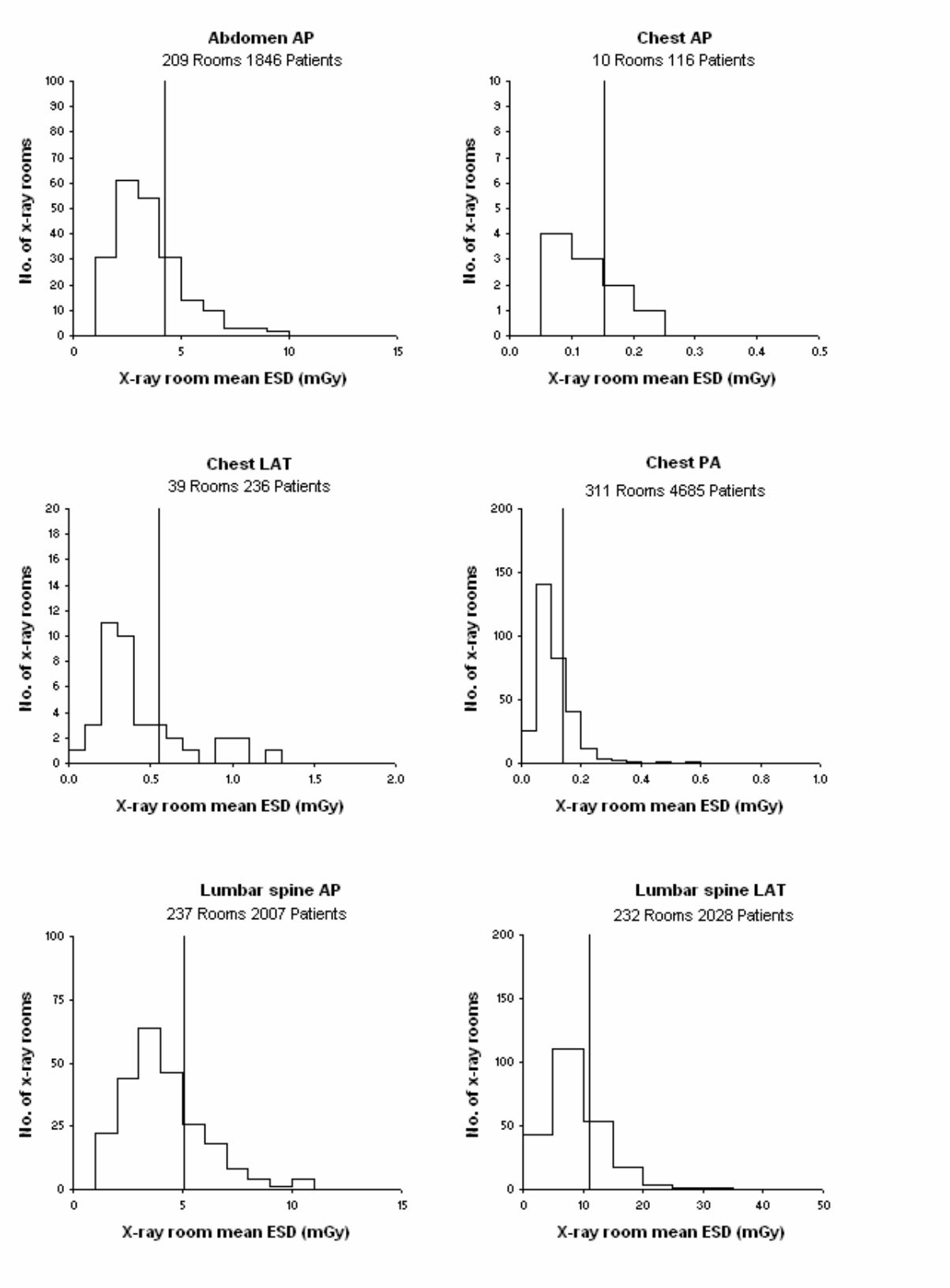


Figure 3 Distribution of x-ray room mean entrance surface dose

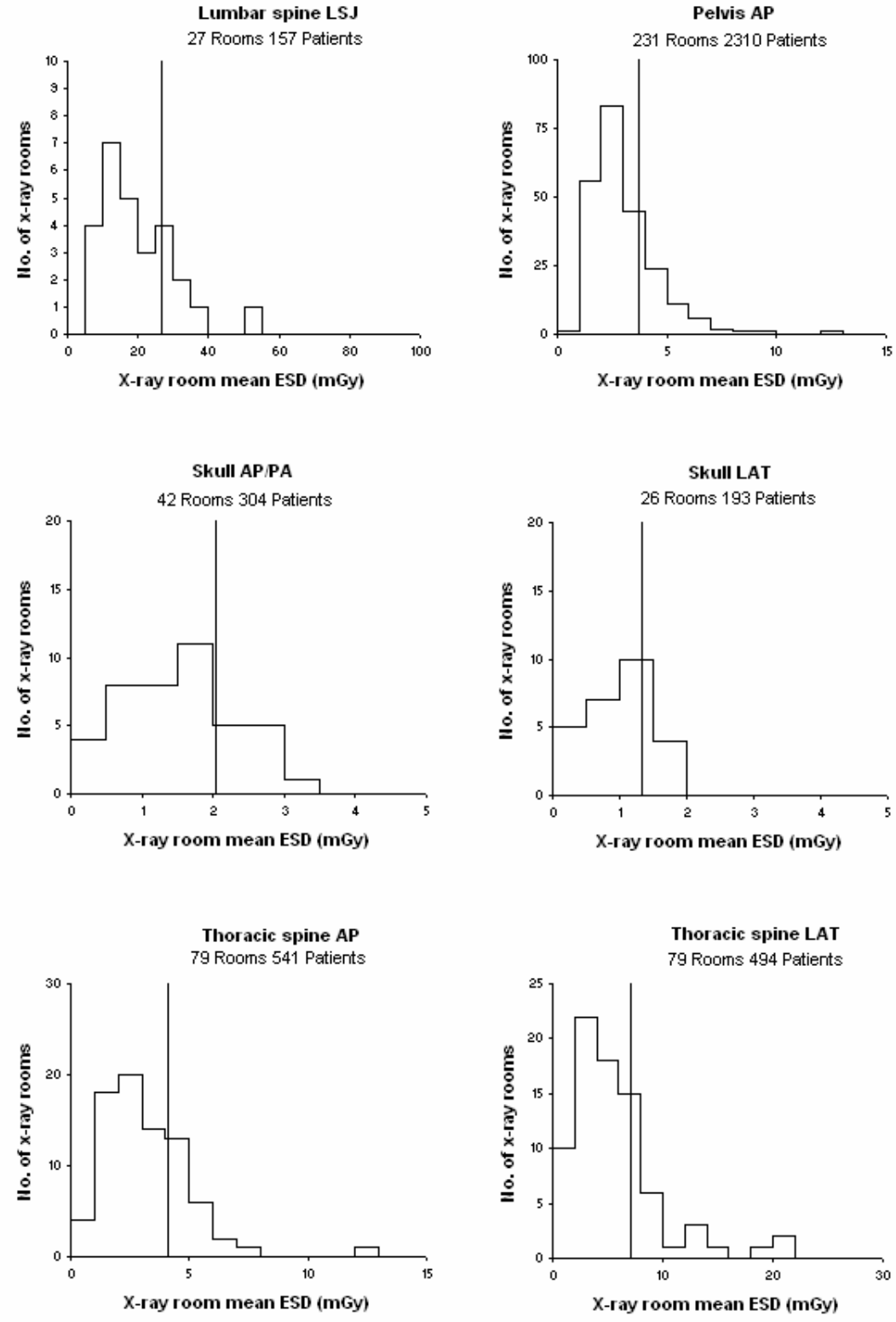


Figure 3 (continued)

Figure 3 shows histograms of x-ray room mean ESD values for the 12 types of radiograph in Table 4. These histograms are drawn from the selected dataset. The vertical axes in Figure 3 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 vertical line indicates the third quartile value of the current data.

Comparisons with similar data from previous reviews of the NPDD are discussed in sections 6.1 and 6.2.

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

Radiograph	Patient age (years)	Patient weight (kg)	Male/Female ratio	Tube voltage (kV)	Total filtration (mm Al)	Exposure setting (mA s)
Abdomen AP	52(17-100)	71(35-124)	1.22	76(40-113)	3.0(2.5-4.0)	31(2-225)
Chest AP	59(26-85)	71(45-108)	1.81	89(66-110)		20(1-300)
Chest LAT	67(49-78)	70(38-144)	0.80	84(60-125)	2.7(2.5-2.8)	11(2-51)
Chest PA	57(16-93)	70(32-154)	1.20	84(55-150)	3.0(2.5-4.0)	4(0.3-80)
Lspine AP	53(16-90)	70(38-139)	0.81	78(59-115)	2.9(2.5-3.7)	36(4-750)
Lspine LAT	53(16-95)	70(37-139)	0.85	88(63-117)	2.9(2.5-3.7)	50(4-500)
Lspine LSJ	50(17-89)	71(50-95)	0.86	93(68-120)	3.2(2.5-3.7)	90(15-296)
Pelvis AP	63(17-95)	70(21-111)	0.62	75(60-96)	2.9(2.5-3.7)	32(2-513)
Skull AP/PA	43(16-94)	71(48-105)	1.55	74(60-91)	2.8(2.5-4.0)	17(3-36)
Skull LAT	43(16-94)	71(32-105)	1.44	72(58-85)	2.7(2.5-3.4)	11(2-71)
Tspine AP	51(16-85)	70(41-133)	0.59	77(60-110)	2.7(2.5-3.5)	29(2-263)
Tspine LAT	55(20-85)	70(41-133)	0.45	75(50-110)	2.8(2.5-3.7)	57(1-400)
All	55(16-100)	70(21-154)	0.93	80(28-150)	2.9(2.5-4.0)	26(0.3-750)

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

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 (apart from chest AP which is tabulated in order to cover the same list of radiographs as in Table 4). This is a longer list of radiographs than those tabulated in the 2000 review, associated with the four times larger quantity of total data collected for DAP per radiograph. (There are more than 30,000 DAP measurements for chest PA alone.) The six additional radiographs which were not listed previously are chest AP and LAT, skull AP/PA and LAT, and thoracic spine AP and LAT.

Table 7 shows the mean and range of the patient characteristics and exposure parameters from the selected dataset for the radiographs listed in Table 6.

Figure 4 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 3. The vertical line indicates the current third quartile value.

Comparisons with similar data from previous reviews of the NPDD are discussed in sections 6.1 and 6.2.

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

	Number			Room mean DAP distribution (Gy.cm^2)					
Radiograph	Hospitals	Rooms	Patients	Mean	Min.	Max.	1st quartile	Median	3rd quartile
Abdomen AP	53	127	7171	2.16	0.77	5.57	1.42	1.96	2.58
Chest AP	8	12	227	0.11	0.06	0.22	0.08	0.09	0.12
Chest LAT	15	23	288	0.25	0.08	0.67	0.14	0.24	0.31
Chest PA	85	210	30883	0.09	0.03	0.29	0.06	0.08	0.11
Lspine AP	64	118	2749	1.33	0.33	2.75	0.96	1.31	1.60
Lspine LAT	63	120	3140	2.14	0.60	5.95	1.58	1.90	2.44
Lspine LSJ	10	25	642	1.94	0.42	4.12	1.25	1.75	2.59
Pelvis AP	74	150	4960	1.90	0.30	6.20	1.37	1.72	2.12
Skull AP/PA	11	20	322	0.62	0.17	1.56	0.44	0.56	0.78
Skull LAT	10	19	363	0.51	0.12	1.81	0.20	0.41	0.49
Tspine AP	25	36	568	0.75	0.05	1.73	0.49	0.72	0.93
Tspine LAT	18	27	541	1.27	0.29	4.31	0.75	1.17	1.42

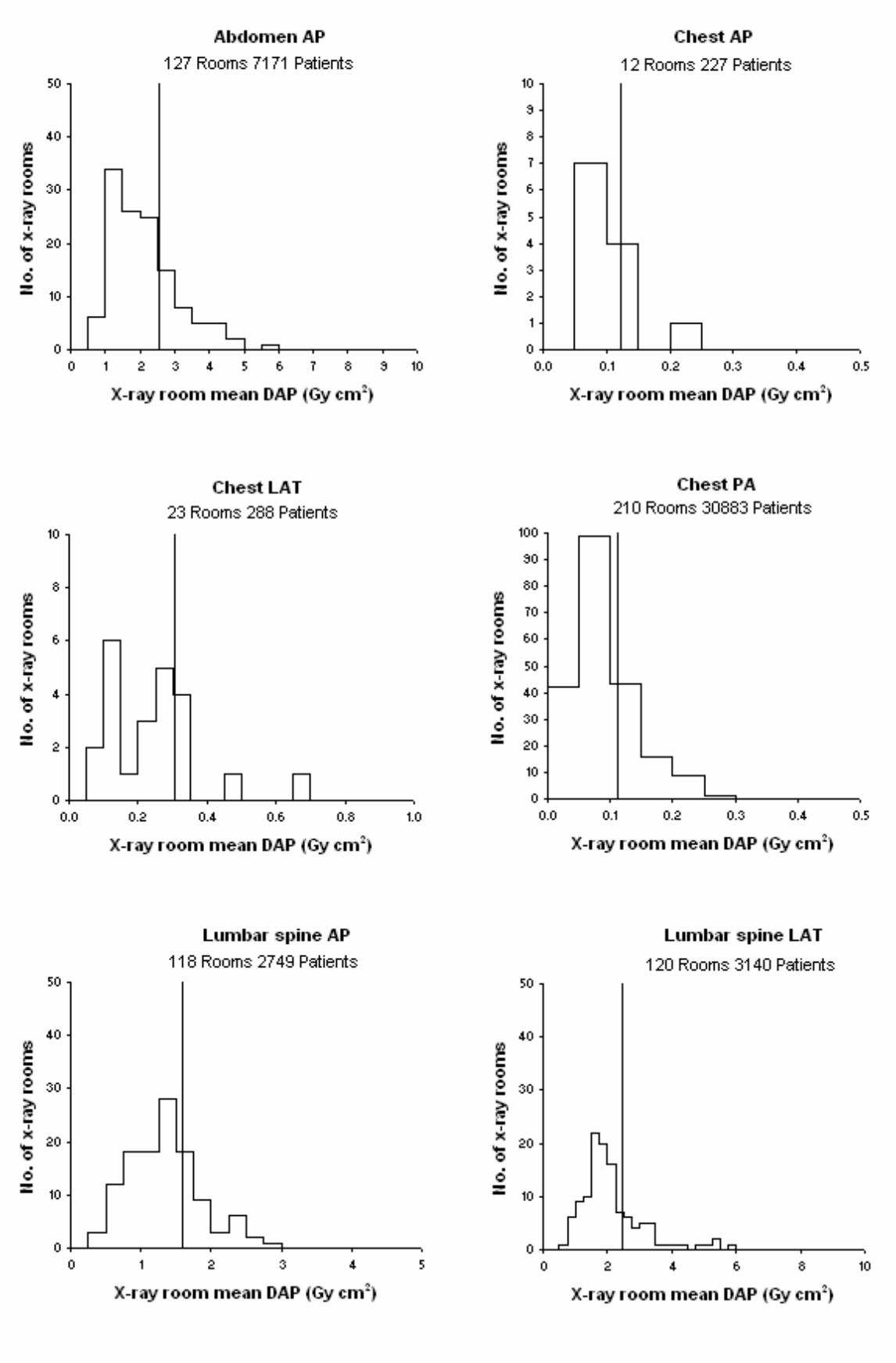


Figure 4 Distribution of x-ray room mean dose-area product per radiograph

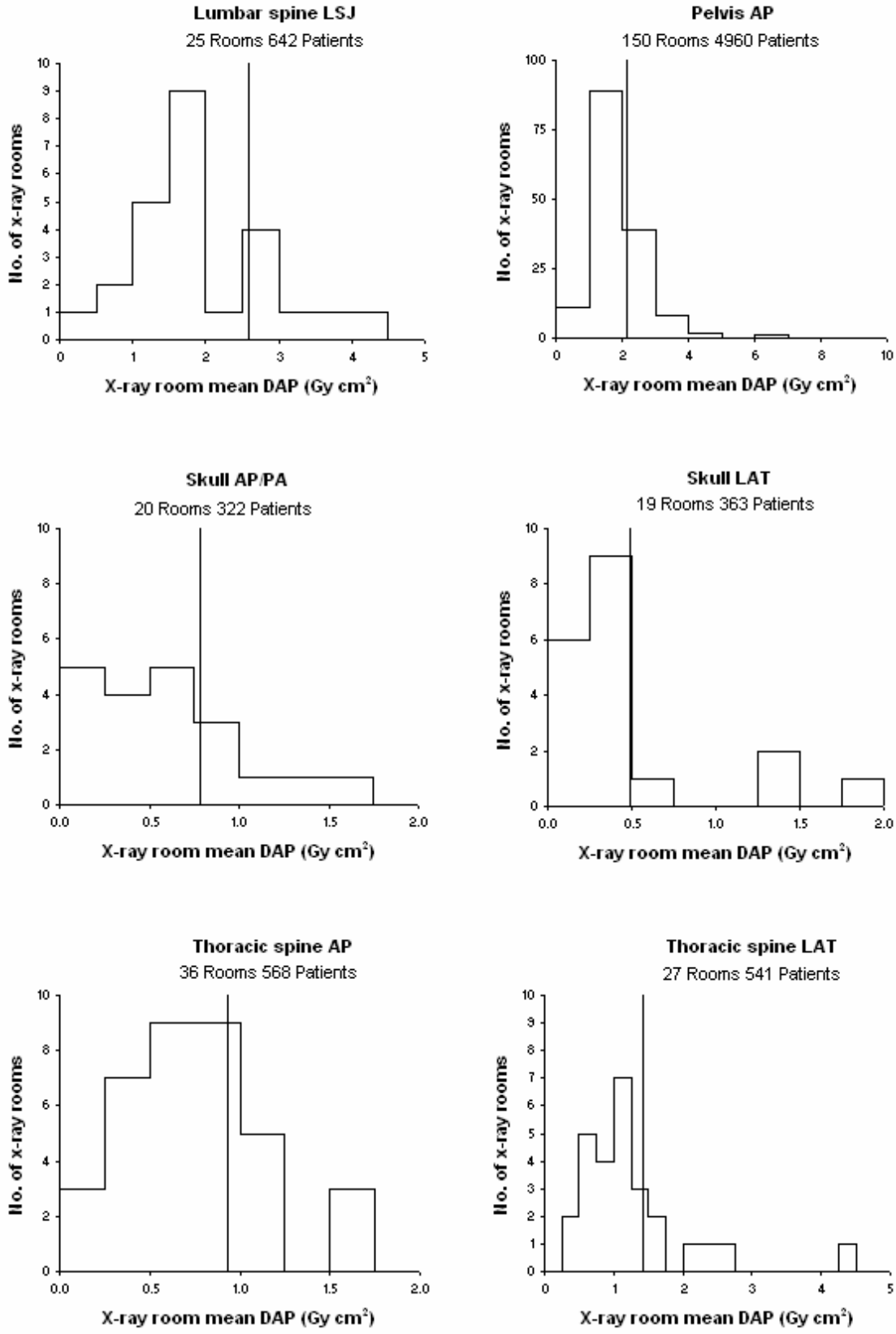


Figure 4 (continued)

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

Radiograph	Patient age (years)	Patient weight (kg)	Male/Female ratio	Tube voltage (kV)	Total filtration (mm Al)	Exposure setting (mA s)
Abdomen AP	51(16-97)	71(38-115)	1.20	73(60-125)	3.0(2.5-4.0)	93(1-970)
Chest AP	59(29-78)	72(44-92)	1.34	73(70-96)	2.8(2.5-3.6)	17(2-167)
Chest LAT	62(42-76)	69(44-86)	1.08	88(66-109)	2.8(2.6-3.1)	11(6-25)
Chest PA	59(16-101)	70(20-135)	1.11	86(55-136)	3.1(2.5-4.0)	15(1-116)
Lspine AP	58(17-91)	70(42-111)	0.66	76(63-109)	3.1(2.5-4.0)	43(2-658)
Lspine LAT	58(17-91)	70(42-114)	0.62	87(60-125)	3.1(2.5-4.0)	54(2-492)
Lspine LSJ	56(20-79)	70(48-95)	0.63	88(80-100)	3.4(2.9-4.0)	104(2-428)
Pelvis AP	63(16-100)	70(48-110)	0.57	71(60-125)	3.1(2.5-4.0)	193(2-950)
Skull AP/PA	45(17-89)	70(51-90)	1.03	68(63-77)	3.4(3.4-3.4)	20(16-32)
Skull LAT	47(17-89)	71(44-102)	0.91	65(62-75)		16(12-20)
Tspine AP	56(22-94)	69(39-96)	0.37	81(65-96)	3.2(2.5-4.0)	18(3-80)
Tspine LAT	55(17-83)	69(45-96)	0.43	73(60-90)	3.2(2.5-4.0)	43(1-200)
All	58(16-101)	70(20-135)	0.86	80(55-136)	3.1(2.5-4.0)	63(1-970)

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

4.1.3 DAP per diagnostic examination

For this review the results of DAP measurements on interventional procedures are described separately from purely diagnostic examinations in section 4.2. 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 (also including, for comparison, retrograde pyelography for which the distributions were tabulated in the 2000 review). A brief description of each examination is given in a glossary in Appendix C. As was found in the previous review, 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 for this examination in order to maximise the sample of patients. Three examinations appear in this table which were not listed in the 2000 review. These are:

a) fistulography

b) sinography

c) a combined barium meal and swallow.

The latter gives the same mean DAP as a barium meal alone, probably because many radiologists routinely carry out a very quick examination of the oesophagus while the barium is being swallowed for a barium meal, and refer to the examination as a meal and swallow, rather than just a meal.

ERCPs are discussed in section 4.2 on interventional procedures.

Table 9 shows the mean and range of the patient characteristics and exposure parameters from the selected dataset for the examinations listed in Table 8. The final

column of Table 9 shows the mean and range for the number of digital spot images per examination, instead of the number of film-screen images per examination which was tabulated in the two previous reviews. We have made this change because the data in this review show that digital spot imaging is now used more often than film-screen imaging. Digital spot imaging is used for 70% of all diagnostic examinations for which a DAP measurement was taken, while film-screen imaging is used for 30%. It is noticeable that the mean and maximum numbers of digital spot images are generally much higher than those for film-screen images (see section 5.4 for the impact of DSI on patient doses).

