UK Health Security Agency

Patient doses from radiographic and simple fluoroscopic X-ray imaging procedures in the UK

2019 review

Contents

Abstract

The UK Health Security Agency (UKHSA) and its predecessor organisations have provided national benchmarks of patient radiation dose for diagnostic radiographic and fluoroscopy imaging procedures in UK hospitals and clinics since 1986, by undertaking national dose surveys.

The 2019 national general patient diagnostic dose survey is the fifth UK survey and provides insight into Dose Area Product (DAP) received by adult patients from plain radiographic exams and simple fluoroscopic imaging procedures between 2017 and 2019. It reviews collected dose index data, and other information, in order to propose National Diagnostic Reference Levels (NDRLs). UK legislation requires NHS and other healthcare organisations to compare their local dose values with NDRLs, where available.

Dose Area Product data for over 4,700 system exam data sets, based on approximately 1.4 million DAP values, from 475 radiography systems and 239 fluoroscopy systems, was received. Data was requested for 18 named plain radiography single projections, 11 plain radiography examinations, 9 simple fluoroscopy examinations and 17 simple interventional radiology procedures. Participants also sent data for other exams which they considered important. The data was collected using Excel questionnaires, voluntarily submitted from 169 hospitals and clinics distributed throughout the UK.

The survey also accepted fluoroscopy time and cumulative air kerma at the IEC reference point data (an entrance surface dose surrogate) from participants if they wished to provide it, but insufficient data was received to propose any NDRL values for these dose indices.

This survey proposes NDRLs based on the distribution of system medians, rather than on system means as in previous surveys. The impact of this change of method, assessed by analysis of the 2019 data, was typically of the order of 20% for plain radiography single projections and examinations. The parameters based on the distribution of system means were also used for an approximate comparison with dose index values from previous surveys.

Updated NDRL DAP values for adults are proposed for 18 plain radiography single projections, 11 plain radiography examinations, 5 simple fluoroscopy examinations and 8 interventional radiology procedures. These are based on the third quartile (75th percentile) of the distribution of system median DAP values.

The proposed NDRL values are lower than current NDRLs for most exams with a wide variation in decrease according to exam. The average decrease for plain radiography single projections was 30%, with generally larger decreases for more complex examinations and procedures. The reduced NDRL values indicate a general decrease in patient exposure, even taking into account that the values are influenced by the change to using system median values, and by other changes in data collection methodology.

The general decrease in patient exposures is considered to be due to a combination of advances in available technologies, high standards of radiographic technique, the increased importance placed on dose optimisation, and availability of national dose survey data.

Introduction

In the UK, for the last 40 years (1), periodic reviews have been conducted of patient dose index values from medical and dental diagnostic imaging examinations for a range of ionising radiation imaging modalities by the UK Health Security Agency (UKHSA) and its predecessor organisations (the National Radiological Protection Board (NRPB) (1970 to March 2005), the Health Protection Agency (HPA) (April 2005 to March 2013) and Public Health England (PHE) (April 2013 to October 2021)).

Since 1989 (2,3,4) these reviews have been used to recommend National Reference Doses (NRD) for the UK. From the 2000 review to the 2011 CT review, NRDs were formally adopted as National Diagnostic Reference Levels (NDRL) for plain radiography, fluoroscopy, interventional radiology, dental radiography, and CT (5 to 10). Subsequent reviews have directly proposed UK NDRLs for dental radiography and CT (11,12,13).

These reviews also provide important information towards tracking national trends in population exposure to medical diagnostic imaging (14,15,16).

UK NDRLs are national dose index benchmarks against which diagnostic imaging facilities can assess their establishment's local Diagnostic Reference Level (DRL) values, as recommended by both International Commission on Radiological Protection (ICRP) (17) and International Atomic Energy Agency (IAEA) (18), and as required by the Ionising Radiation (Medical Exposures) Regulations (IR(ME)R) 2017,2018 as amended) (19,20). Guidance on the use of NDRLs for assessing local Diagnostic Reference Levels (DRL) is provided by IPEM and other professional bodies (21,22,23). Information from NDRL surveys also assists with estimating the contribution of diagnostic medical exposures to population dose.

The 2019 review is a successor to the series of reviews established in 1995 to collate dose index parameter data from patient exposures for common radiographic and fluoroscopic X-ray examinations in hospitals and clinics throughout the UK. These reviews were based on data collected for each of the 5-year periods preceding 1995, 2000, 2005 and 2010 (4 to 7). As well as adult exposure data, paediatric data was collected for all 4 surveys, with sufficient data obtained by the 2000, 2005 and 2010 surveys to recommend national reference doses for all 5 paediatric weight groups for micturating cystourethrography (MCU), barium meal and barium swallow exams. Dental radiography doses were also included in the 2005 and 2010 reviews (6,7).

This review did not consider dental exposures as dental NDRLs were updated in 2020, when the recommendations of the 2017 dental survey (11) were approved by the UKHSA Working Party on National Patient Dose Surveys and NDRLs (24). Nor did the survey consider paediatric diagnostic doses as separate paediatric audits were planned (25).

Historically NDRLs were set using the means of dose index values from radiography systems for general X-ray and fluoroscopy examinations. Now, the median values are used, in accordance with the recommendations of ICRP publication 135 'Diagnostic Reference Levels in Medical Imaging' (17). ICRP publication 135 recommends the use of NDRL values based on median values as these are generally more representative of typical practice, being less influenced in a sample of reasonable size by outliers when compared with sample means. Therefore, the NDRL values proposed by this report are the rounded third quartile values for an exam's median dose index distribution from a nationally representative sample of radiography systems. The effect of basing NDRLs on system median values rather than system mean values is presented and discussed in the Results and Discussion chapters and in Appendix H. From information provided by survey participants, it is evident that some teams have already moved to setting DRLs using median values.

Guidance on conducting national dose surveys for the purpose of establishing and maintaining NDRLs is given in National Diagnostic Reference Levels (NDRLs): process to generate, adopt and maintain (24). This guidance applies to all such surveys including UKHSA surveys, such as that reported in this review. In the UK, the Department of Health and Social Care (DHSC) has delegated the formal adoption of proposed NDRL values to UKHSA. UKHSA performs this duty through the work of the UKHSA Working Party on National Patient Dose Surveys and NDRLs which independently reviews proposed NDRLs as presented in formal reports or peer reviewed papers.

Methods

The principal purpose of this report of the 2019 general survey is to propose NDRL values for the UK for plain radiography projections and examinations, simple fluoroscopy examinations and some simple interventional radiology (IR) procedures. These are given as Dose Area Product (DAP) values, for adult patients, and are based on data provided by UK hospitals and clinics from diagnostic imaging principally performed between 1 January 2017 and 31 December 2019. A summary is given of the supporting data received by the survey, together with information on the percentile distributions of DAP and fluoroscopy time for a range of exams. The findings of this review are discussed and compared with those of previous UK reviews.

The survey was designed following consultation with the UKHSA Working Party (WP), colleagues and other stakeholders, and learning from similar recent surveys. It should be noted that the survey took place under UKHSA's predecessor organisation Public Health England (PHE) and so that title is used in most documents associated with the survey.

Participants were encouraged to liaise with other colleagues in their local organisation whose work is associated with plain radiography, fluoroscopy and interventional radiology procedures when collecting information for the survey to assist with gaining the most comprehensive response.

The