Figure 5 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 3. The vertical line indicates the third quartile value of the current data.

Comparisons with similar data from previous reviews of the NPDD are discussed in sections 6.1 and 6.2.

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

	Number			Room mean DAP distribution (Gy.cm^2)					
Examination	Hospitals	Rooms	Patients	Mean	Min.	Max.	1st Quartile	Median	3rd Quartile
Barium Enema	108	222	44057	17.8	1.71	45.0	11.1	17.2	24.3
Barium Follow Through	43	97	4579	10.0	1.05	47.5	5.36	9.07	11.6
Barium Meal	49	104	2750	9.98	1.15	28.1	5.65	9.76	13.8
Barium Meal & Swallow	22	75	4122	9.98	1.67	89.6	4.87	8.88	11.2
Barium Swallow	60	144	14249	6.35	0.12	24.1	3.66	5.89	8.14
Coronary Angiography*	38	110	34236	25.7	11.7	72.5	18.9	23.5	29.0
Femoral Angiography	26	52	4584	34.3	6.69	135.3	17.5	23.7	53.4
Fistulography	14	22	131	14.7	2.69	82.8	4.98	8.18	13.2
Hysterosalpingography	27	71	2731	2.05	0.02	7.98	0.59	1.51	2.85
IVU	29	35	2707	11.6	0.32	38.7	8.15	11.3	13.6
MCU	14	28	349	9.26	1.48	38.3	4.03	7.75	12.0
Nephrostography	13	35	576	8.33	0.20	36.7	2.50	4.47	11.8
Retrograde Pyelography	12	13	79	8.75	1.43	25.6	3.98	6.01	8.08
Sialography	11	20	329	1.59	0.46	3.11	1.07	1.45	2.00
Sinography	15	39	201	6.41	0.01	26.5	2.29	5.66	8.49
Small Bowel Enema	23	37	744	27.1	3.35	70.8	12.3	18.1	40.5
T Tube Cholangiography	15	37	262	6.12	0.44	17.6	2.97	5.74	7.89
Venography	16	27	245	6.83	0.82	25.5	2.47	5.03	7.46
Water Soluble Enema	15	38	466	17.7	2.13	40.7	13.2	15.6	23.4
Water Soluble Swallow	13	26	299	9.5	0.55	76.2	2.21	6.29	9.99

* Mean patient weight range 75-85 kg

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

Examination	Patient age (years)	Patient weight (kg)	Male/Female ratio	Radiographic tube voltage (kV)	Fluoroscopy time (seconds)	No. of digital spot images per exam
Barium Enema	63(16-99)	71(41-200)	0.62	90(50-130)	122(3-4896)	12(1-465)
Barium Follow Through	49(16-105)	69(38-130)	0.63	84(50-120)	106(5-3420)	6(1-743)
Barium Meal	60(16-97)	70(35-195)	0.86	84(50-120)	122(4-1260)	14(1-99)
Barium Meal & Swallow	60(16-99)	71(37-129)	0.80	79(50-120)	103(6-6060)	22(1-194)
Barium Swallow	61(16-100)	70(40-200)	0.85	84(50-120)	113(1-4800)	26(1-408)
Coronary Angiography*	62(16-99)	79(29-183)	1.94	79(50-120)	247(6-6000)	737(6-2200)
Femoral Angiography	68(17-99)	72(45-180)	1.84	75(50-120)	234(6-5724)	70(1-1000)
Fistulography	58(20-90)	70(49-102)	1.39	76(50-120)	221(18-1728)	36(1-286)
Hysterosalpingography	33(17-76)	69(34-170)	--	77(50-120)	65(1-1800)	3(1-24)
IVU	55(16-101)	74(38-150)	1.62	71(50-120)	31(6-3000) #	8(2-21)
MCU	56(18-98)	72(37-117)	1.01	80(50-120)	92(6-450)	7(1-45)
Nephrostography	61(19-96)	68(25-150)	1.03	85(60-120)	231(6-1470)	5(1-19)
Retrograde Pyelography	55(24-84)	72(55-85)	1.15	77(60-90)	114(6-288)	9(1-14)
Sialography	53(16-93)	71(38-150)	0.56	70(50-120)	83(6-396)	8(1-36)
Sinography	58(16-94)	70(34-111)	1.08	80(60-120)	116(6-798)	7(1-89)
Small Bowel Enema	47(16-91)	68(40-130)	0.66	91(60-120)	304(6-1386)	12(1-46)
T Tube Cholangiography	64(22-95)	70(45-121)	0.76	79(50-120)	104(6-1068)	5(1-18)
Venography	58(19-91)	72(34-115)	0.89	75(50-120)	110(6-1728)	19(1-185)
Water Soluble Enema	67(16-94)	70(42-111)	1.17	86(60-120)	149(6-1284)	9(1-68)
Water Soluble Swallow	65(21-94)	69(40-110)	1.72	85(60-120)	129(6-3600)	18(1-300)

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

40% of IVU examinations included fluoroscopy

* Mean patient weight range 75-85 kg

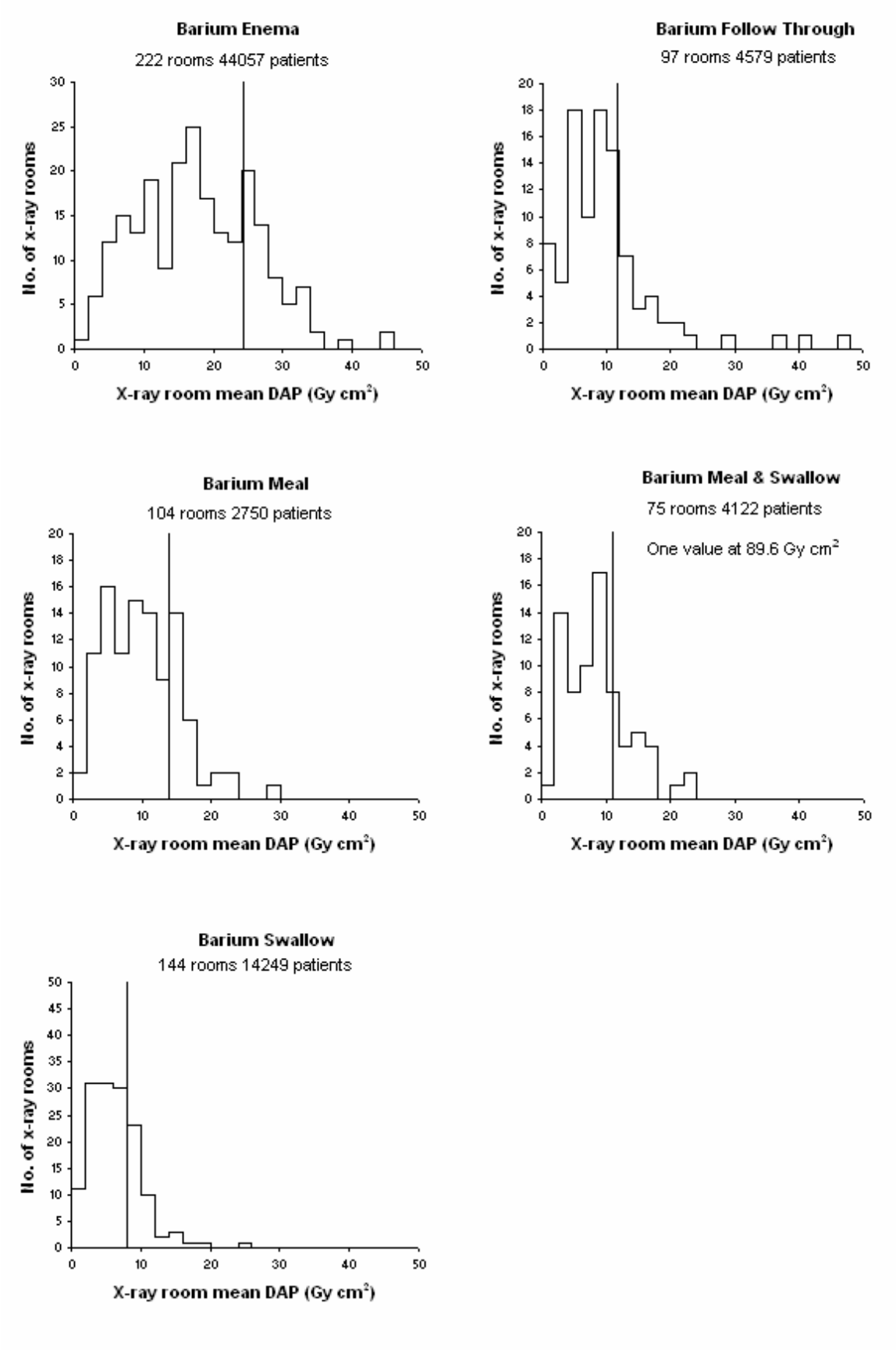


Figure 5 Distribution of x-ray room mean dose-area product per examination

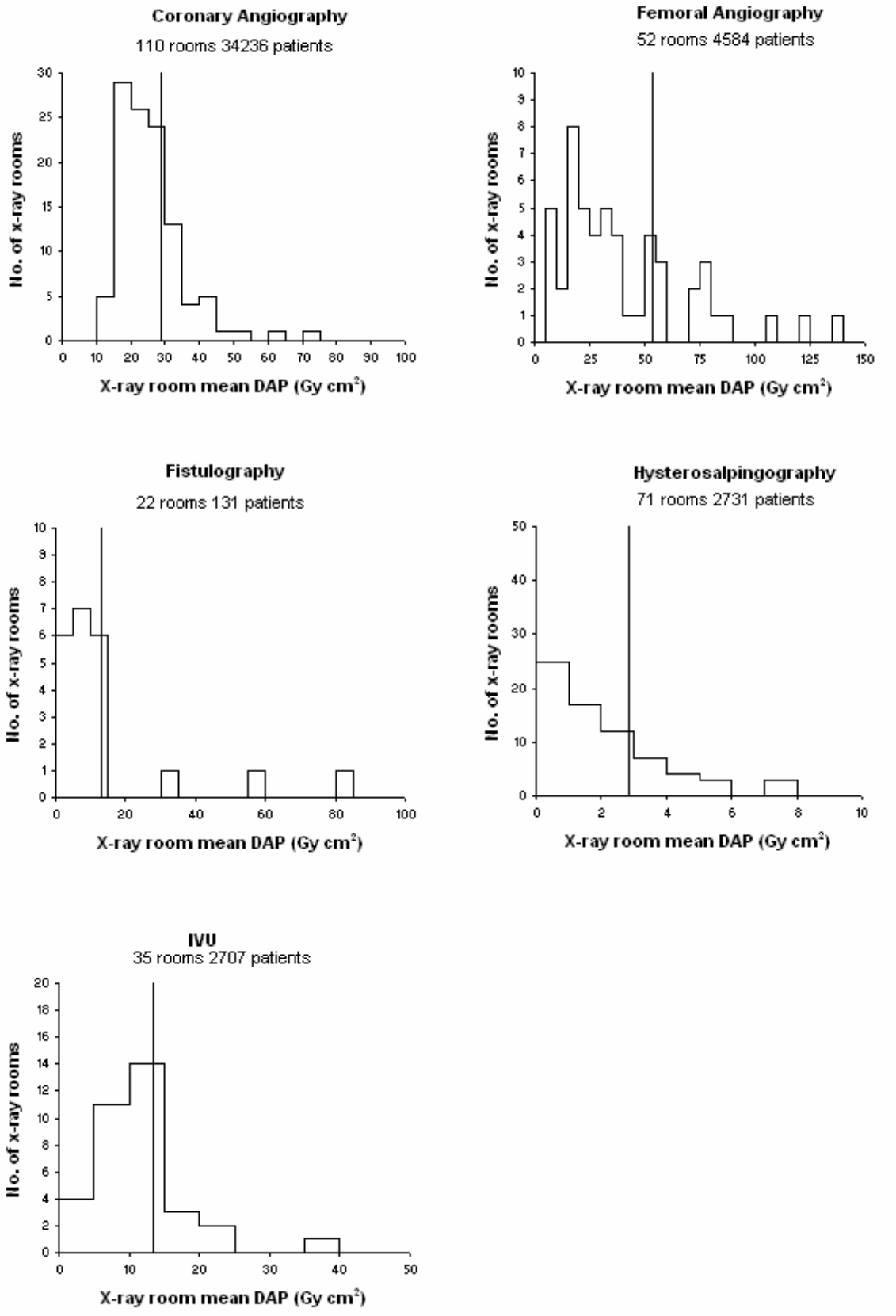


Figure 5 (continued)

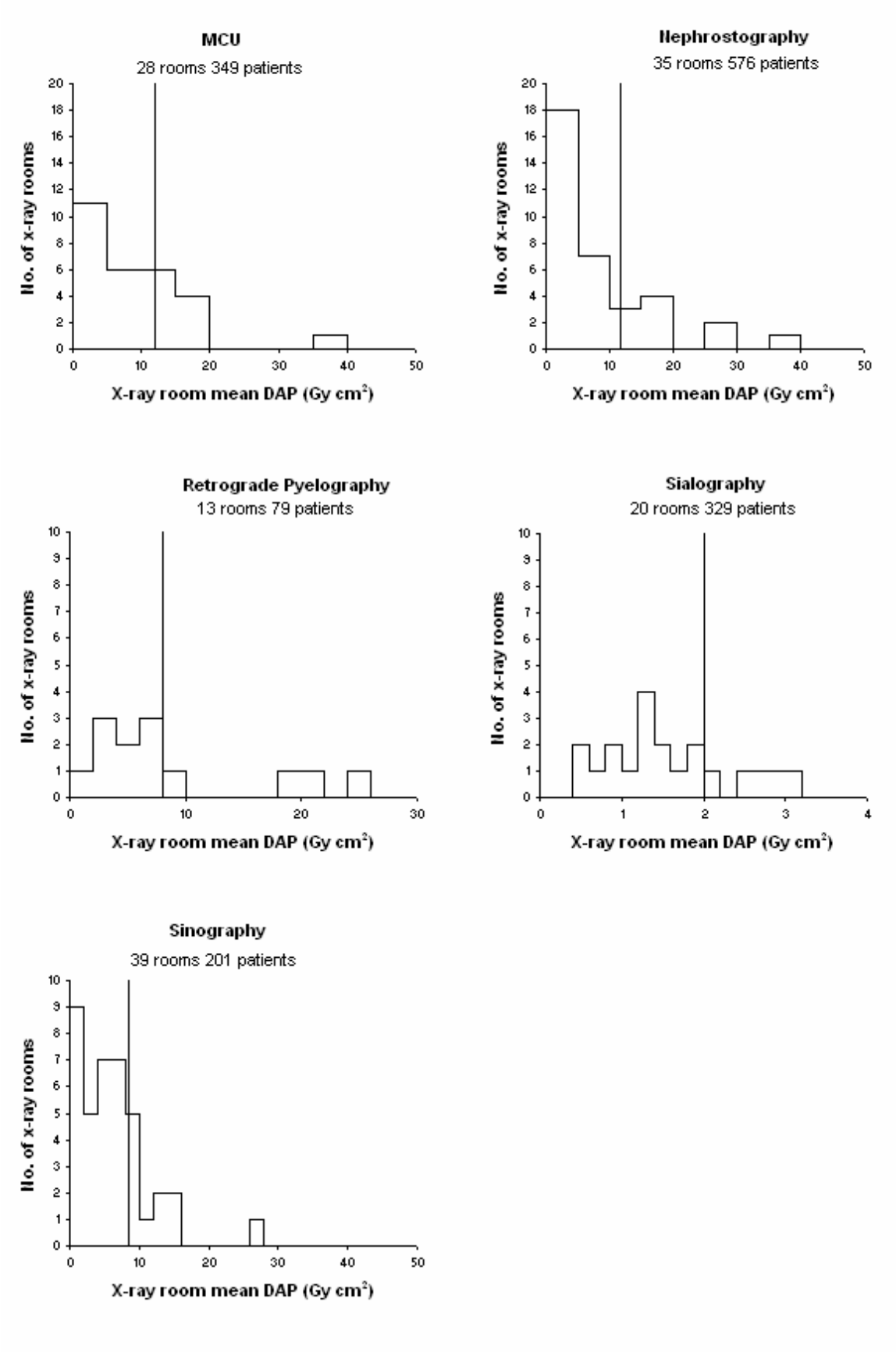
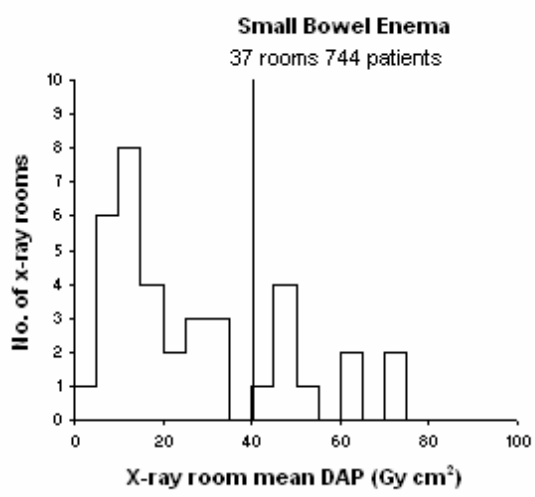
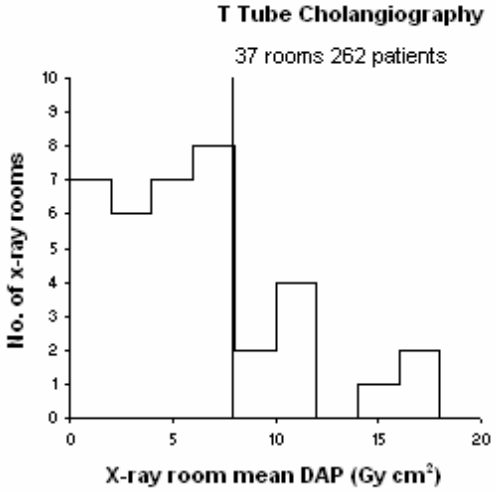
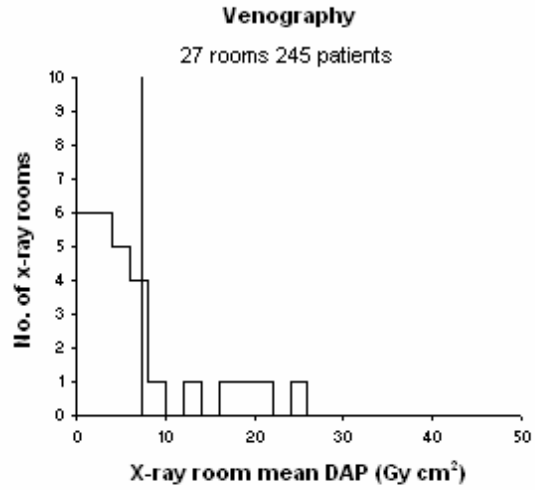
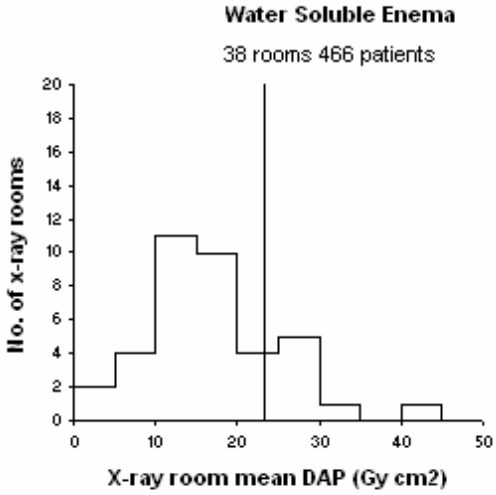


Figure 5 (continued)









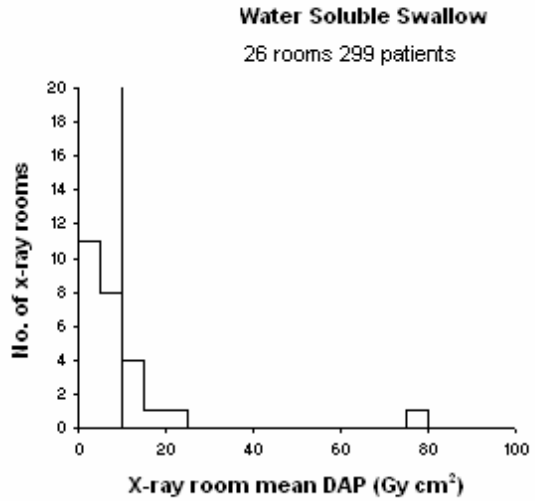


Figure 5 (continued)

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 on 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 of the distribution of mean fluoroscopy time per room for the same examinations as listed in Table 9, with the exception of IVUs which are generally a purely radiographic examination. 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 6 shows histograms of the distribution of x-ray room mean fluoroscopy time per examination. The vertical line indicates the third quartile of the distribution.

TABLE 10 Complete examinations : mean fluoroscopy time per room

	Number			Room mean fluoroscopy time distribution (seconds)					
Examination	Hospitals	Rooms	Patients	Mean	Min.	Max.	1st Quartile	Median	3rd Quartile
Barium Enema	84	195	43252	138	45	388	102	128	166
Barium Follow Through	36	90	4550	123	38	514	82	103	133
Barium Meal	43	99	2679	134	1	257	103	131	162
Barium Meal & Swallow	22	75	4122	140	38	2118	89	109	131
Barium Swallow	49	133	14320	109	16	202	85	108	132
Coronary Angiography*	34	101	34659	246	93	606	195	231	270
Femoral Angiography	24	49	4174	243	49	700	116	188	296
Fistulography	13	20	82	216	54	674	96	137	225
Hysterosalpingography	24	68	2591	50	8	167	31	41	57
MCU	14	28	348	97	24	240	51	83	112
Nephrostography	12	34	507	199	30	516	104	166	285
Retrograde Pyelography	12	13	105	110	9	252	84	100	145
Sialography	11	20	319	87	25	154	69	85	103
Sinography	15	39	201	112	6	432	77	92	124
Small Bowel Enema	20	34	596	366	40	809	200	318	549
T Tube Cholangiography	15	37	262	92	26	263	60	81	112
Venography	15	26	235	119	30	693	49	88	133
Water Soluble Enema	15	38	465	132	16	237	93	127	179
Water Soluble Swallow	13	26	297	160	12	974	92	110	161

* Mean patient weight range 75-85 kg

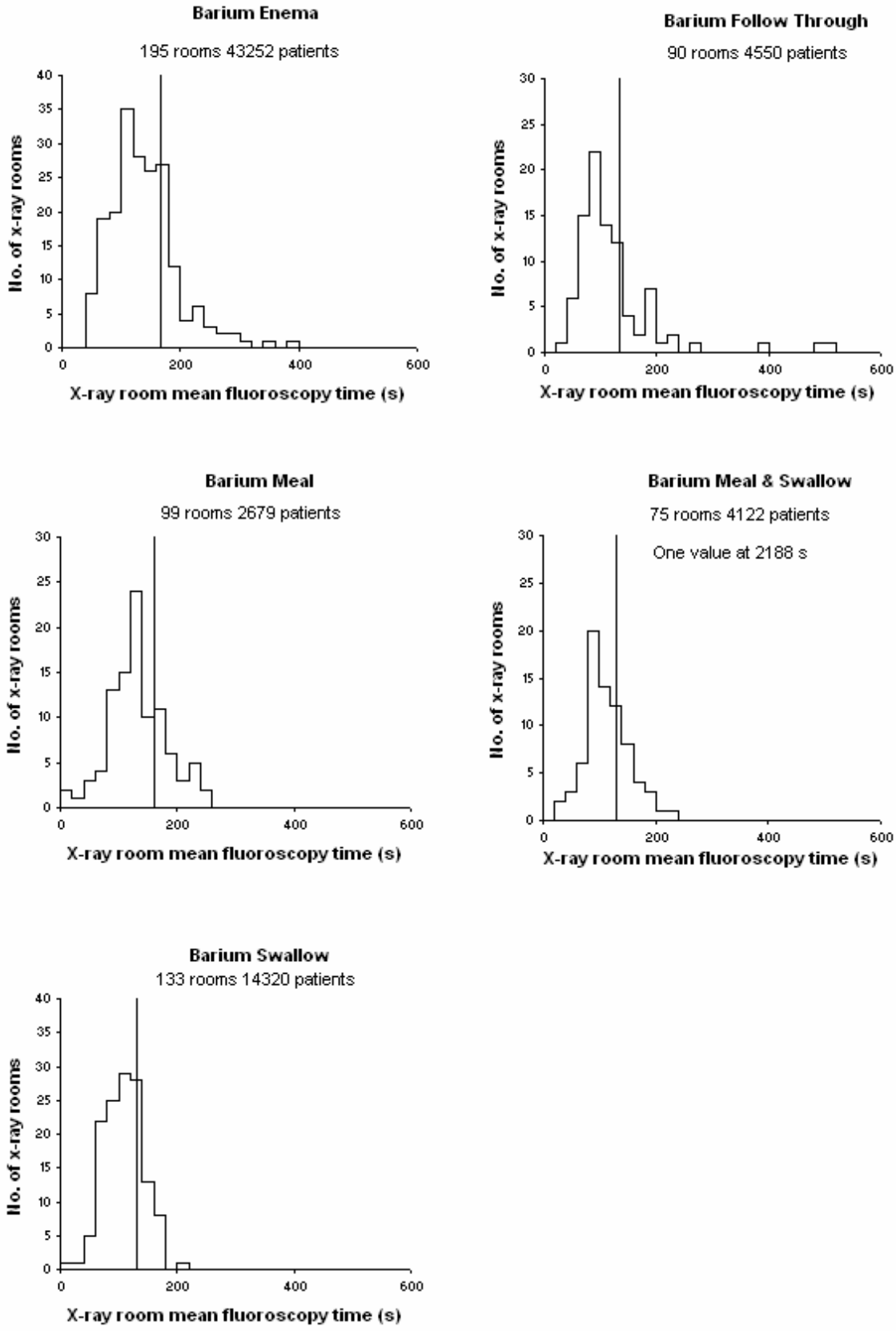
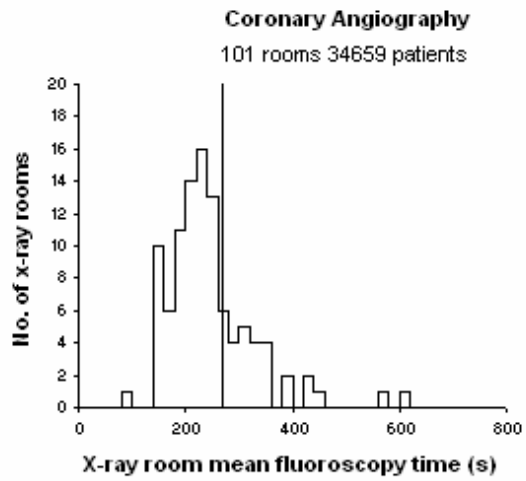
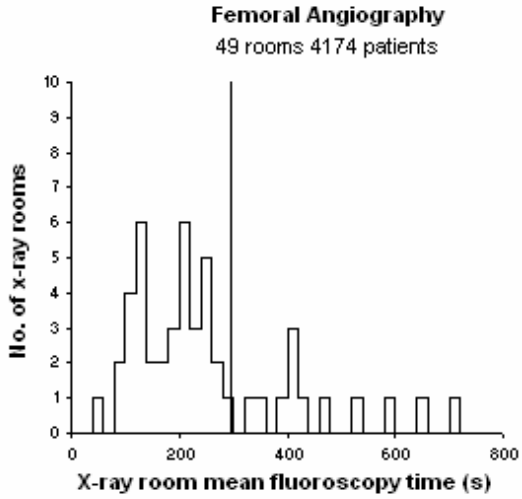
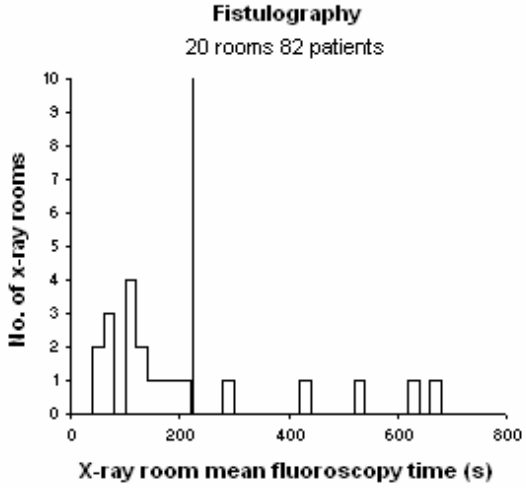
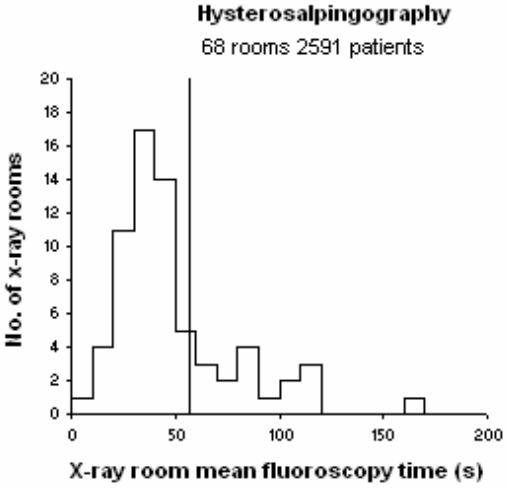


Figure 6 Distribution of x-ray room mean fluoroscopy time per examination









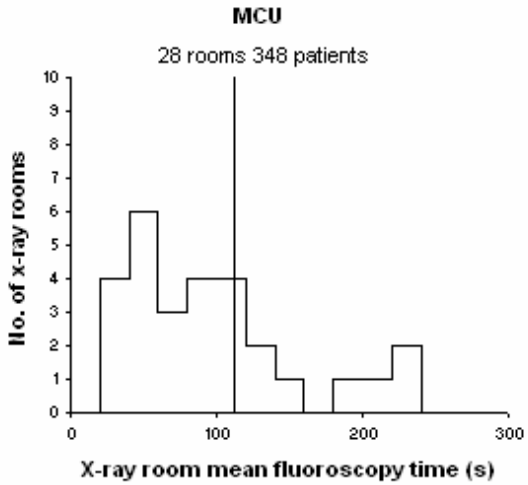
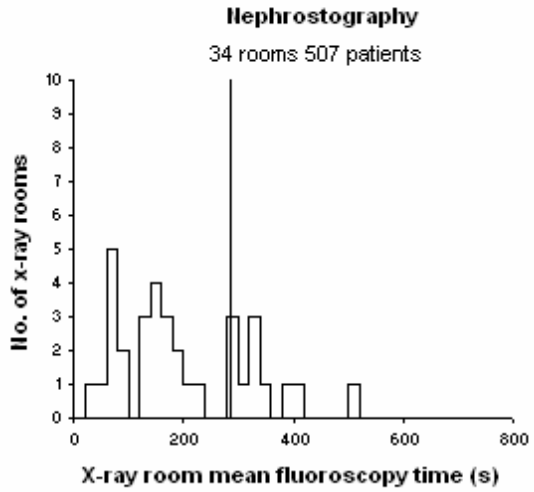
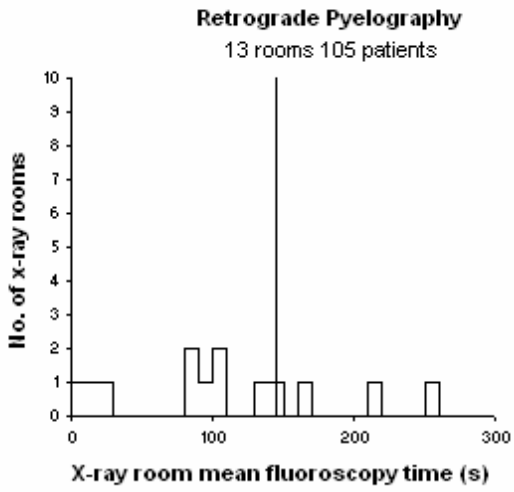
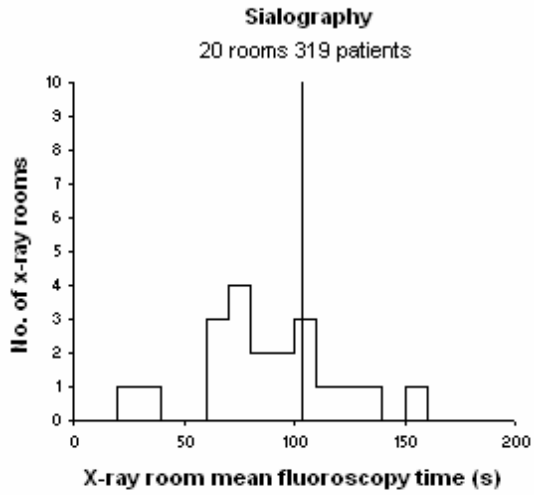
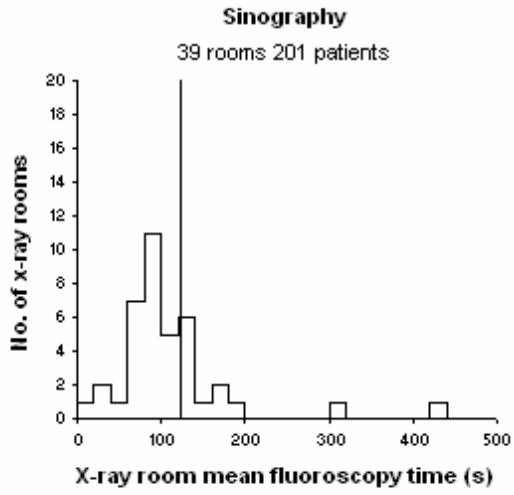


Figure 6 (continued)









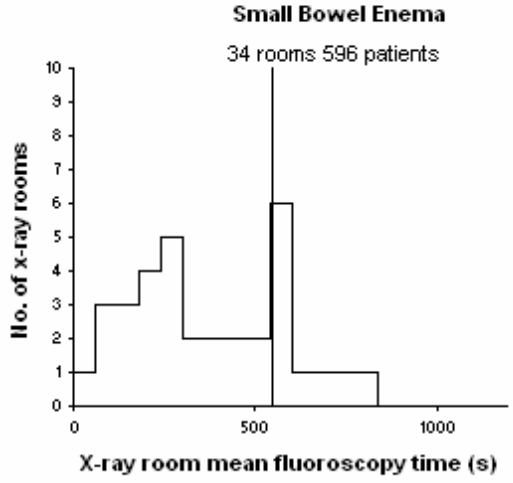


Figure 6 (continued)

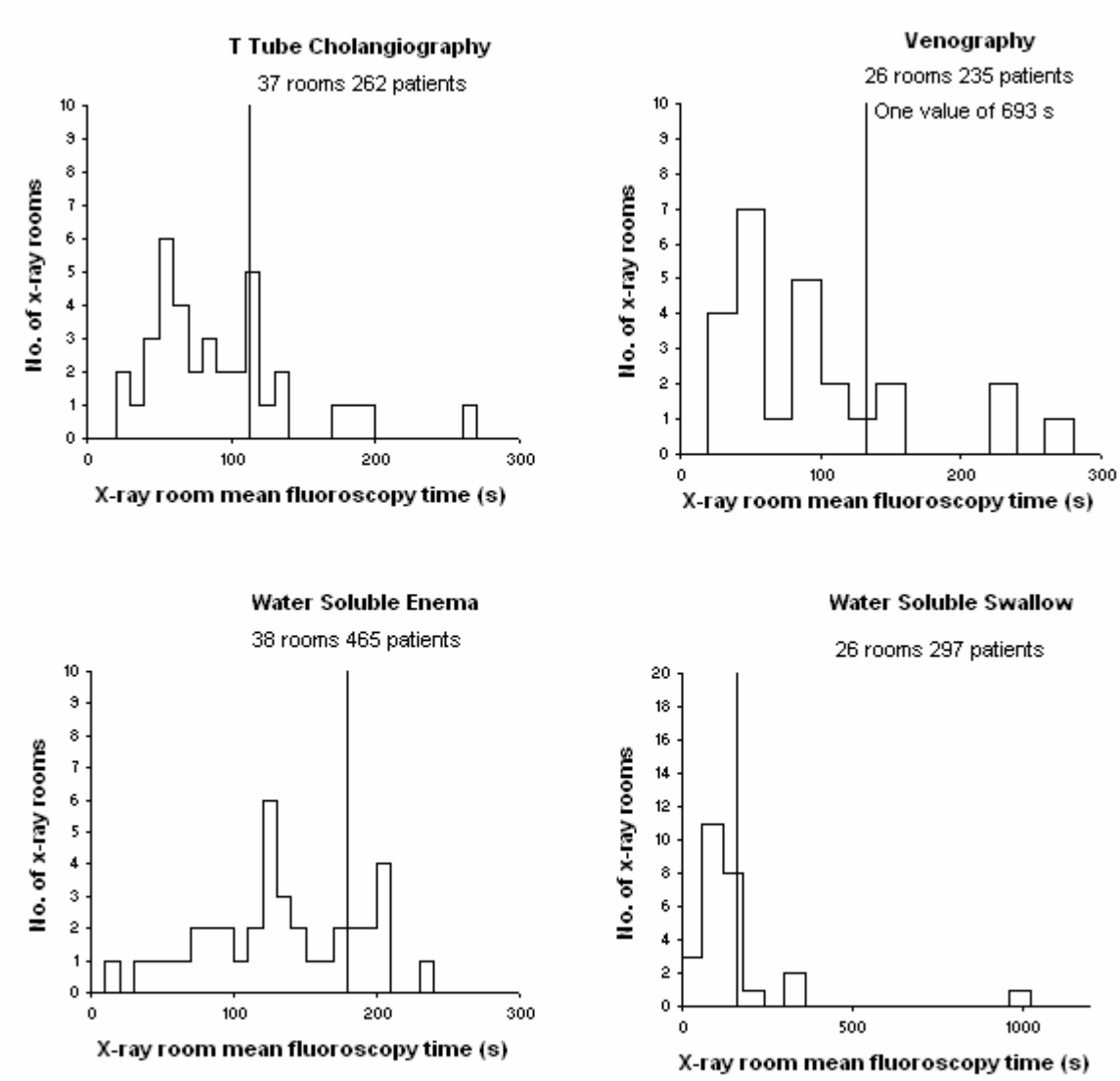


Figure 6 (continued)

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. Biliary drainage is also included because its distribution was tabulated in the 2000 review, and because many of the procedures listed separately as 'biliary intervention' may well be purely biliary drainage. PTCAs involving one stent are included for the first time for reasons explained towards the end of this section. ERCPs can be either a purely diagnostic or an interventional procedure (see Appendix C) but this distinction was made for only a small fraction (25%) of ERCPs in the NPDD. So the proportion of the ERCPs included in the table that were truly interventional procedures is unknown. Two further procedures appear in this table which were not listed in the 2000 review, these are facet joint injections and oesophageal stents. It is assumed that none of the 'oesophageal dilation' procedures (that are also in the Table) included stent insertion.

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

	Number			Room mean DAP distribution (Gy.cm^2)					
Procedure	Hospitals	Rooms	Patients	Mean	Min.	Max.	1st Quartile	Median	3rd Quartile
Biliary Drainage	6	7	82	38.3	11.8	111.3	14.4	16.6	49.9
Biliary Intervention	11	32	528	33.7	2.46	100.1	12.9	29.5	49.9
ERCP*	21	49	3371	13.7	0.31	45.2	8.46	13.0	16.7
Facet Joint Injection	11	23	887	3.76	0.58	10.3	1.94	3.27	5.24
Hickman Line Insertion	19	47	1274	1.99	0.06	5.94	0.78	1.18	2.98
Nephrostomy	19	30	445	11.8	0.81	58.8	5.09	8.27	14.4
Oesophageal Dilation	11	22	161	8.19	0.74	36.3	2.90	4.74	10.8
Oesophageal Stent	13	24	208	15.8	0.85	37.9	7.65	14.3	24.6
Pacemaker (permanent)	17	45	2682	8.59	2.16	19.7	4.52	8.06	11.0
PTCA 1 stent	9	28	6111	43	21	119	29	36	50.3

* Unknown mix of diagnostic and interventional procedures

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

Examination	Patient age (years)	Patient weight (kg)	Male/Female ratio	Radiographic tube voltage (kV)	Fluoroscopy time (seconds)	No. of digital spot images per exam
Biliary Drainage	69(25-96)	70(41-100)	1.09	81(60-120)	717(24-2598)	5(1-40)
Biliary Intervention	70(23-97)	69(38-154)	1.18	79(50-120)	672(12-3354)	5(1-103)
ERCP	67(16-99)	69(36-140)	0.64	79(50-120)	250(6-4740)	5(1-70)
Facet Joint Injection	53(19-88)	72(36-120)	0.79	82(50-120)	76(6-864)	5(1-290)
Hickman Line Insertion	54(16-99)	71(38-180)	1.35	80(50-120)	65(3-1566)	2(1-141)
Nephrostomy	58(19-92)	71(49-105)	1.73	81(50-120)	276(6-1950)	3(1-12)
Oesophageal Dilation	67(16-97)	69(40-102)	1.48	77(50-120)	127(6-870)	3(1-15)
Oesophageal Stent	71(29-99)	68(41-115)	1.50	81(50-120)	298(10-1626)	4(1-80)
Pacemaker (permanent)	73(16-99)	72(38-121)	1.43	75(50-120)	404(6-6480)	13(1-1592)
PTCA 1 stent	61(20-99)	81(32-180)	2.5	71(50-90)	681(6-7800)	12(1-90)

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

Table 12 shows the mean and range of the patient characteristics and exposure parameters from the selected dataset for the procedures listed in Table 11.

Figure 7 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 3. The vertical line indicates the third quartile value of the current data.

We had hoped to provide national reference doses for coronary angioplasties (PTCAs) of different levels of complexity according to the number of arteries dilated or stents inserted (Bernardi 2000, Padovani 2001, Peterzol 2005). As shown in Table 13, some data was obtained for PTCAs for which an indication of their complexity was given. (As for coronary angiography, a mean patient weight of 75-85 kg was used in selecting this data.) Unfortunately none of these datasets have a sample size which is sufficient to be representative of national practice according to our criteria. However, the sample for single stent PTCAs has such a large number of patients from 28 rooms that it could be regarded as sufficient despite being from 9 hospitals rather than 10. Although the sample sizes for 2 and 3 stent PTCAs are much smaller, they do show the expected increase in dose as the complexity of the procedure increases.

TABLE 13 Mean and third quartile DAP for PTCAs*

	Number			DAP (Gy cm^2)	
Procedure	Hospitals	Rooms	Patients	Mean	3rd Quartile
PTCA 1 artery	4	15	2445	34.3	37.8
PTCA 1 stent	9	28	6111	42.7	50.3
PTCA 2 stent	5	9	779	64.2	74.1
PTCA 3 stent	5	6	289	98.3	130

* Mean patient weight range 75-85 kg

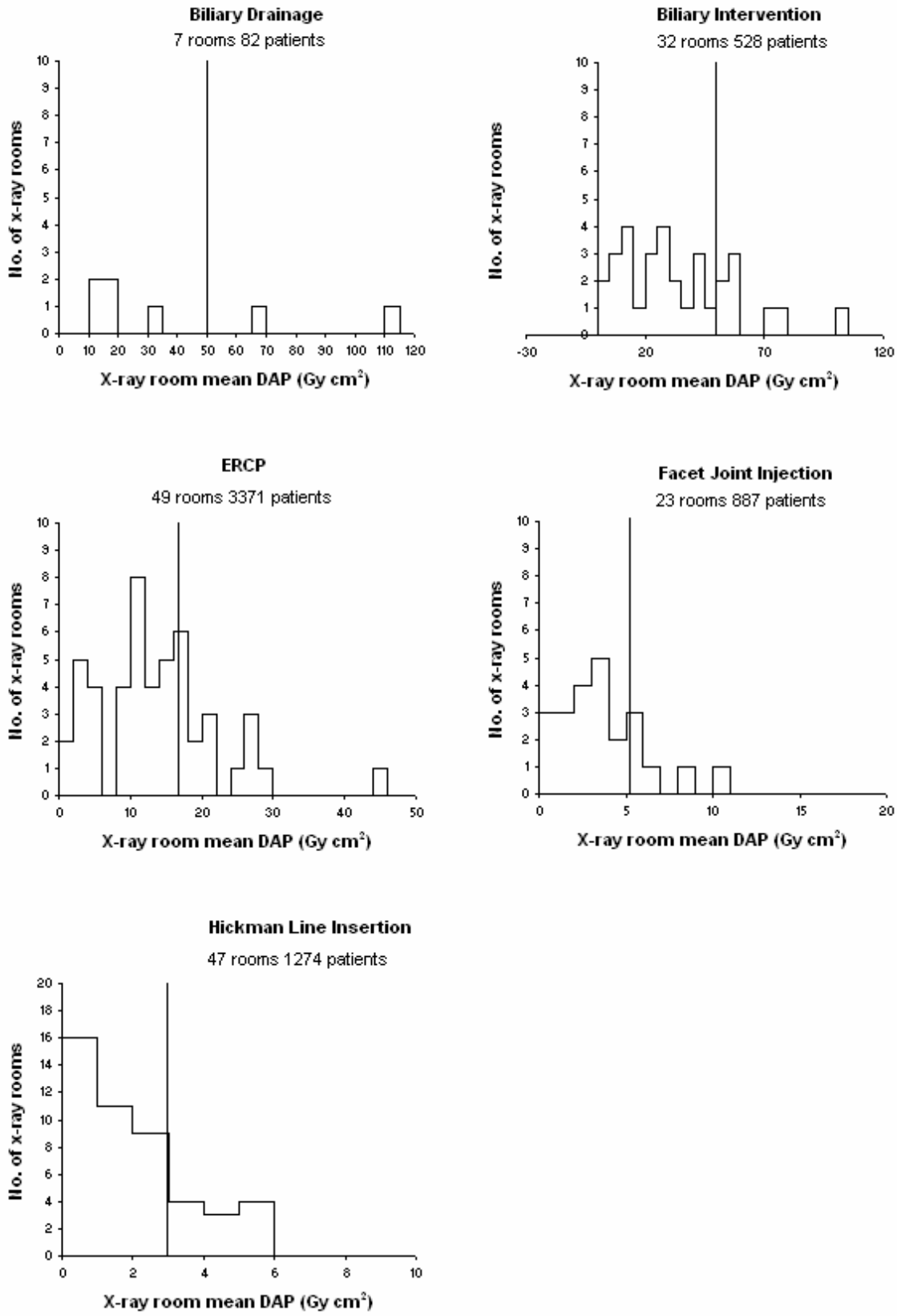


Figure 7 Distribution of x-ray room mean dose-area product per procedure

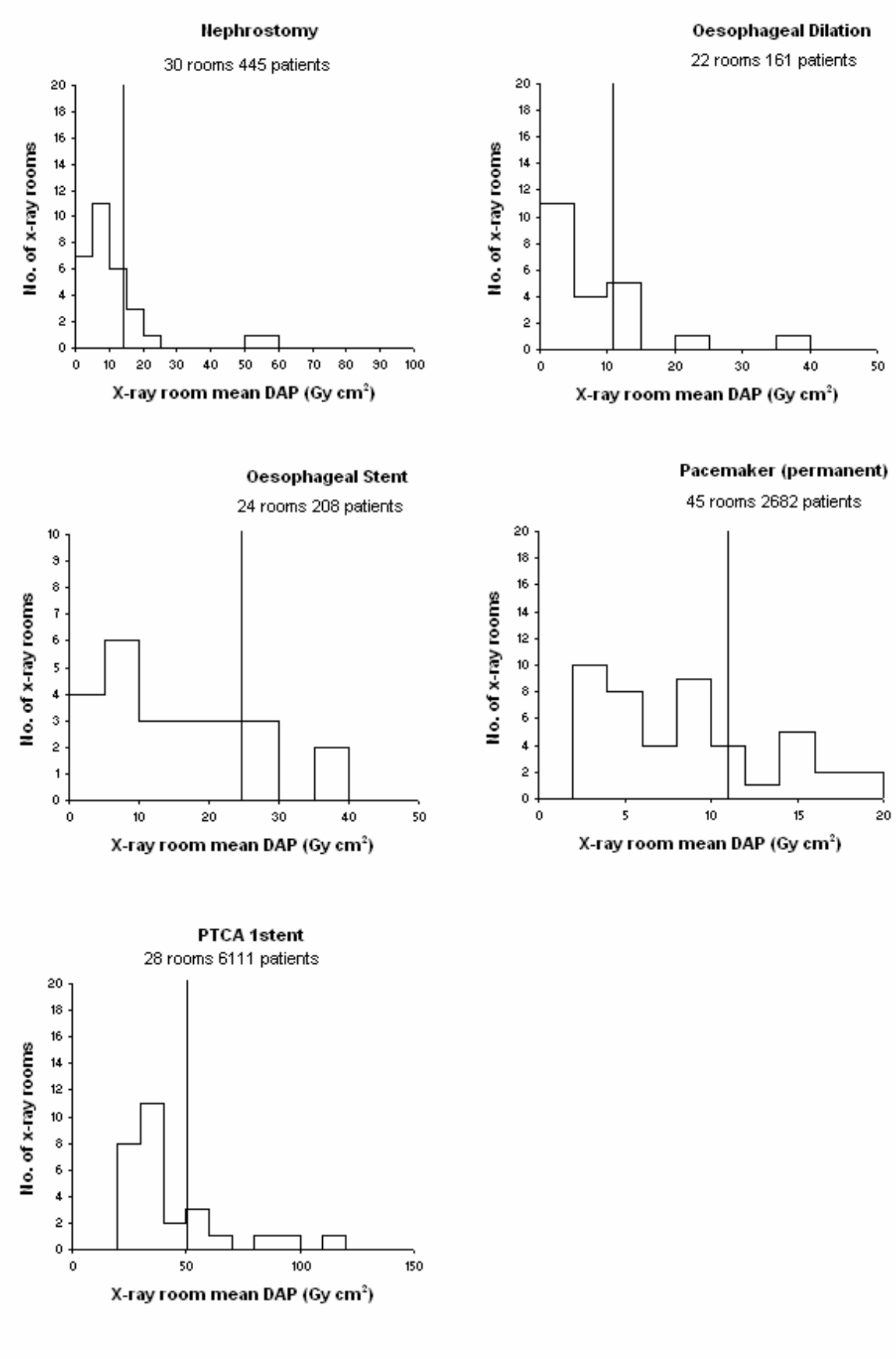


Figure 7 (continued)

4.2.2 Fluoroscopy time per interventional procedure

Table 14 shows key parameters of the distribution of mean fluoroscopy time per room for the same procedures as listed in Table 11. The fluoroscopy times shown in Table 14 differ from those in Table 12 because the former are based on room mean data and the latter on individual patient data. Comparisons with similar data from previous reviews of the NPDD are discussed in section 6.1.

TABLE 14 Interventional procedures: mean fluoroscopy time per room

	Number			Room mean fluoroscopy time distribution (seconds)					
Procedure	Hospitals	Rooms	Patients	Mean	Min.	Max.	1st Quartile	Median	3rd Quartile
Biliary Drainage	6	7	82	698	426	994	484	725	887
Biliary Intervention	10	31	460	633	30	1670	455	624	805
ERCP	18	49	3205	246	102	448	205	238	291
Facet Joint Injection	9	20	746	82	10	151	58	87	106
Hickman Line Insertion	16	43	1054	63	3	165	33	62	86
Nephrostomy	16	28	320	256	60	654	155	250	304
Oesophageal Dilation	11	22	161	148	30	546	74	87	165
Oesophageal Stent	11	22	171	290	78	729	176	242	355
Pacemaker (permanent)	17	45	2602	397	90	822	284	366	493
PTCA 1 stent	8	26	5945	732	403	1258	606	705	799

Figure 8 shows histograms of the distribution of x-ray room mean fluoroscopy time per procedure. The vertical line indicates the third quartile of the distribution.

Table 15 shows the data on fluoroscopy time for PTCAs of increasing complexity. Strictly, none of these datasets have a sample size which is sufficient to be representative of national practice according to our criteria. However, the sample for single stent PTCAs has such a large number of patients from 26 rooms that it could be regarded as sufficient despite being from 8 hospitals rather than 10.

TABLE 15 Mean and third quartile fluoroscopy time for PTCAs*

	Number			Fluoroscopy time (s)	
Procedure	Hospitals	Rooms	Patients	Mean	3rd Quartile
PTCA 1 artery	3	15	2749	872	1133
PTCA 1 stent	8	26	5945	732	799
PTCA 2 stent	4	7	667	837	1066
PTCA 3 stent	4	4	183	1100	1332

* Mean patient weight range 75-85 kg

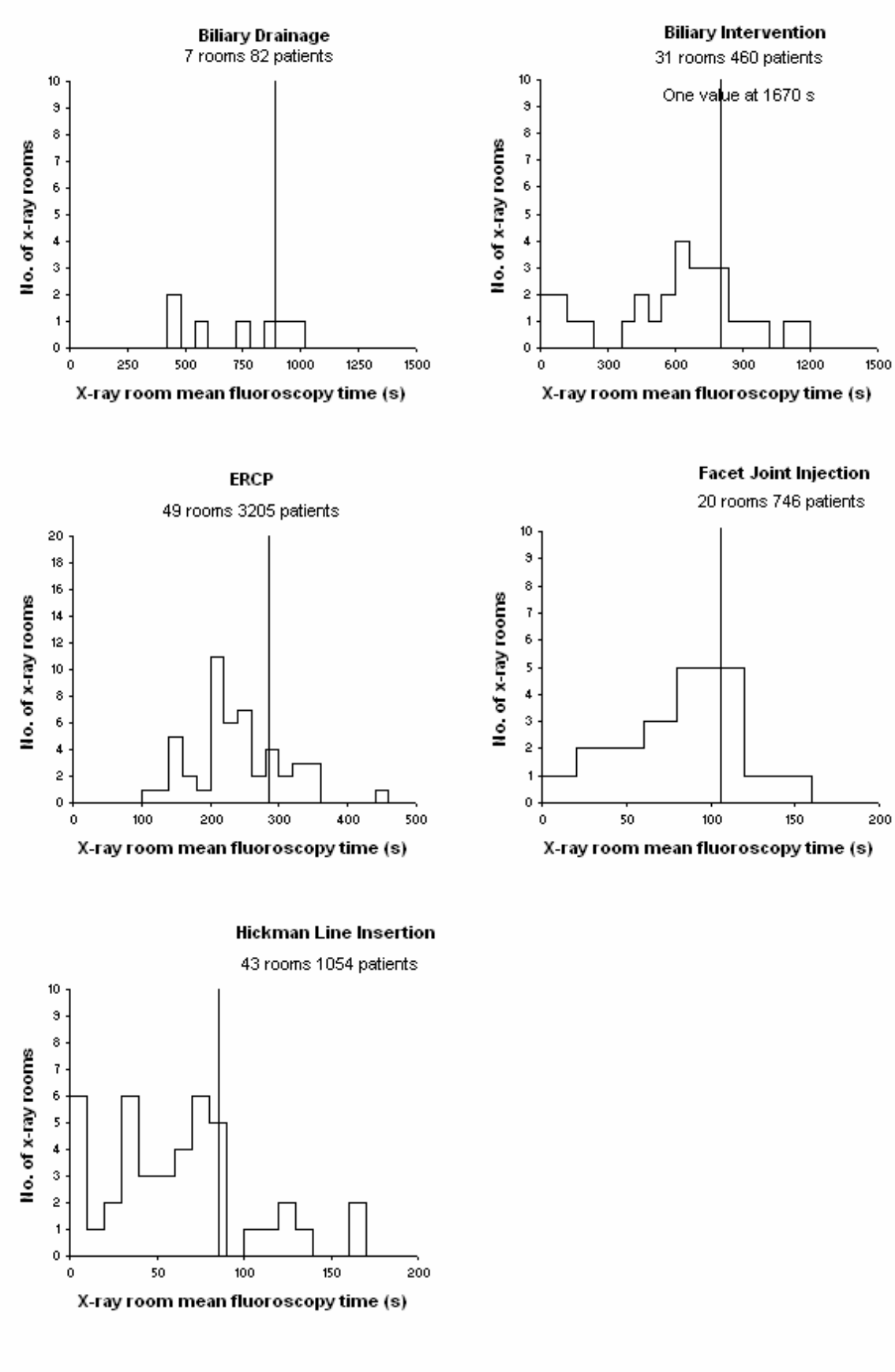
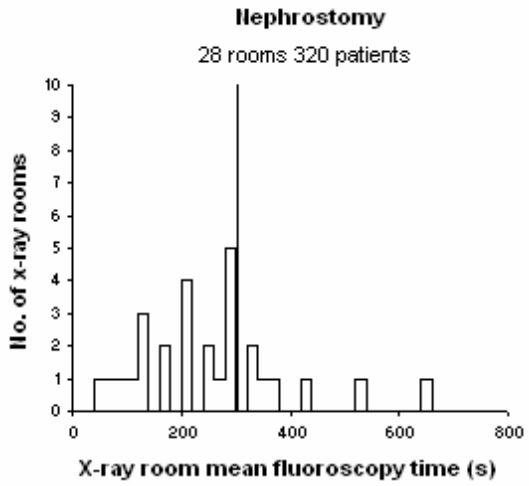
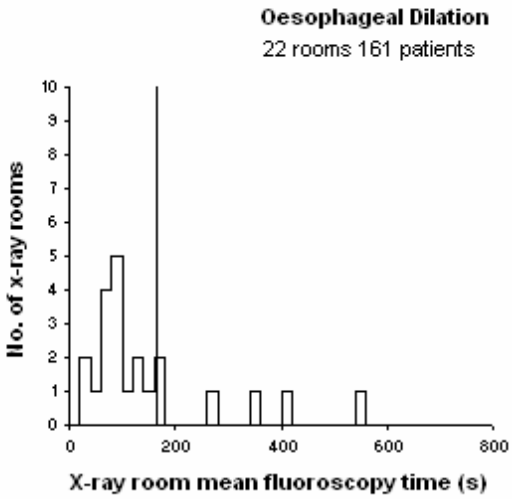
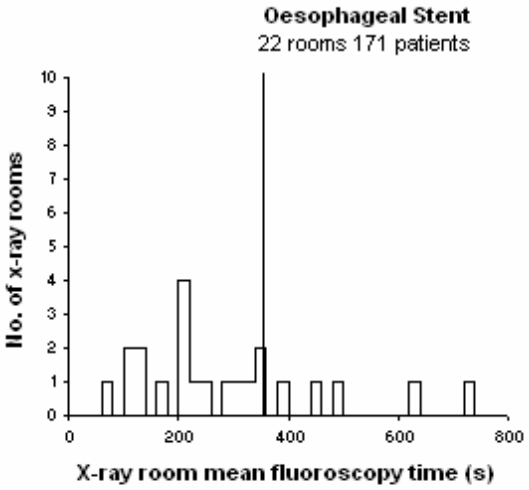
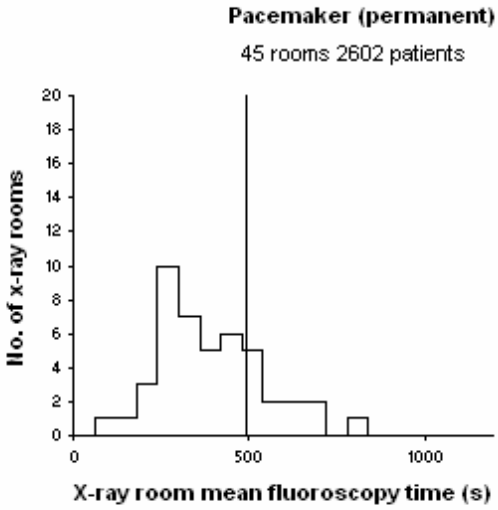


Figure 8 Distribution of x-ray room mean fluoroscopy time per procedure









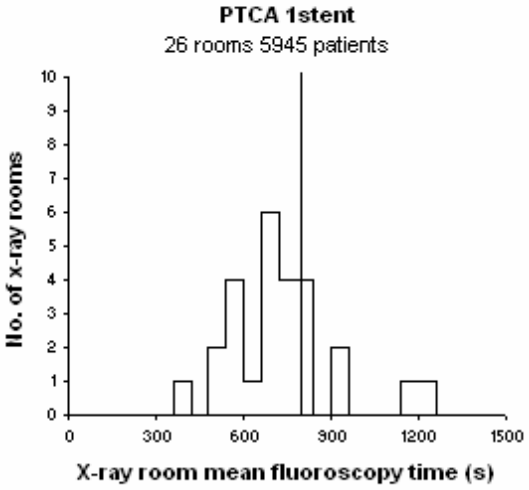


Figure 8 (continued)

4.3 More limited data on other examinations and procedures on adults

Table 16 shows a summary of data for 25 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 16 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.

Although there was plenty of data for angioplasty procedures (12 hospitals, 24 rooms and 647 patients) there was no specific information as to their anatomical location, which are mostly carried out in a limb or the trunk. Table 16 shows that angioplasty of the iliac artery in the trunk gives a mean DAP which is more than twice that for angioplasty of the femoral artery in the thigh. Anatomical location thus has a critical effect on the patient dose. Therefore angioplasty procedures of unspecified location have not been included in Tables 11 or 12, and have not been considered for a reference dose.

Embolisation and mesenteric angiography are both very high dose procedures; the mean DAP and fluoroscopy time for these procedures is roughly similar to those presented in the previous review.

Doses for the relatively rare TIPS procedure (transjugular intrahepatic portosystemic shunt) are reported to be high (McParland, 1998). However, data for TIPS in this review were few in number, as they were for the 2000 review. Combining the data from 2000 and 2005 gave a total of 23 patients from 11 rooms at 4 hospitals. For this combined dataset the room mean DAP was 242 Gy cm^2 and the mean fluoroscopy time was 2264 seconds. So the fluoroscopy time for TIPS is nearly twice as long as for any other procedure in Table 16, and the mean DAP appears comparable to that for mesenteric angiography.

TABLE 16 : Summary of data on other examinations and interventional procedures

Examination/procedure	Hospitals	Number Rooms	Patients	Mean of room mean DAP (Gy cm^2)	Mean of room mean fluoro. time (seconds)	Mean tube voltage (kV)
Angiography(Carotid)	6	12	68	41.4	393	69
Angiography(Cerebral)	5	11	2099	62.4	504	82
Angiography(Coronary graft)	6	11	226	42.3	615	
Angiography(Mesenteric)	10	15	158	240.4	1013	75
Angiography(Renal)	8	21	502	87.8	280	72
Angioplasty	12	24	647	22.2	381	75
Angioplasty(Femoral)	6	7	261	29.8	452	
Angioplasty(Iliac)	5	7	169	65.0	313	
Aortography	8	9	48	40.3	357	90
Aortography(Arch)	6	9	147	28.3	295	83
Arthrography(Shoulder)	8	10	33	1.4	88	67
Bladder Pressure	5	17	1344	2.9	47	90
Embolisation	11	13	150	106.6	1308	90
Feeding Tube Insertion	8	15	83	10.2	287	78
Filter(Inferior Vena Cava)	7	9	57	26.9	220	82
Herniography	9	10	86	17.8	151	82
Pain relief in spine	6	7	98	5.1	69	89
Pouchography	7	13	154	11.4	96	91
Proctography	7	17	405	12.3	93	111
PTC	6	8	74	25.4	679	70
RF cardiac ablation	6	12	238	24.9	1341	77
Stent(Biliary)	9	9	125	42.0	737	74
Stent(Bowel)	5	7	36	79.6	968	80
Stent(Ureteric)	10	19	203	30.2	664	77
Urethrography	9	16	77	6.5	126	84

PTC = percutaneous transhepatic cholangiography

RF cardiac ablation = radio-frequency cardiac catheter ablation

4.4 Medical x-ray examinations on children

We have applied the methods described in NRPB-R318 (Hart, 2000) to the limited amount of paediatric data in the NPDD for which the patient thickness or both the height and weight were available. This enabled us to adjust the DAP per examination measurements 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.

Unfortunately, as was the case for the last review, there were insufficient measurements of either ESD or DAP per radiograph (where the patient size was available) to apply this method to any paediatric radiographs. In fact, there was even less data for dose per radiograph than there was for the 2000 review. This was insufficient to be representative of national practice and to derive reliable national reference doses.

However, there was a sufficient amount of data on DAP per examination and patient size for the same three examinations as in the 2000 review: micturating cystourethrography (MCUs), barium meals and barium swallows. The main parameters of the distributions of room mean doses for these examinations after they had been adjusted for patient size are shown in Table 17. There were about twice the number of rooms but a similar number of patients for MCU and barium swallow examinations in this review compared to the 2000 review. There were however fewer patients (but a similar number of rooms) for barium meals in this review than were available for the 2000 review, perhaps due to a continuation of the downward trend in the numbers of such examinations (Tanner, 2000).

The means and third quartiles of the dose distributions are mostly between 50 and 75% of what they were for the 2000 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. Conversely, the mean values of the doses adjusted to the standard new-born baby size are about a factor of three lower than those for the 1 year old and 5 year old; and those for the standard 10 year old are about a factor of two higher. The implications of these findings on the setting of national paediatric reference doses are discussed in section 6.2.2.

TABLE 17 Analysis of paediatric data

Standard age (years)	No. of rooms	Min.	1st quart	Median	Mean	3rd quart	Max.
		Adjusted DAP/examination (mGy cm^2)*					
MCU (2020 patients)							
0	53	7	53	126	274	300	3020
1	59	33	151	281	483	681	2283
5	58	55	214	335	740	820	4660
10	44	88	329	680	1155	1480	7165
15	30	50	505	1357	1911	2460	9775
Barium meal (335 patients)							
0	16	8	47	127	378	381	1983
1	25	56	251	490	765	1067	3836
5	20	93	264	707	845	1281	2458
10	22	126	560	1636	2012	2432	8339
15	25	217	920	1952	3466	6384	10796
Barium swallow (594 patients)							
0	26	5	132	273	529	412	4837
1	40	58	303	623	863	1221	3320
5	36	50	262	640	858	1263	2644
10	41	173	787	1577	2272	2914	10840
15	40	41	869	1763	2528	3538	14152

* Adjusted to nearest standard size

4.5 Dental x-ray examinations on adults and children

4.5.1 Intra-oral mandibular molar radiographs

Table 18 shows some key parameters of 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 DXPS, hence the smaller number of x-ray sets for child exposures.

TABLE 18 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	6170	1.85	0.02	30	1.15	1.6	2.25
Child	253	1.15	0.02	3.55	0.7	1.0	1.5

The data from DXPS alone had a mean adult PED of 1.9 mGy, while the mean adult PED for the data supplied by medical physicists was 1.7 mGy. These doses are sufficiently close to indicate that there were no fundamental systematic differences in the dose assessments by the two different sources.

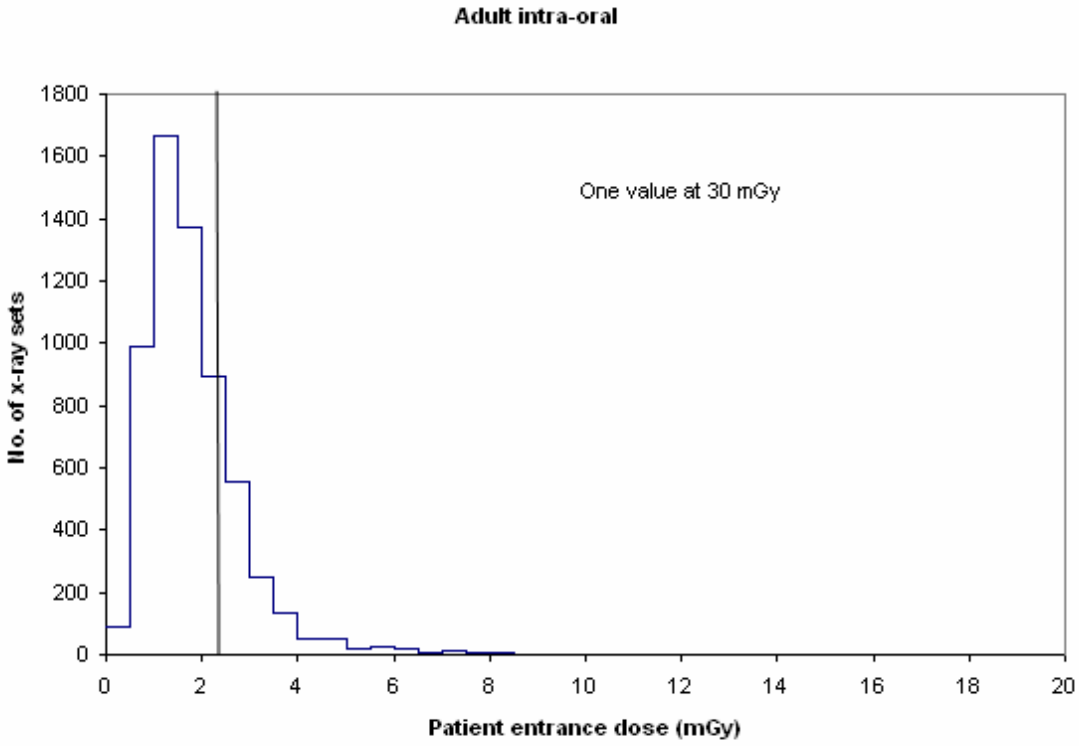
Figure 9 shows histograms of the distributions in Table 18. The vertical line indicates the third quartile of the distribution.

Table 19 shows the mean exposure parameters for the radiographs listed in Table 18. Modern intra-oral equipment is generally fitted with timer control units which have some form of patient size selection. This is usually just an ‘adult’ and a single ‘child’ setting, but sometimes more options are available. Exposure times are generally reduced by about two-thirds for a child patient compared to an adult, but the tube voltage is rarely adjusted and the tube filtration remains the same.

TABLE 19 Intra-oral radiographs: exposure parameters

Exposure conditions	Mean exposure time (sec)	Mean kV	Mean filtration (mm Al)
Adult	0.36 (0.02-1.6)	64 (39-81)	2.8 (1.2 - 5)
Child	0.21 (0.08-0.76)	68 (60-70)	ditto
The range from minimum to maximum is given in brackets			

Table 20 shows the distribution in the type of detector used for the adult radiographs. Unfortunately, for a large proportion of the x-ray sets the detector was not specified or was placed in two or more possible categories. It is nevertheless clear that D speed films are still commonly used (24% of specified detectors) whereas 76% were either E or F speed films or digital systems. Data for 2005 suggests that around 15% of dentists are using digital systems for intra-oral radiography (Andrew Gulson, personal communication).



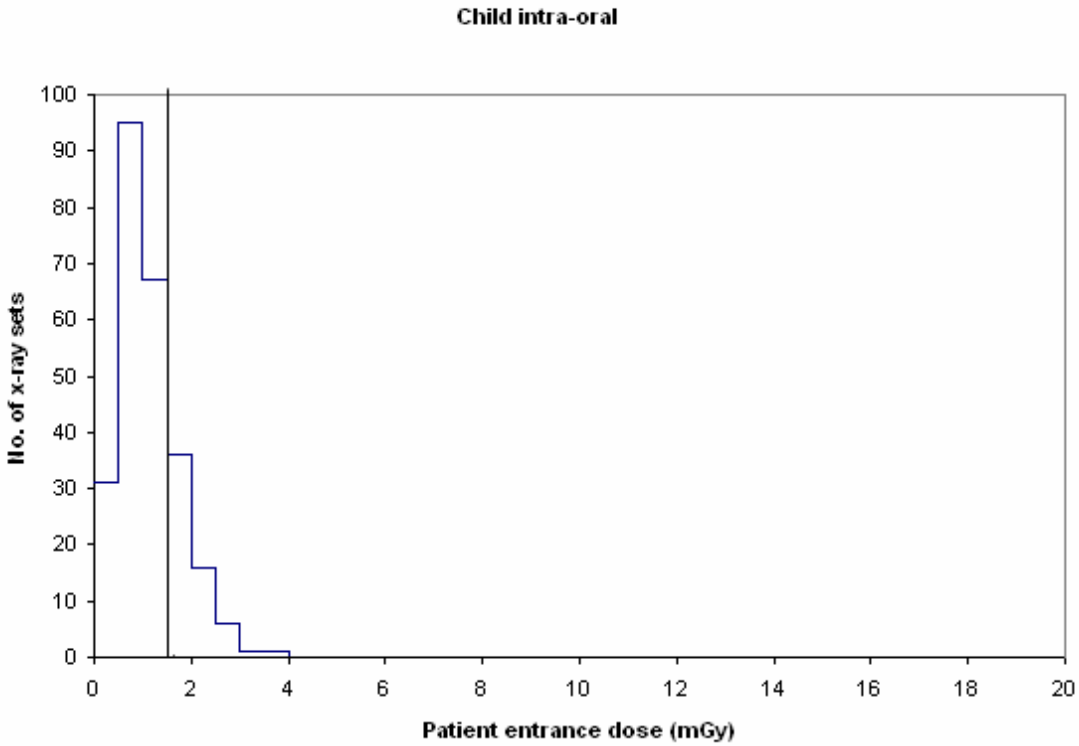


Figure 9 Distribution of patient entrance dose for intra-oral radiographs

TABLE 20 Intra-oral radiographs: type of detector used

Detector	Number	% of specified detectors
D film	1181	24
D/E film	2	
E film	325	6.6
E/F film	366	7.5
F film	47	1
E/F/digital	2942	60
CR	13	0.3
Other digital	9	0.2
Total	4885	
Unknown	1285	
Total	6170	

CR = computed radiography (photostimulable phosphor)

More detailed analyses of the DXPS data are available in Gulson, 2007.

4.5.2 Panoramic radiographs

Table 21 shows some key parameters of 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 number of panoramic sets for child exposures.

TABLE 21 Panoramic radiographs

Exposure conditions	No. of sets measured	Dose-width product (mGy mm)					
		Mean	Min.	Max.	1st Quartile	Median	3rd Quartile
Adult	2175	52	10	270	37	48	60
Child	38	54	19	102	45	52	65
Both	2213	52	10	270	37	48	60
		Dose-area product (mGy cm^2)					
Adult	1910	70	15	440	50	65	82
Child	38	70	25	180	57	68	89
Both	1948	70	15	440	50	65	82

The data from DXPS alone (Gulson, 2007) had a mean adult DWP of 51.8 mGy mm, while the mean adult DWP for the data supplied by medical physicists was 51.2 mGy mm. This would seem to indicate no fundamental systematic difference in assessing DWP. The data from DXPS alone had a mean adult DAP of 68 mGy cm^2, while the mean adult DAP for the data supplied by medical physicists was 88 mGy cm^2. All the

DXPS DAP values were obtained by multiplying the DWP by the estimated height of the x-ray beam, whereas 27% of the DAP values from the medical physicists were obtained by this method and 27% were measured directly with a DAP meter (the other 46% were unspecified).

Figures 10 and 11 show histograms of the adult and child dose distributions in Table 21. The vertical line indicates the third quartile of the distribution.

Table 22 shows the mean exposure parameters for the radiographs listed in Table 21. Exposure times for the small number of child measurements appear to be very similar to those for adults, but the tube voltages tend to be slightly lower while the tube filtration remains the same.

TABLE 22 Panoramic radiographs: exposure parameters

Exposure conditions	Mean exposure time (sec)	Mean tube voltage (kV)	Mean tube filtration (mm Al)
Adult	15.8 (10-24)	73 (54-124)	3.9 (1.8 – 8.5)
Child	15.5 (10-20)	65 (55-75)	ditto

The range from minimum to maximum is given in brackets

Information on the detector system (e.g. film, CR, digital) was supplied for only 120 panoramic sets (about 5% of those surveyed). Of these, 88% were film-screen, 5% were CR and 7% were other digital systems. For only 51 of the film-screen systems was there enough information to specify their speed. For this small sample, 29% used film-screen speed classes of 200 to 300, and 71% used 400.

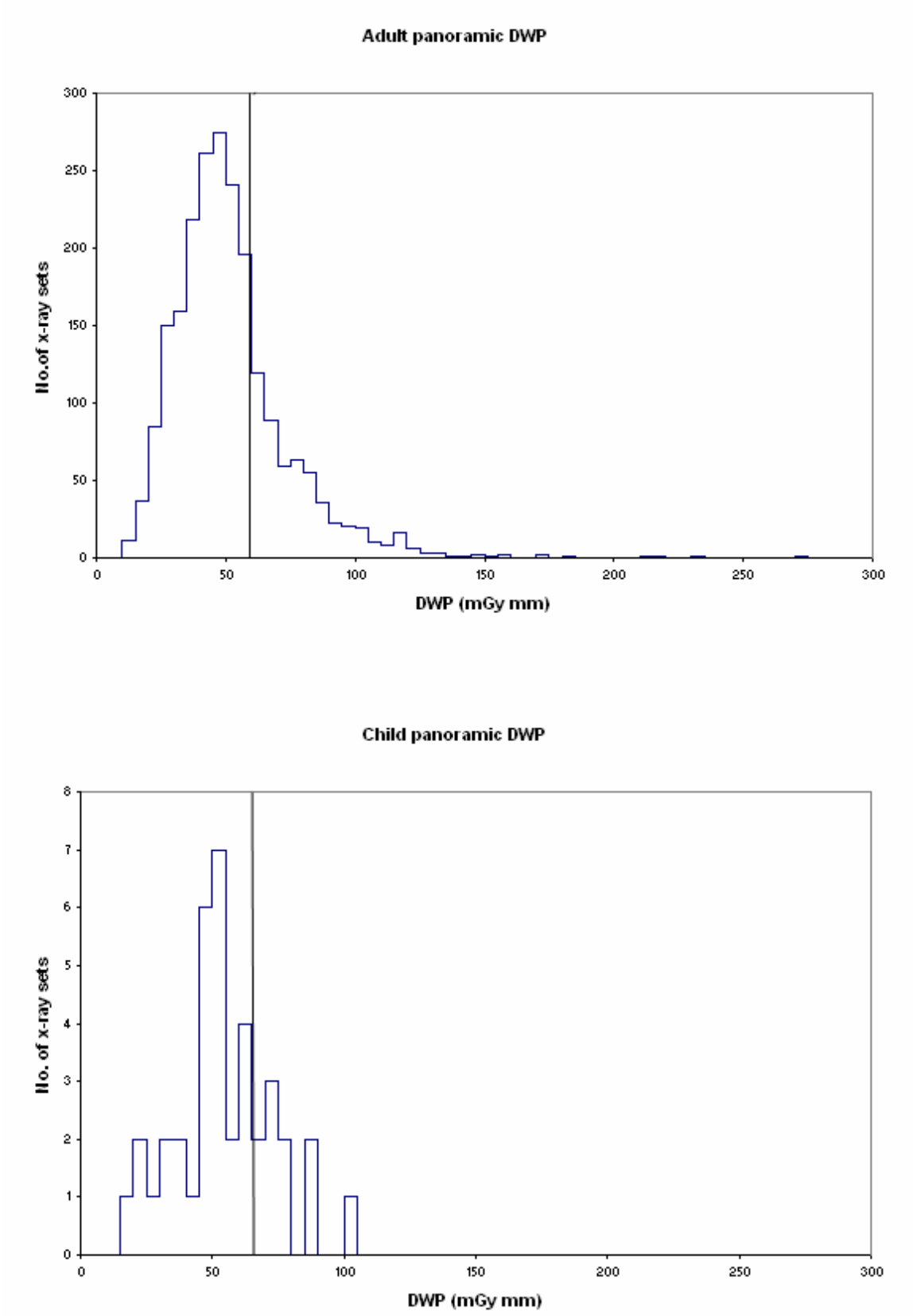
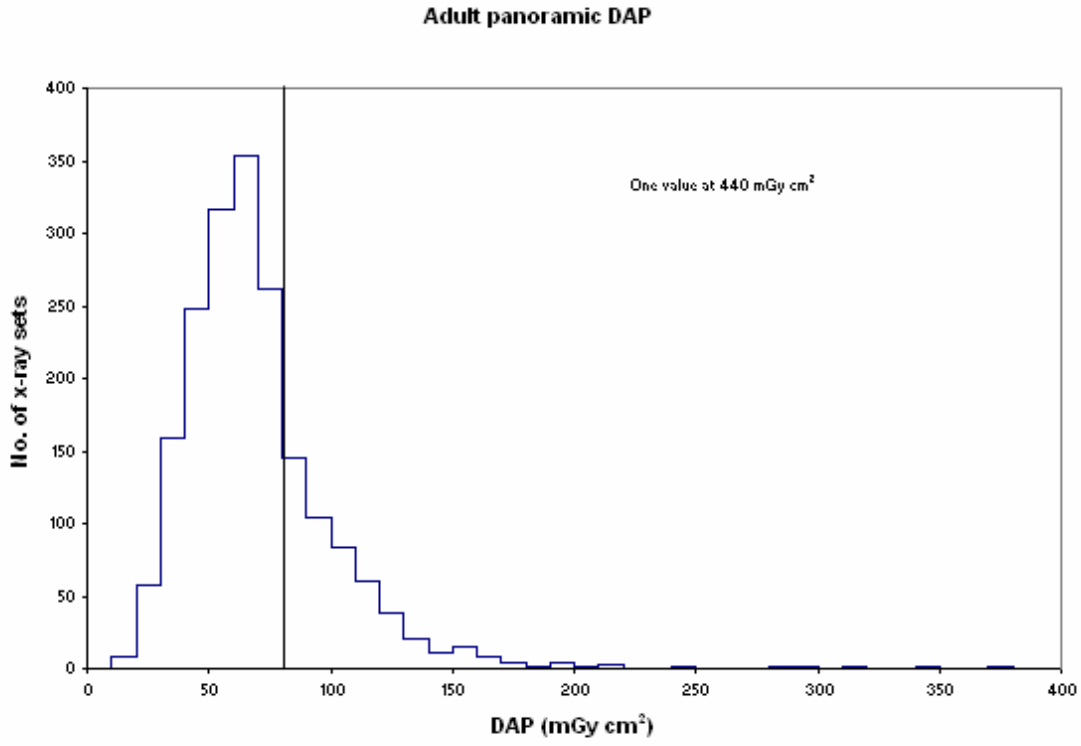


Figure 10 Distribution of dose-width product for panoramic radiographs



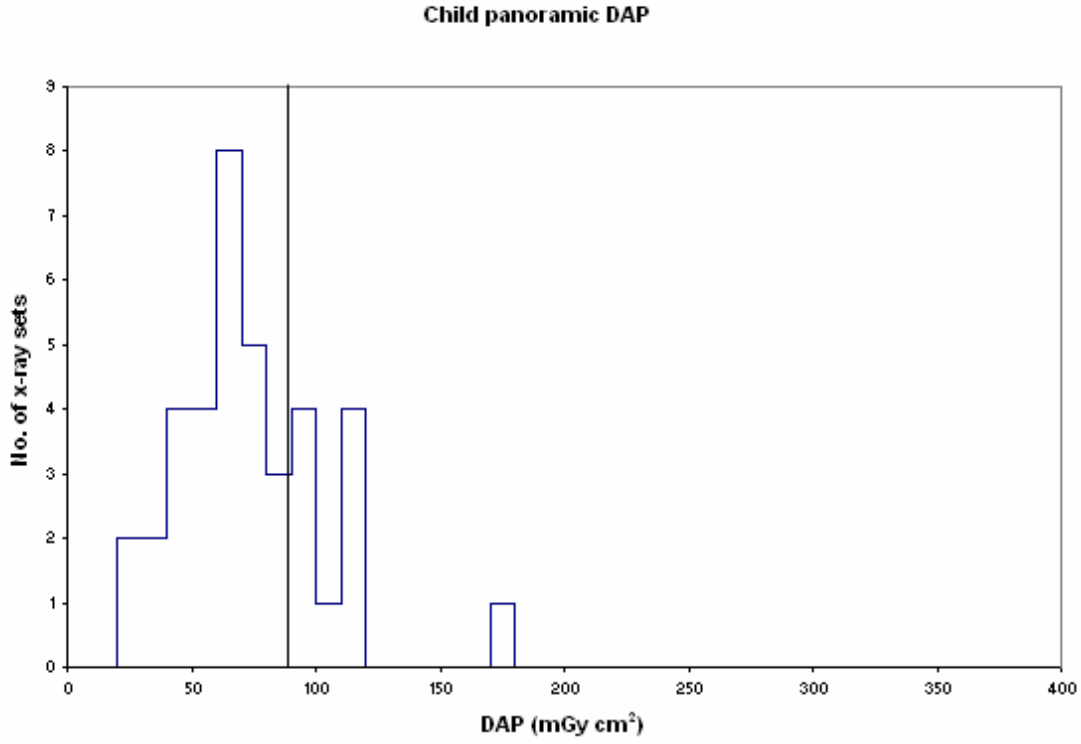


Figure 11 Distribution of dose-area product for panoramic radiographs

5 INFLUENCE OF IMAGING EQUIPMENT OR TECHNIQUE ON PATIENT DOSE

5.1 Film-screen speed

For the 24% of rooms where information on the type of imaging equipment for simple medical radiographic examinations was provided: 55% used a film-screen combination, 40% used computed radiography (CR), and 5% used a direct digital system. In the previous review, film-screen systems were used in 98% of rooms, with only 2% being definitively identified as using CR. There has thus been a noticeable change in the type of imaging equipment used over the last five years.

Information on the make and type of x-ray film and intensifying screen and/or the speed class of the film-screen combination was provided for about 9% of the dose per radiograph measurements in the database (see Table 3). This is much lower than the 35% provision in the last review, and is probably partly due to the much greater use of CR since 2000. Appendix D lists all the makes and types of film-screen combination which were recorded in the NPDD between 2001 and 2006. This is a shorter list than given in the last review, probably again due to the much greater use of CR.

Table 23 shows the percentage of film-screen combinations of various speeds for which data were provided in the current (2005) and previous reviews of the NPDD (Hart 1996, Hart 2002) and in the national patient dose survey conducted in the mid-1980s (Shrimpton 1986).

TABLE 23 Percentage use of the different film-screen speed classes

	Percentage use			
Speed-class	2005 review	2000 review	1995 review	1980s survey
50	0	1	0	0
100/150	2	2	2	6
200	0	5	18	71
250/300	10	12	20	0
400	51	67	52	23
600	1	11	7	0
700/800	36	2	1	0

Whereas speed-class 200 was most common in the mid-1980s, speed-class 400 is the most common in all the subsequent reviews. The table also shows that the use of film-screen combinations with speed-classes greater than 400 rose from 8% in the 1995 review, to 13% in the 2000 review and to 37% currently. Speed class 800 is now used for 35% of exposures utilising film-screen combinations.

Taking a weighted average over each of the columns of Table 23, the mean speed used in the mid-1980s was 250, in the 1995 review it was 350 and for the 2000 review it was 390. The weighted-average speed is now 530. This change in mean speed would be expected to lead to about a 25% reduction in dose/radiograph for film-screen radiographs between the 2005 and the 2000 reviews. However the potential reduction across all radiography will be affected by the influence of computed radiography on overall doses.

5.2 Computed radiography

Computed radiography (CR) has been commercially available in the UK since 1989, but has had a significant take-up only during recent years. The current national roll-out of Picture Archiving and Communication Systems across the English NHS means that such digital systems are likely to be much more common than film by the time of the next review. CR uses photo-stimulable phosphor plates which can be directly substituted for film-screen systems. CR phosphor plates generally use barium fluorohalides with a k-edge of 37 keV, while the screens in film-screen systems generally use 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, 2005) that a tube voltage of 75 to 90 kV is best for CR, allowing image quality to be maintained while minimising effective dose. Other authors have reported that doses with the use of CR systems are approximately the same as those for a 300 speed screen-film system (Compagnone, 2006). If so, then higher doses can be expected using CR than with current film-screen systems with an average speed of around 500.

135 rooms in the NPDD were using CR, of which 55 rooms were equipped with a Fuji system, 29 with Philips, 6 with Agfa, 3 with Kodak, and there were 42 other rooms for which the CR manufacturer was not specified.

Table 24 shows a comparison of the NPDD mean ESD/radiograph using film and CR systems for those radiographs with doses from at least 2 rooms for each imaging modality, using the standard selection procedure as described in section 2.4.1. A minimum of two rooms was chosen in order to present data for several types of radiograph. The mean ESD for CR is less than that for film in 8 of the 10 cases. However, the application of a student's T-test shows that only 4 of the 10 cases are significantly different at the 98% confidence level. These cases are abdomen AP, skull AP/PA, skull LAT and thoracic spine AP. For all four of these cases the CR dose is less than that for film by 40-50%.

TABLE 24 Mean of room mean ESDs per radiograph (mGy) for CR and film

	Computed radiography			Film		
Radiograph	Hospitals	Rooms	ESD	ESD	Hospitals	Rooms
Abdomen AP	12	18	2.71	4.82	17	20
Chest PA	17	29	0.11	0.10	24	35
Lumbar Spine AP	11	18	4.46	4.91	23	29
Lumbar Spine LAT	10	18	11.5	9.61	24	31
Lumbar Spine LSJ	3	3	14.8	25.7	7	8
Pelvis AP	13	21	2.91	3.29	25	30
Skull AP/PA	2	3	0.95	1.70	11	11
Skull LAT	2	3	0.71	1.17	6	6
Thoracic Spine AP	5	7	2.63	5.04	9	10
Thoracic Spine LAT	2	2	4.42	5.65	7	9

Table 25 shows a comparison of the mean DAP/radiograph using film and CR systems for those radiographs with doses from at least 2 rooms, using the standard selection procedure. The application of a student's T-test shows that none of these 10 cases are significantly different at the 98% confidence level. The general picture is therefore that CR doses are on the whole similar to those for film, but for a few types of radiograph significant ESD reductions have been achieved with CR.

TABLE 25 Mean of room mean DAPs per radiograph (Gy cm^2) for CR and film

	Computed radiography			Film		
Radiograph	Hospitals	Rooms	DAP	DAP	Hospitals	Rooms
Abdomen AP	16	37	2.43	2.21	10	22
Chest AP	2	2	0.09	0.09	4	7
Chest LAT	3	3	0.18	0.26	4	4
Chest PA	22	54	0.13	0.10	16	30
Lumbar Spine AP	15	29	1.41	1.55	13	25
Lumbar Spine LAT	14	30	2.48	1.95	14	24
Lumbar Spine LSJ	1	2	2.26	2.0	5	13
Pelvis AP	20	37	2.08	1.95	16	28
Thoracic Spine AP	10	13	0.78	0.61	8	12
Thoracic Spine LAT	6	9	1.64	1.09	8	13

5.3 Flat panel detectors

Flat panel detectors began to be installed in the UK in about the year 2000. 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. In our dataset it was found that most flat panel detectors were used in cardiac catheterisation laboratories.

Table 26 shows a comparison of the mean of the room mean DAP per cardiac procedure for flat panel detectors and for 'conventional' systems, meaning those that do not involve CR or flat panel detectors. The data in the table was based on selecting for a mean patient weight of 75 to 85 kg because the mean weight for these cardiac patients was above the normal range used in this report of 65-75 kg. For six out of the eight procedures, flat panel detectors appear to give a higher dose than the conventional system. However, the application of a student's T-test shows that none of the 8 cases are significantly different at the 98% confidence level. This is still a disappointing result given that, in theory, flat panel detectors can be operated at an equivalent of up to speed 1600 (Rapp-Bernhardt, 2003).

There were two rooms in the database that used CR for coronary angiography. The mean DAP for these two rooms was 37 Gy cm^2, which is higher than the mean dose for flat panel detectors or conventional systems as shown in Table 26. However, much of the dose from coronary angiography arises from fluoroscopy for which CR is not used.

TABLE 26 Mean DAP/procedure for flat panel detectors and conventional systems*

	Flat panel detectors		Conventional	
Procedure	Mean DAP (Gy.cm^2)	Rooms	Mean DAP (Gy.cm^2)	Rooms
Angiography of coronary bypass graft	66	2	42	34
Coronary angiography	28	14	25	94
PTCA	58	4	52	24
PTCA 1 artery	32	2	35	13
PTCA 1 stent	67	3	40	25
PTCA 2 stent	83	2	59	7
PTCA 3 stent	121	2	87	4
RF cardiac ablation	13	2	23	23

* Mean patient weight range 75-85 kg

The only type of radiograph for which doses were acquired for more than 1 room using flat panel detectors was chest PA. For 2 such rooms the average ESD was 0.16 mGy. This is greater than the mean doses using CR or film as shown in Table 24.

5.4 Digital spot imaging

Table 27 shows a comparison, for film-screen imaging and digital spot imaging, of the mean DAP for each of 10 examinations that were carried out in at least 10 rooms for each imaging system. Five of the examinations have a lower mean DAP when performed with DSI, while five have a lower mean DAP with film-screen. However, only two of these differences were significant at the 98% confidence level; these were barium enemas and hysterosalpingography. For the latter, DSI appears to give a higher dose while for barium enemas it appears to give a lower dose. This result may indicate

that there is little overall difference in the dose from the two systems, or that fluoroscopy plays the biggest role in determining the total DAP for most examinations. This is a different result from that found in the previous review, where it appeared that DSI might be lowering the DAP.

TABLE 27 Effect of film-screen and digital spot imaging equipment on DAP per examination – 2005 review

Examination	Film-screen		Digital spot imaging	
	Mean DAP (Gy cm^2)	No. of rooms	Mean DAP (Gy cm^2)	No. of rooms
Barium Enema	21.2	71	13.7	131
Barium Follow Through	7.6	36	8.8	106
Barium Meal	11.5	23	10.0	121
Barium Meal & Swallow	10.9	26	9.3	106
Barium Swallow	7.8	36	6.4	126
Coronary Angiography	17.7	10	28.2	25
Hysterosalpingography	1.3	11	2.5	74
IVU	14.2	39	9.7	23
Sinography	5.3	10	6.6	92
Water Soluble Enema	12.4	12	16.3	69

6 DISCUSSION

6.1 Trends in patient doses with time

In comparison with earlier surveys the results from this current review indicate a continuing downward trend in doses to adult patients for most of the common radiographs and diagnostic examinations studied. Figure 12 shows the trends in the mean value of the room mean ESDs between the mid-1980s survey, the 1995, 2000 and 2005 reviews, for all types of radiograph except those of the chest. All show a distinct downward trend with time, with the exception of thoracic spine AP, which shows a slight increase in the 2005 review compared with the 2000 review. Mean ESD values for chest PA radiographs are too small to show clearly on the same bar chart but they also showed a distinct downward trend with time. Reductions between 2000 and 2005 are slightly larger than between 1995 and 2000 (average reductions 21% and 18% respectively). Dose reductions for 2000-2005 are significant at the 98% confidence level for abdomen AP, chest PA, lumbar spine AP & LAT, pelvis AP, skull AP and thoracic spine LAT.

Figure 13 shows the trends in the mean value of the room mean DAPs between the 2000 and 2005 reviews for the six types of radiograph where we have sufficient data. These also show a downward trend (average reduction 11%) but the reduction is statistically significant at the 98% confidence level only for pelvis AP.

Figure 14 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. Where data for 1985 are available, there is seen to be a substantial fall in dose by 1995 and a more gradual decline since then to 2005. The slight increase in dose between the 1995 and 2000 reviews for IVUs is not statistically significant, since the 1995 mean was based on data from only 10 rooms. The average reduction in DAP per examination was 15% for 2000-2005 compared with 10% for 1995-2000. The reduction from 2000 to 2005 was statistically significant at the 98% confidence level for barium enemas, barium swallows, coronary angiographies, hysterosalpingographies and small bowel enemas.

It might be expected that interventional procedures, which are becoming increasingly sophisticated, would exhibit an upward trend in dose between the 2000 and 2005 reviews. This would not appear to be the case. For the ten interventional procedures listed in Table 11, the mean DAP/procedure has stayed about the same for biliary drainage/intervention, but has decreased for all the rest (excluding ERCPs because these are not all interventional, and excluding PTCAs with 1 stent because there was no data for the 2000 review). For oesophageal dilation, oesophageal stents, and pacemakers, the reduction is by about a factor of two. However, a student's T-test indicates that none of the differences for these eight procedures are significant at the 98% confidence level. Therefore, all that can be said is that the doses from these interventional procedures show no indication of rising.

As well as examining how the overall mean dose values have changed, it is instructive to see how the distribution of room mean doses has altered in successive reviews. In

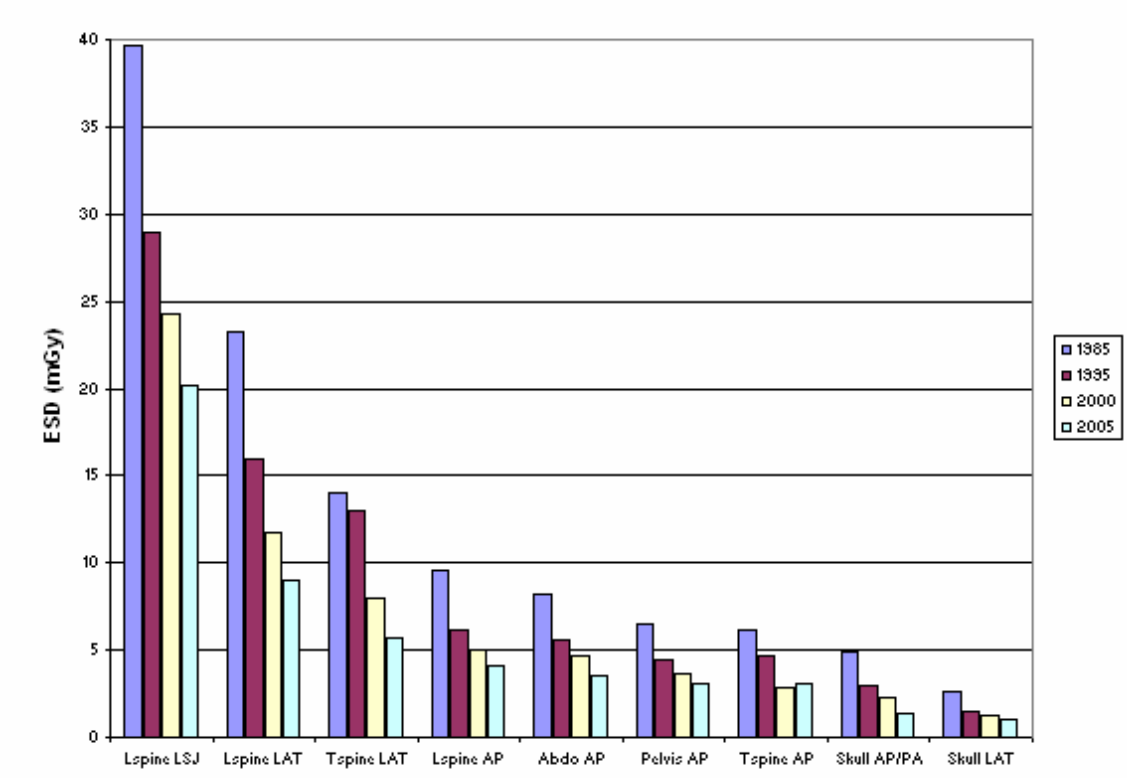


Figure 12 Mean entrance surface dose per radiograph

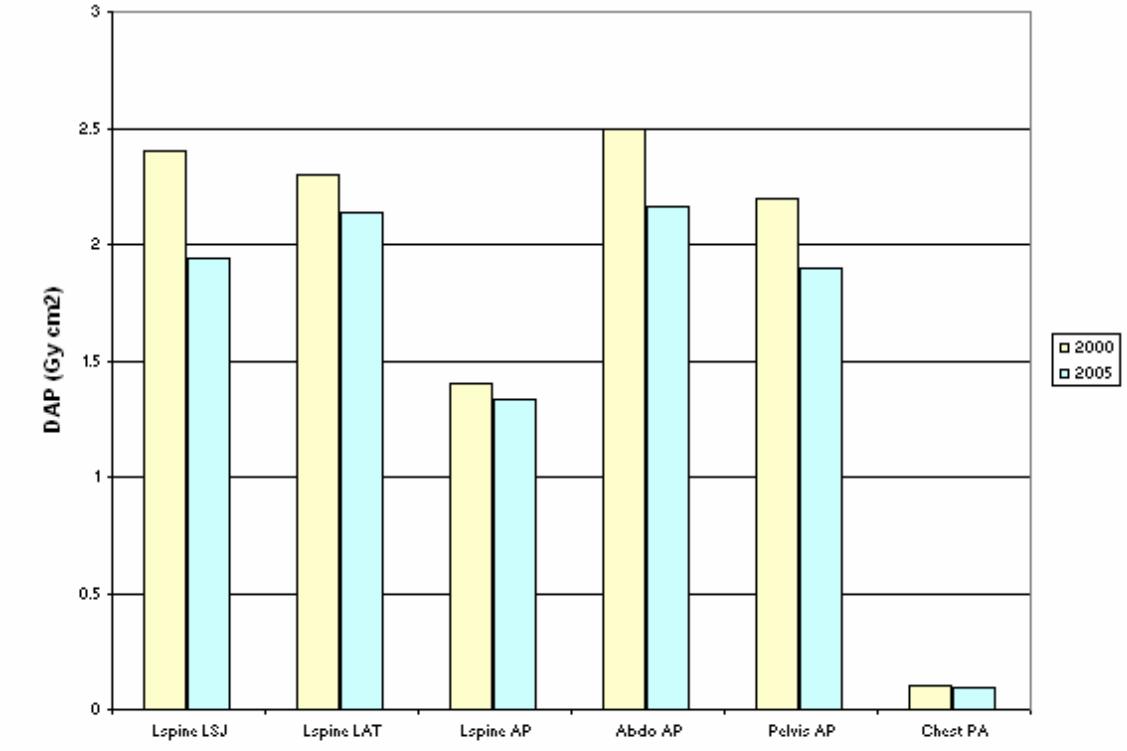


Figure 13 Mean dose-area product per radiograph

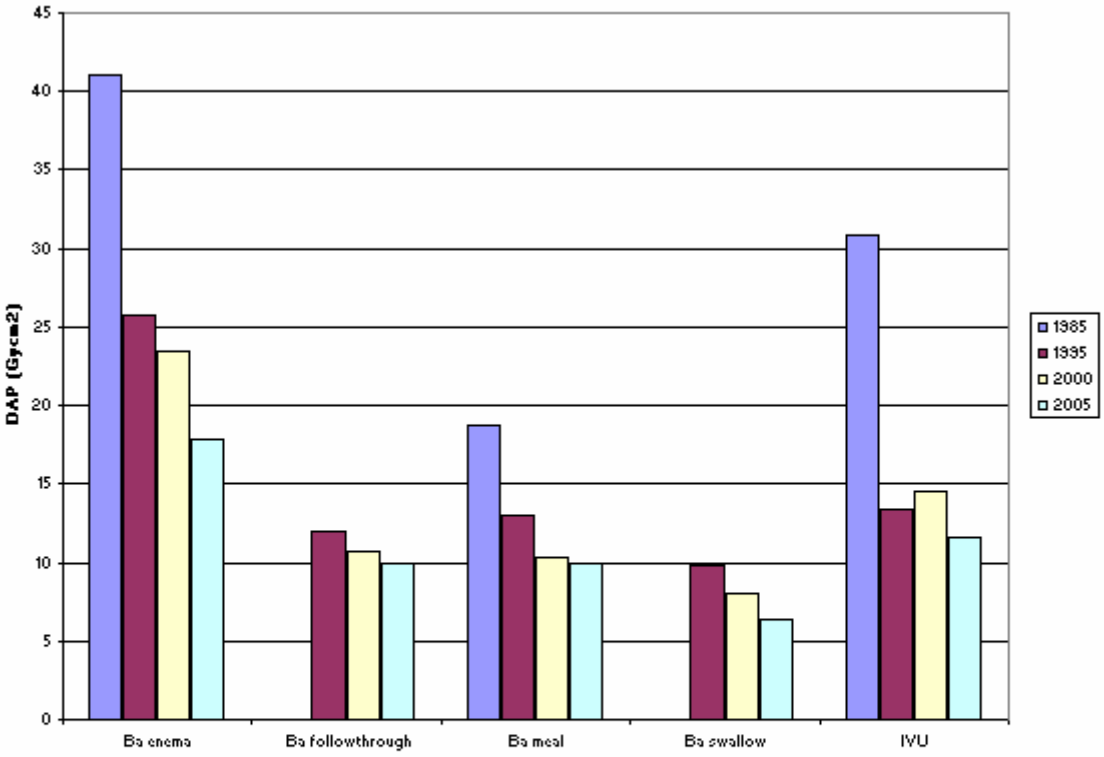


Figure 14 Mean dose-area product per examination

particular it would be interesting to observe whether the existence of national reference doses since 1992, which focus attention on the upper quartile of the dose distributions, has had any effect on the shape of the distributions. It might be expected, for example, that the high dose tails seen in the wide and skewed dose distributions of earlier surveys, are now much reduced. Figure 15 compares the histograms of room mean ESDs for the 12 types of radiograph in Table 4 with corresponding histograms from the 1995 and 2000 reviews. Generally speaking, it can be seen that the high dose tails of the distributions have decreased over the years and the distributions have become slightly narrower, but not as much as might be expected if all hospitals exceeding the reference doses had taken corrective action. The third quartiles of the room mean ESD values are indicated by a vertical line on the histograms in Figure 15 and it can be seen that they have become progressively lower with each review for all the radiographs, except for thoracic spine AP and for chest LAT.

Figure 16 compares the histograms of the room mean DAP values for barium contrast examinations of the alimentary tract over the same three reviews – 1995, 2000 and 2005. For barium enemas and swallows, the high dose tail and third quartile values have decreased slightly over the ten years, but for barium meals and follow-throughs the distributions are just as wide. Although the current third quartile value for follow-throughs is slightly lower than for the 2000 review, for barium meals it is slightly higher.

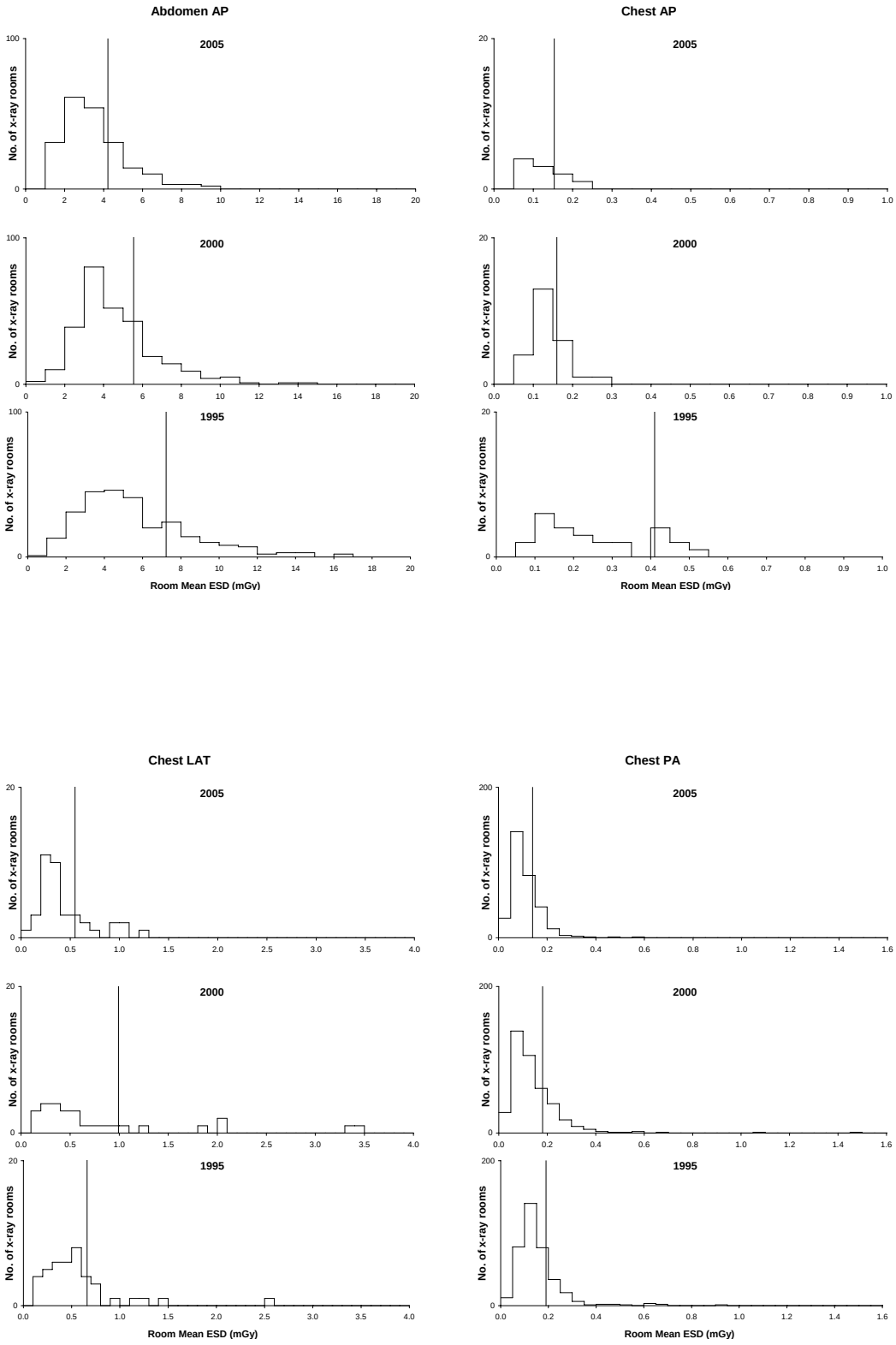
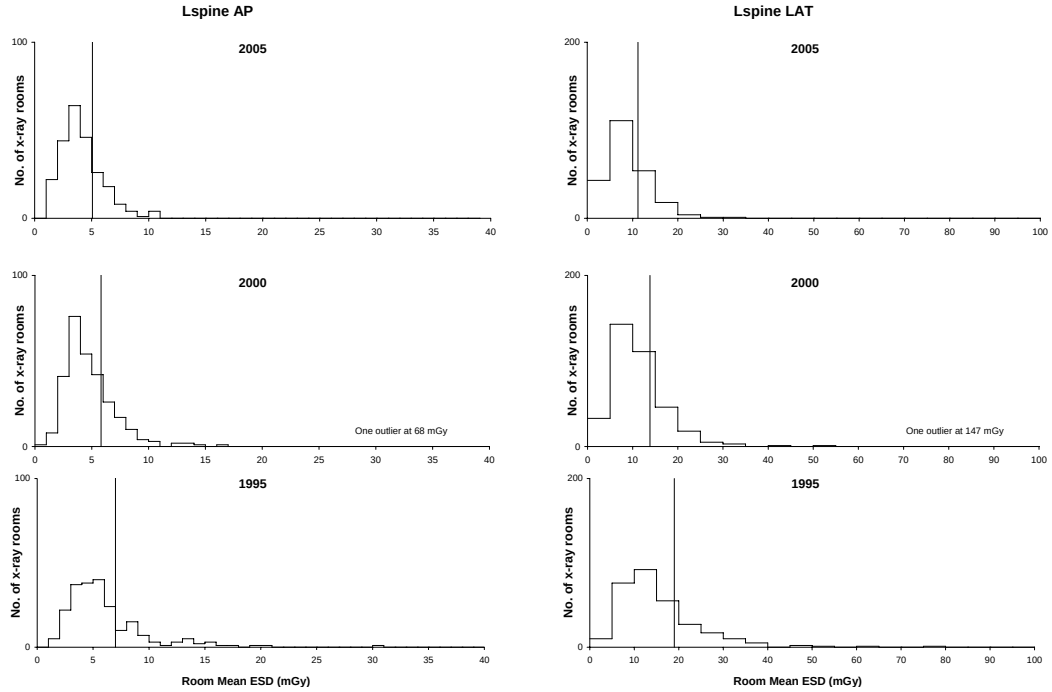


Figure 15 Comparison of room mean ESD distributions for all 3 reviews



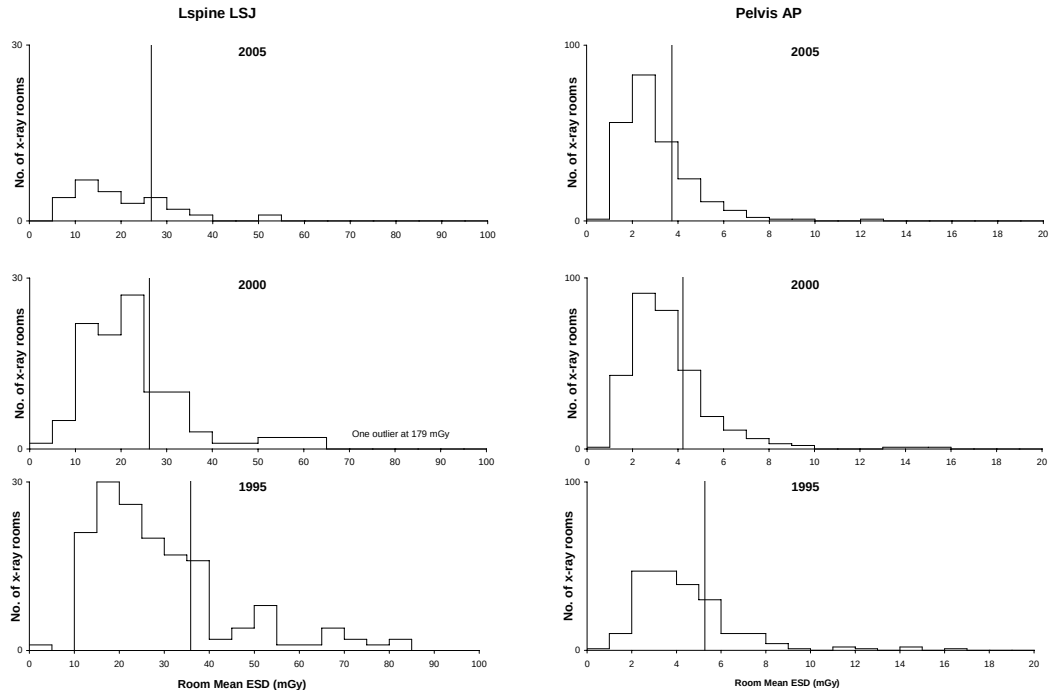
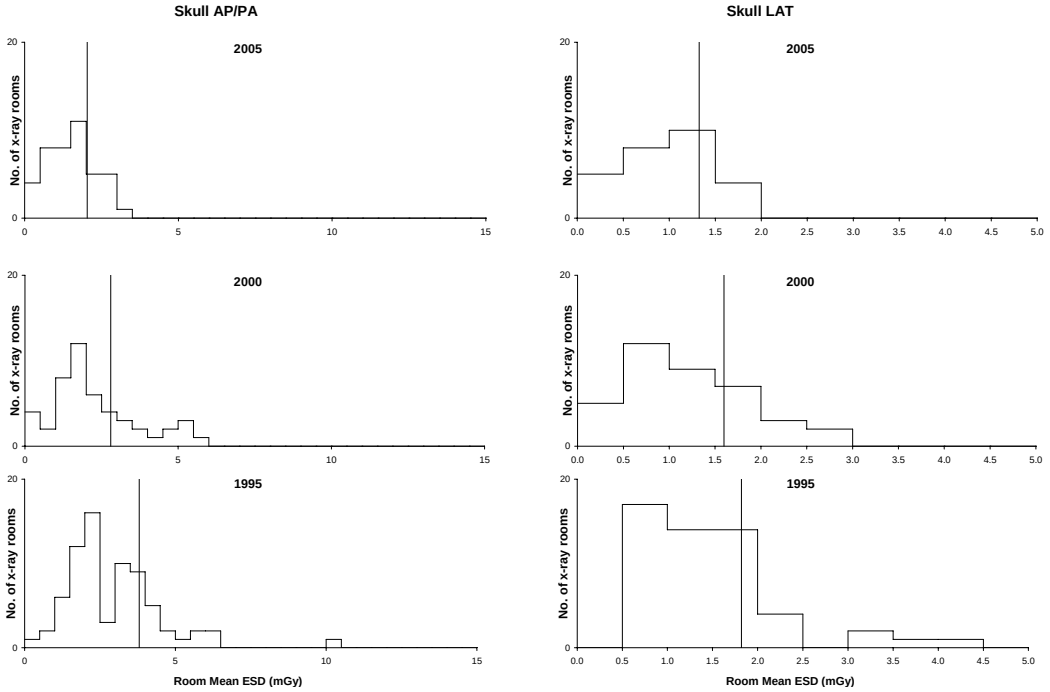


Figure 15 (continued)



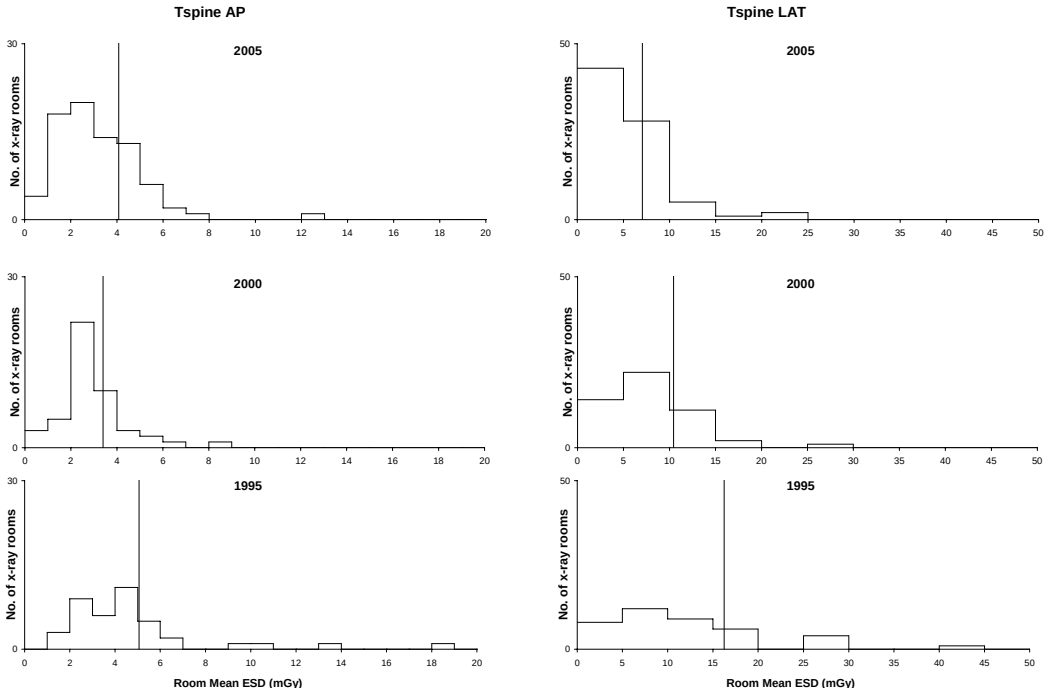


Figure 15 (continued)

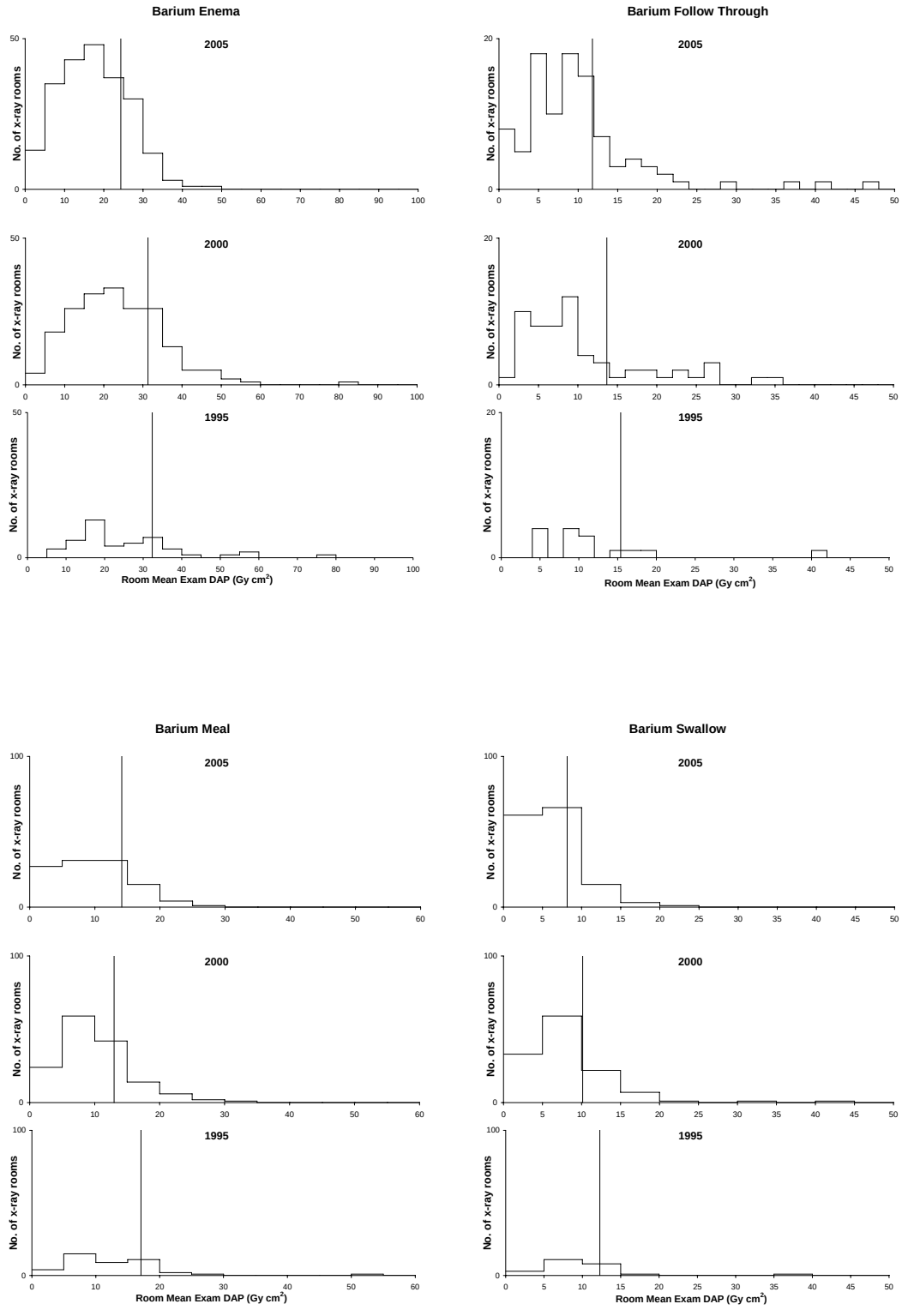


Figure 16 Comparison of room mean DAP distributions for all 3 reviews

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. 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 proposed national diagnostic reference levels for formal adoption by the Department of Health in compliance with IR(ME)R, as discussed in the Introduction.

6.2.1 Adult patients

Third quartile values of doses for typical adult patients from the current 2005 review, rounded to no more than 2 significant figures, are compared with earlier values in Table 28. 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 20 years since the survey of the mid-1980s. The current third quartiles are on average 16% lower than the third quartiles for the 2000 review.

For all types of radiograph the 2005 third quartile values of both ESD and DAP are lower than or equal to the 2000 values apart from thoracic spine AP where the ESD is about 14% higher (in line with the increased mean dose discussed in section 6.1). For all types of diagnostic examination and interventional procedures the 2005 third quartile DAP values are lower than the 2000 values, apart from barium meals and femoral angiography which are less than 10% higher, and sialography and venography which are 25% and 40% higher respectively.

For the 2000 review, data were supplied for venography of the leg for more than 10 hospitals, 20 rooms and 100 patients. Whereas in the 2005 review (and the 1995 review) data have been supplied for unspecified venography, which may not be entirely comparable with the data on venography of the leg.

The third quartiles of fluoroscopy time were listed for 23 examinations in the 2000 review. For 14 of these examinations the third quartile values are now lower than they were in the 2000 review. For 9 examinations the third quartiles are higher than they were in the 2000 review, though in most cases only marginally.

TABLE 28 Rounded third quartile values from the current and previous reviews of national patient dose data

	Rounded third quartile values			
	Mid-1980s Survey	1995 review	2000 review	2005 review
Radiographs	ESD per radiograph (mGy)			
Abdomen AP	10	7	6	4
Chest LAT	1.5	0.7	1	0.6
Chest PA	0.3	0.2	0.2	0.15
Lumbar spine AP	10	7	6	5
Lumbar spine LAT	30	20	14	11
Lumbar spine LSJ	40	35	26	26
Pelvis AP	10	5	4	4
Skull AP/PA	5	4	3	2
Skull LAT	3	2	1.6	1.3
Thoracic spine AP	7	5	3.5	4
Thoracic spine LAT	20	16	10	7
Radiographs	DAP per radiograph (Gy cm^2)			
Abdomen AP			3	2.6
Chest PA			0.12	0.11
Lumbar spine AP			1.6	1.6
Lumbar spine LAT			3	2.5
Lumbar spine LSJ			3	2.6
Pelvis AP			3	2.1
Diagnostic examinations	DAP per examination or procedure (Gy cm^2)			
Barium enema	60	32	31	24
Barium follow through		15	14	12
Barium meal	25	17	13	14
Barium swallow		12	11	8
Coronary angiography			36	29
Femoral angiography			33	36
Hysterosalpingography			4	3
IVU	40	23	16	14
MCU			17	12
Nephrostography			13	12
Retrograde pyelography			13	8
Sialography			1.6	2
Small bowel enema			50	40
T-tube cholangiography			10	8
Venography		6	5	7
Interventional procedures				
Biliary drainage/intervention			54	50
Hickman Line			4	3
Nephrostomy			19	14
Oesophageal dilation			16	11
Pacemaker			27	11

In the current 2005 review there are data from a sufficient number of rooms to set reference doses that are reasonably representative of national practice for a larger selection of radiographs and examinations than was possible previously. On the assumption that a minimum of about 20 rooms is necessary, there are sufficient data on both ESD and DAP per radiograph to recommend reference doses in terms of both these quantities for all of the types of radiograph for which ESD reference doses were previously available. The latest set of recommended national reference doses for individual radiographs on adult patients is shown in Table 29. The number of rooms supplying data for each radiograph is also indicated in the table.

Table 29 Recommended national reference doses for individual radiographs on adult patients – 2005 review

Radiograph	ESD per radiograph (mGy)	No. of Rooms	DAP per radiograph (Gy cm^2)	No. of rooms
Abdomen AP	**4**	209	**2.6**	127
Chest LAT	**0.6**	39	**0.3**	23
Chest PA	**0.15**	311	**0.11**	210
Lumbar spine AP	**5**	237	**1.6**	118
Lumbar spine LAT	**11**	232	**2.5**	120
Lumbar spine LSJ	**26**	27	**2.6**	25
Pelvis AP	**4**	231	**2.1**	150
Skull AP/PA	**2**	42	**0.8**	20
Skull LAT	**1.3**	26	**0.5**	19
Thoracic spine AP	**4**	79	**0.9**	36
Thoracic spine LAT	**7**	79	**1.4**	27

Similarly the latest set of national reference doses for complete diagnostic examinations, in terms of both the total DAP and the total fluoroscopy time (expressed in minutes) for the examination, is shown in Table 30. The number of rooms supplying data for each examination is also indicated in the table. Reference doses can be recommended for an additional 6 types of complete examination when compared to the 2000 review, in terms of both DAP and fluoroscopy time. Water-soluble enemas and swallows have been combined with barium enemas and swallows and given the same reference doses in Table 30, since the respective DAP and fluoroscopy time values in Tables 8 and 10 are fairly similar for these examinations when performed with the two types of contrast media. It should be remembered that the data for coronary angiography relate to patients with a weight range of 75-85 kg, as discussed in section 4.3.

The latest set of national reference doses for interventional procedures, in terms of both the total DAP and the total fluoroscopy time (expressed in minutes) for the procedure, is shown in Table 31. The data for ERCP examinations shown in Tables 11 and 14 have been omitted from Table 31 because a clear distinction between purely diagnostic ERCPs and interventional ERCPs was made for only a few of the rooms supplying

data. Most of the room mean doses and fluoroscopy times relate to an unknown mixture of diagnostic and interventional ERCP procedures. More clearly specified data are required before separate reference doses can be set for diagnostic and interventional ERCP procedures. The biliary drainage and biliary intervention procedures described separately in Tables 11 and 14, have been combined in Table 31, since the respective DAP and fluoroscopy time values are fairly similar for these examinations. Biliary interventions and PTCAs have a higher reference dose (50 Gy cm^2) than all other examinations, whereas insertion of a Hickman line is a fairly simple procedure and the reference dose is comparatively low.

The national reference doses in Tables 29, 30 and 31 are, in general, slightly lower than or equal to the corresponding reference doses for the 2000 review. The exceptions are the ESD reference dose for thoracic spine AP, the DAP/examination for barium meals, femoral angiography, sialography and venography, and the fluoroscopy times for femoral angiography, nephrostography and sialography.

Table 30 Recommended national reference doses for diagnostic examinations on adult patients – 2005 review

Examination	DAP per exam (Gy cm^2)	No. of Rooms	Fluoroscopy time per exam (mins)	No. of Rooms
Barium (or water soluble) enema	**24**	269	**2.8**	233
Barium follow through	**12**	97	**2.2**	90
Barium meal	**14**	104	**2.7**	99
Barium meal & swallow	**11**	75	**2.2**	75
Barium (or water soluble) swallow	**9**	173	**2.3**	159
Coronary angiography	**29**	110	**4.5**	101
Femoral angiography	**36**	52	**5.5**	14
Fistulography	**13**	22	**3.8**	20
Hysterosalpingography	**3**	71	**1**	68
IVU	**14**	35	**-**	-
MCU	**12**	28	**1.9**	28
Nephrostography	**12**	35	**4.8**	34
Sialography	**2**	20	**1.7**	20
Sinography	**9**	39	**2.1**	39
Small bowel enema	**40**	37	**9.2**	34
T-tube cholangiography	**8**	37	**1.9**	37
Venography	**7**	27	**2.2**	26

Table 31 Recommended national reference doses for interventional procedures on adult patients – 2005 review

Interventional procedure	DAP per exam (Gy cm^2)	No. of Rooms	Fluoroscopy time per exam (mins)	No. of Rooms
Biliary drainage/intervention	**50**	39	**15**	38
Facet joint injection	**5**	23	**1.8**	20
Hickman line	**3**	47	**1.4**	43
Nephrostomy	**14**	30	**5.1**	28
Oesophageal dilation	**11**	22	**2.8**	22
Oesophageal stent	**25**	24	**5.9**	22
Pacemaker	**11**	45	**8.2**	45
PTCA (single stent)	**50**	28	**13**	26

6.2.2 Paediatric patients

As discussed in section 4.4 and shown in Table 17, 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 32.

Table 32 Recommended national reference doses for complete examinations on paediatric patients – 2005 review

Examination	Standard age (y)	DAP per examination (Gy cm^2)	No. of rooms
MCU	**0**	**0.3**	53
	1	**0.7 (0.8)**	59
	5	**0.8 (0.8)**	58
	10	**1.5**	44
	15	**2.5**	30
Barium meal	**0**	**0.4**	16
	1	**1.1 (1.2)**	25
	5	**1.3 (1.2)**	20
	10	**2.4**	22
	15	**6.4**	25
Barium swallow	**0**	**0.4**	26
	1	**1.2 (1.3)**	40
	5	**1.3 (1.3)**	36
	10	**2.9**	41
	15	**3.5**	40

As mentioned in section 4.4, there are only small differences between the rounded third quartile values of the doses for the 1 year old and 5 year old standard-sized patient, for all three examinations. Conversely, the mean values of the doses adjusted to the standard newborn baby size are about a factor of three lower than those for the 1 year old and 5 year old standard sizes; and those for the 10 year old standard size are about a factor of two higher. In view of their numerical similarity, it would appear to be unnecessary to set different reference doses for the 1 year old and 5 year old standard-sized patients and so, it is suggested that the same reference dose be applied to both. The recommended value is shown in brackets in Table 32.

It might be considered that 15 year old children are, on average, so close in size to adults that their doses will be similar and there is no need to provide size-corrected reference doses for children of this age. However, there are wide variations in growth rate in teenage children and age is an even less reliable indicator of size than for younger children. A size-specific reference dose for a 'standard 15 year old patient' should therefore be of considerable value. Moreover the 2005 review indicates that doses to 15 year olds for MCUs, barium meals, and barium swallows are lower (by about a factor of three on average) than those to adults. Separate reference doses for 15 year olds and adults would therefore appear to be necessary.

The national reference doses in Table 32 are, in general, slightly lower than or equal to the reference doses for the 2000 review. The only exception to this is a barium swallow for a ten year old, which is now slightly higher. It may be noted that these national reference doses are higher by a factor of 4 to 10 than the local DRLs in use at the Great Ormond Street Hospital for Sick Children (Hiorns, 2006). Although paediatric data from that hospital were supplied for this review, the information in Tables 17 and 32 does not reflect the low doses at Great Ormond Street because information on patient size was not available from that hospital.

6.2.3 Dental radiography

Reference doses for dental radiography have previously been presented by Napier (1999) based on a survey of over 6000 intra-oral x-ray sets and nearly 400 panoramic x-ray sets by the NRPB Dental X-ray Protection Service between 1995 and 1998. The national reference doses for dental radiography recommended by Napier were 4 mGy PED for adult intra-oral radiography, and 65 mGy mm DWP for adult panoramic radiography. Using Napier's results, IPEM Report 88 gives guidance on DRLs for dental radiology (IPEM, 2004) and IPEM Report 91 bases its remedial levels for patient doses in dental radiography on the same national reference doses (IPEM, 2005).

Recommended national reference doses for dental radiography have not previously been included in the reviews of the National Patient Dose Database, but are presented for the first time in this review. They are shown in Table 33, and are based on the rounded third quartiles of the dose distributions reported in section 4.5.

Table 33 Recommended national reference doses for dental radiography – 2005 review

Radiograph	PED per radiograph (mGy)	No. of x-ray sets
Intra-oral (adult)	**2.3**	6170
Intra-oral (child)	**1.5**	253
DWP per radiograph (mGy mm**)**		
Panoramic (adult & child)	**60**	2175
DAP per radiograph (mGy cm^2**)**		
Panoramic (adult & child)	**82**	1910

Separate national reference doses for adults and children are recommended for intra-oral radiographs. The new adult reference dose is about 40% lower than the 1999 value, probably due to the use of faster film-screen and digital systems.

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. The national reference doses for panoramic dental radiographs shown in Table 33 are expressed in terms of both DWP and DAP, and apply to both adults and children. There are advantages in expressing the reference dose for panoramic radiography in terms of DAP rather than DWP. It is more consistent with the approach adopted for medical x-ray examinations, and is more closely related to patient dose, since the DAP measured at the post-patient collimator (in the absence of the patient) is, to a first approximation, the same as the DAP measured at the patient's entrance surface. DAP values can be derived from the DXPS data, since the height as well as the width of the x-ray beam is measured in the DXPS postal service. DAP is consequently likely to become the preferred patient dose quantity for panoramic dental radiography in the future. The new reference doses for panoramic dental radiography are only about 10% lower than the 1999 reference doses.

7 CONCLUSIONS

This review of the data added to the National Patient Dose Database during the period January 2001 to February 2006 has shown further reductions in patient doses in the UK since the previous review which covered the 5 years up to the end of the year 2000.

A considerably larger number of dose measurements for medical x-ray examinations and interventional procedures have been analysed this time (about 288,000) than in the 2000 review (about 180,000). The data have been contributed by 316 hospitals of all sizes from all over the UK. Patient dose distributions have been presented for more than 40 different types of procedure on adult patients, and for 3 types of medical x-ray examination on children. National reference doses, based on rounded third quartile values of these dose distributions, have been recommended and are expressed in terms of entrance surface dose, dose-area product or fluoroscopy time (for medical procedures). 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.

In addition, for the first time in this series of reviews, an analysis of the dose distributions for dental x-ray examinations has been presented. This was based on dose measurements on a total of over 8,000 dental x-ray sets. For dental x-ray examinations, national reference doses have been expressed in terms of patient entrance dose for intra-oral radiographs, and dose-width product and dose-area product for panoramic radiographs.

The current reference doses are on average about 16% lower than the reference doses for the 2000 review, and have more than halved over the last 20 years. 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 country 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 opportunities for improvement.

For the next review of the National Patient Dose Database, we shall want to receive plenty of data on doses from digital imaging equipment.

For the next review, it would be helpful to receive doses for paediatric radiographs together with information on the size of the patient (both the height and weight, or the thickness of the body part being x-rayed). This would enable us to recommend reference doses for common radiographs taken of children, such as abdomen AP, chest AP/PA, pelvis AP, skull AP and skull LAT.

It would be helpful to receive doses for adult patients for ERCPs which are either purely diagnostic or interventional. For coronary angioplasties, information on the number of artery dilations and the number of stents fitted would allow the setting of reference doses for procedures of different complexity. For other angioplasties, and embolisations, information on the anatomical location in which they are carried out might enable reference doses to be suggested for these specific procedures.

The national reference doses recommended in this review are complementary to those given for computed tomography in NRPB-W67 (Shrimpton, 2005).

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.

M Bowers, L Bridge, J Carfoot, T Cayton-Smith, CL Chapple, R Corbett, R Corrigall, J Crossman, A Davis, M Dixon, M Dunn, F England, SC Evans, I Fife, R Fong, J George, D Gordon, A Gulson, M Hill, M Hiorns, P Hollaway, J Horrocks, A Jefferies, B Johnson, P Jones, S Knapp, H Langston, S Lowther, CJ Martin, A Miller, R Mooney, N Moore, G Morrison, R Nicholson, J O'Neil, E Paisley, S Parkinson, M Pryor, I Roberts, J Roberts, A Sandison, L Sawyer, A Shaw, S Smith, S Spencer, D Stretton, W Thomas, A Walker, B Walmsley.

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

9 REFERENCES

Bernardi G et al (2000). Clinical and technical determinants of the complexity of percutaneous transluminal coronary angioplasty procedures: analysis in relation to radiation exposure parameters. *Catheter Cardiovasc Interv*. 51(1), 1-9.

British Dental Association (2006) www.bda.org

Compagnone G et al (2006). Comparison of radiation doses to patients undergoing standard radiographic examinations with conventional screen-film radiography, computed radiography and direct digital radiography. *Br J Radiol*, 79, 899-904.

Department of Health (2007) http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_074067

Department of Health (2005) www.performance.doh.gov.uk

Department of Health (2000) The Ionising Radiation (Medical Exposure) Regulations 2000 (together with notes on good practice). www.doh.gov.uk/irmer.htm

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. Leeds, HPA-RPD-022.

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. Chilton, NRPB-R289.

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

Hart D, Hillier MC and Wall BF (2002). Doses to patients from medical x-ray examinations in the UK – 2000 review. Chilton, NRPB – W14.

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.

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.

Informa Healthcare (2003). Directory of hospitals and trusts 2003/2004. Seventeenth edition.

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

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

McParland BJ (1998). A study of patient radiation doses in interventional radiological procedures. *Br J Radiol*, 71, 175-185.

Napier I (1999). Reference doses for dental radiography. *British Dental Journal* 186, 392-96.

Padovani R et al (2001). Patient dose related to the complexity of interventional cardiology procedures. *Radiat Prot Dosimetry* 94(1-2), 189-92.

Peterzol A et al (2005). Reference levels in PTCA as a function of procedure complexity. *Radiat Prot Dosimetry* 117(1-3), 54-8.

Rapp-Bernhardt U, et al (2003). Flat panel x-ray detector based on amorphous silicon versus asymmetric screen-film system. *Radiology* 227, 484-492.

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. Chilton, NRPB-R200.

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

Tanner RJ, Wall BF, Shrimpton PC, Hart D and Bungay DR (2000). Frequency of medical and dental x-ray examinations in the UK – 1997/98. Chilton, NRPB-R320.

APPENDIX A

Participating Hospitals

HOSPITAL NAME	DOMAIN	TOWN	COUNTRY
Accrington Victoria Community Hospital	N	Accrington	E
Addenbrooke's Hospital	N	Cambridge	E
Alexandra Hospital	P	Cheadle	E
Alexandra Hospital	P	Manchester	E
Alton Community Hospital	N	Alton	E
Altrincham General Hospital	N	Altrincham	E
Antrim Area Hospital	N	Antrim	N
Armagh Community Hospital	N	Armagh	N
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
Barry Hospital	N	Barry	W
Belfast City Hospital	N	Belfast	N
Belvoir Park Hospital	N	Belfast	N
Berwick Infirmary	N	Berwick	E
Birmingham Dental Hospital	N	Birmingham	E
Birmingham Heartlands Hospital	N	Birmingham	E
Bishop Auckland General Hospital	N	Bishop Auckland	E
Blackburn Royal Infirmary	N	Blackburn	E
Bognor Regis War Memorial Hospital	N	Bognor Regis	E
Bolton Radiology	P	Bolton	E
Bo'ness Health Centre	N	Bo'ness	S
Booth Hall Children's Hospital	N	Manchester	E
Borders General Hospital	N	Melrose	S
Braid Hospital	N	Ballymena	N
Bridgnorth & S.Shropshire Infirmary	N	Bridgnorth	E
Bronglais General Hospital	N	Aberystwyth	W
Bucknall Hospital	N	Stoke	E
Burnley General Hospital	N	Burnley	E
Caerphilly District Miner's Hospital	N	Caerphilly	W
Cambridge Lea BUPA Hospital	P	Cambridge	E
Cambridge Military Hospital	N	Aldershot	E
Campbeltown Hospital	N	Campbeltown	S
Cannock Chase Hospital	N	Cannock	E
Cardigan & District Memorial Hospital	N	Cardigan	W

Carrickfergus Hospital	N	Carrickfergus	N
Castle Douglas Hospital	N	Castle Douglas	S
Castle Hill Hospital	N	Cottingham	E
Caterham Dene Hospital	N	Caterham on the Hill	E
Causeway Hospital	N	Coleraine	N
Central Out-Patients Department	N	Stoke	E
Chailey Heritage Hospital	N	Lewes	E
Chase Community Hospital	N	Bordon	E
Cheltenham General Hospital	N	Cheltenham	E
Chesterfield & North Derbyshire Royal Hospital	N	Chesterfield	E
Chippenham Community Hospital	N	Chippenham	E
Chorley & District Hospital	N	Chorley	E
Christie Hospital	N	Withington	E
City Hospital	N	Birmingham	E
Clydebank Health Centre	N	Clydebank	S
Coatbridge Health Centre	N	Coatbridge	S
Coathill Hospital	N	Coatbridge	S
Conquest Hospital	N	St. Leonards on Sea	E
Corby Community Hospital	N	Corby	E
Crawley Hospital	N	Crawley	E
Crosshouse Hospital	N	Kilmarnock	S
Cumberland Infirmary	N	Carlisle	E
Cumbernauld Central Health Centre	N	Cumbernauld	S
Dalriada Hospital	N	Ballycastle	N
Darlington Memorial Hospital	N	Darlington	E
Devizes Community Hospital	N	Devizes	E
Dorking Community Hospital	N	Dorking	E
Dr Patton & Partners' Radiology Practice	P	Manchester	E
Dr S Gupta Radiology Practice	P	Manchester	E
Dr W St C Forbes Radiology Practice	P	Manchester	E
Drumchapel Hospital	N	Glasgow	S
Dumbarton Health Centre	N	Dumbarton	S
Dumfries & Galloway Royal Infirmary	N	Dumfries	S
Dunaros Hospital	N	Aros	S
Dunoon General Hospital	N	Dunoon	S
East Ayrshire Community Hospital	N	Cumnock	S
East Surrey Hospital	N	Redhill	E
Eastbourne District General Hospital	N	Eastbourne	E
Edenbridge and District War Memorial Hospital	N	Tunbridge	E
Erne Hospital	N	Enniskillen	N
Falkirk & District Royal Infirmary	N	Falkirk	S
Falmouth Hospital	N	Falmouth	E
Farnham Community Hospital	N	Farnham	E
Fleet and District Hospital	N	Aldershot	E
Foscote Private Hospital	P	Banbury	E
Freeman Hospital	N	Newcastle-upon-Tyne	E
Frimley Park Hospital	N	Camberley	E

Furness General Hospital	N	Barrow in Furness	E
Garrick Hospital	N	Stranraer	S
Gartnavel General Hospital	N	Glasgow	S
Glasgow Royal Infirmary	N	Glasgow	S
Glenfield Hospital	N	Leicester	E
Golden Jubilee National Hospital	N	Glasgow	S
Good Hope District General Hospital	N	Sutton Coldfield	E
Gorbals Health Centre	N	Glasgow	S
Gosport War Memorial Hospital	N	Gosport	E
Great Ormond Street Hospital for Sick Childen	N	London	E
Guy's Hospital	N	London	E
Hairmyres Hospital	N	East Kilbride	S
Hammerwich Hospital	N	Walsall	E
Harefield Hospital	N	Uxbridge	E
Hartshill Orthopaedic Hospital	N	Stoke	E
Haslemere & District Community Hospital	N	Haslemere	E
Havant Health Centre	N	Havant	E
Hawick Cottage Hospital	N	Hawick	S
Haywood Centre	N	Stoke	E
Heart Hospital, The	N	London	E
Heathfield Clinic	N	Ayr	S
Hereford County Hospital	N	Hereford	E
Hereford General Hospital	N	Hereford	E
Hexham General Hospital	N	Hexham	E
Hinchingbrooke Hospital	N	Huntingdon	E
Hope Hospital	N	Salford	E
Hove Polyclinic	N	Hove	E
Hull Royal Infirmary	N	Hull	E
Hurstwood Park Neurological Centre	N	Haywards Heath	E
Inverclyde Royal Hospital	N	Greenock	S
Ipswich Hospital	N	Ipswich	E
Isebrook Hospital	N	Wellingborough	E
Islay Hospital	N	Bowmore	S
James Cook University Hospital	N	Middlesbrough	E
James Paget Hospital	N	Great Yarmouth	E
Kent & Sussex Hospital	N	Tunbridge Wells	E
Kent County Opthalmic & Aural Hospital	N	Maidstone	E
Kettering General Hospital	N	Kettering	E
Kilsyth Health Centre	N	Kilsyth	S
King's Cross Hospital	N	Dundee	S
Kirkcudbright Hospital	N	Kirkcudbright	S
Lady Margaret Hospital	N	Isle of Cumbrae	S
Lagan Valley Hospital	N	Lisburn	N
Lancaster Moor Hospital	N	Lancaster	E
Leek Moorlands Hospital	N	Leek	E
Leicester General Hospital	N	Leicester	E
Leicester Royal Infirmary	N	Leicester	E
Leigh Infirmary	N	Leigh	E

Lincoln County Hospital	N	Lincoln	E
London Chest Hospital	N	London	E
Lorn & Islands District General Hospital	N	Oban	S
Ludlow Hospital	N	Ludlow	E
Maidstone Hospital & Community Unit	N	Maidstone	E
Malmesbury Hospital	N	Malmesbury	E
Manchester Royal Infirmary	N	Manchester	E
Mater Infirmorum Hospital	N	Belfast	N
Melksham Community Hospital	N	Melksham	E
Mid-Argyll Hospital	N	Lochgilphead	S
Middlesbrough General Hospital	N	Middlesbrough	E
Mid-Ulster Hospital	N	Magherafelt	N
Milford Hospital	N	Godalming	E
Milton Keynes General Hospital	N	Milton Keynes	E
Monklands Hospital	N	Airdrie	S
Montrose Links Health Centre	N	Montrose	S
Morriston Hospital	N	Swansea	W
Moseley Hall Hospital	N	Birmingham	E
Moyle Hospital	N	Larne	N
Musgrave Park Hospital	N	Belfast	N
Neath General Hospital	N	Neath	W
Newcastle General Hospital	N	Newcastle-upon-Tyne	E
Newmarket General Hospital	N	Newmarket	E
Newton Stewart Health Centre	N	Newton Stewart	S
Ninewells Hospital	N	Dundee	S
Norfolk & Norwich Hospital	N	Norwich	E
North Hampshire Hospital	N	Basingstoke	E
North Tyneside District General Hospital	N	North Shields	E
Northampton General Hospital	N	Northampton	E
Northern General Hospital	N	Sheffield	E
Nuneaton Private Hospital	P	Nuneaton	E
Orchard Hospital	P	Newport (IOW)	E
Papworth Hospital	N	Cambridge	E
Paulton Memorial Hospital	N	Bristol	E
Pembury Hospital	N	Tunbridge Wells	E
Penrice Hospital	N	St. Austell	E
Perth Royal Infirmary	N	Perth	S
Peterborough District Hospital	N	Peterborough	E
Petersfield Community Hospital	N	Petersfield	E
Port Glasgow Health Centre	N	Port Glasgow	S
Prince Philip Hospital	N	Llanelli	W
Princess of Wales Hospital	N	Bridgend	W
Princess of Wales Hospital	N	Ely	E
Princess Royal Hospital	N	Haywards Heath	E
Princess Royal Hospital	N	Hull	E
Princess Royal Hospital	N	Telford	E
Princess Royal Maternity Unit	N	Glasgow	S
Queen Alexandra Hospital	N	Portsmouth	E

Queen Elizabeth Hospital	N	Gateshead	E
Queen Elizabeth Hospital	N	King's Lynn	E
Queen Elizabeth Hospital	N	Birmingham	E
Queen Victoria Hospital	N	Morecambe	E
Queens Hospital	N	Burton-on-Trent	E
Queen's Park Hospital	N	Blackburn	E
Rossendale General Hospital	N	Rossendale	E
Royal Albert Edward Infirmary	N	Wigan	E
Royal Alexandra Hospital	N	Paisley	S
Royal Alexandra Hospital for Sick Children	N	Brighton	E
Royal Berkshire Hospital	N	Reading	E
Royal Bolton Hospital	N	Bolton	E
Royal Cornwall Hospital	N	Truro	E
Royal Free Hospital	N	London	E
Royal Hallamshire Hospital	N	Sheffield	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 Preston Hospital	N	Preston	E
Royal Shrewsbury Hospital	N	Shrewsbury	E
Royal Surrey County Hospital	N	Guildford	E
Royal Sussex County Hospital	N	Brighton	E
Royal United Hospital	N	Bath	E
Royal Victoria Hospital	N	Belfast	N
Royal Victoria Infirmary	N	Newcastle-upon-Tyne	E
Sandringham Hospital	P	King's Lynn	E
Selly Oak Hospital	N	Birmingham	E
Sharoe Green Hospital	N	Preston	E
Shelton Chest Clinic	N	Stoke	E
Shepton Mallet Community Hospital	N	Shepton Mallet	E
Shettleston Health Centre	N	Glasgow	S
Shotley Bridge General Hospital	N	Shotley Bridge	E
Singleton Hospital	N	Swansea	W
Sir Robert Peel Hospital	N	Tamworth	E
South Tyneside District General Hospital	N	South Shields	E
Southern General Hospital	N	Glasgow	S
Southport & Formby District General Hospital	N	Southport	E
St. Bartholomew's Hospital	N	London	E
St. George's Hospital	N	London	E
St. Leonard's Hospital	N	Sudbury	E
St. Martin's Hospital	N	Bath	E
St. Mary's Hospital	N	London	E
St. Mary's Hospital	N	Portsmouth	E
St. Mary's Hospital for Women & Children	N	Manchester	E
St. Peter's Hospital	N	Chertsey	E
St. Richard's Hospital	N	Chichester	E
St. Thomas' Hospital	N	London	E

Stafford District General Hospital	N	Stafford	E
Stamford and Rutland Hospital	N	Stamford	E
Stepping Hill Hospital	N	Stockport	E
Stirling Royal Infirmary	N	Stirling	S
Stobhill General Hospital	N	Glasgow	S
Stoke City General /N. Staffordshire Hospital	N	Stoke	E
Stonehouse Hospital	N	Larkhall	S
Strathclyde Hospital	N	Motherwell	S
Stretford Memorial Hospital	N	Manchester	E
Sunderland Royal Hospital	N	Sunderland	E
Tameside General Hospital	N	Ashton-under-Lyne	E
Tenbury Wells General Hospital	N	Tenbury Wells	E
Thetford Cottage Hospital	N	Thetford	E
Trowbridge Community Hospital	N	Trowbridge	E
Ulster Hospital	N	Belfast	N
Ulster Independent Clinic	P	Belfast	N
University Hospital of Hartlepool	N	Hartlepool	E
University Hospital of North Durham	N	Durham	E
University Hospital of North Tees	N	Stockton on Tees	E
Vale of Leven Hospital	N	Alexandria	S
Victoria Hospital	N	Blackpool	E
Victoria Hospital	N	Frome	E
Victoria Hospital	N	Lewes	E
Victoria Hospital	N	Lichfield	E
Victoria Infirmary	N	Glasgow	S
Wansbeck General Hospital	N	Ashington	E
Warminster Community Hospital	N	Warminster	E
West Cornwall Hospital	N	Penzance	E
West Cumberland Infirmary	N	Whitehaven	E
West Suffolk Hospital	N	Bury-St-Edmunds	E
West Wales General Hospital	N	Carmarthen	W
Westbourne NHS Centre	N	Hull	E
Westbury Commmunity Hospital	N	Westbury	E
Western Infirmary (Glasgow)	N	Glasgow	S
Westmorland General Hospital	N	Kendal	E
Weybridge Hospital	N	Weybridge	E
Whiteabbey Hospital	N	Newtownabbey	N
Wishaw General Hospital	N	Wishaw	S
Withington Hospital	N	West Didsbury	E
Withybush General Hospital	N	Haverfordwest	W
Woodside Health Centre	N	Glasgow	S
Worcester Royal Infirmary	N	Worcester	E
Worthing Hospital	N	Worthing	E
Wrightington Hospital	N	Wigan	E
Wycombe General Hospital	N	High Wycombe	E
Wythenshawe Hospital	N	Manchester	E
Ystradgynlais Community Hospital	N	Swansea	W

In addition, there were 42 private hospitals 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 are 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 are 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 are 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 are 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

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

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.

Bladder pressure A catheter is passed retrogradely into the urinary bladder, which is slowly filled with contrast medium and pressures are measured.

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.

Embolisation An interventional procedure to block an artery or vein to stop bleeding, or to stop blood supply to a tumour.

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.

Feeding tube insertion using the nasogastric route.

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.

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.

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 into position.

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.

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.

PTC Percutaneous transhepatic cholangiography. 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.

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.

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.

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.

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

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.

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.

APPENDIX D

Film-screen speed classes

FILM MAKE	FILM TYPE	SCREEN MAKE	SCREEN TYPE	SPEED CLASS
Agfa	Curix Blue HCSL	Agfa	Curix Blue 800HC	700
Agfa	Curix HT1000G	Fuji	G8	400
Agfa	Curix HT1000L	Agfa	Curix Ortho Regular	400
Agfa	Curix HTL Plus	Agfa	Curix Ortho Regular	400
Agfa	Curix HTU	Agfa	Curix Ortho Regular	400
Agfa	Curix Ortho HTG	Agfa	Curix Ortho Regular	400
Agfa	Curix Ortho HTG	Kodak	Lanex Regular	400
Agfa	Curix Ortho HTL	Agfa	Curix Ortho Fast	700
Agfa	Curix Ortho HTL	Agfa	Curix Ortho Regular	400
Du Pont	Cronex 10S	Du Pont	Quanta Rapid	400
Du Pont	Cronex 10T	Du Pont	Quanta Rapid	400
Du Pont	Ultravision G	Agfa	Curix Ortho Regular	300
Du Pont	Ultravision G	Du Pont	Ultravision Rapid	400
Du Pont	Ultravision L	Du Pont	Ultravision Rapid	400
Du Pont	Ultravision L	Du Pont	Ultravision Super Rapid	800
Fuji	HR-E	Fuji	G8	400
Fuji	HRE30	Fuji	G8	400
Fuji	Super HRE30	Fuji	G8	400
Fuji	Super HRL	Fuji	G8	400
Imation	XDA+	Imation	Trimax T2	100
Imation	XLA+	Imation	Trimax T16	600
Kodak	Insight VHC	Kodak	Insight VHC	400
Kodak	T-Mat G	Kodak	Lanex Regular	400
Kodak	T-Mat L	Kodak	Lanex Medium	250
Kodak	T-Mat L	Kodak	Lanex Regular	400
Kodak	T-Mat S	Imation	Trimax T2	100
Kodak	T-Mat S	Imation	Trimax T8	400
Kodak	T-Mat S	Kodak	Lanex Fast	600
Kodak	T-Mat S	Kodak	Lanex Regular	400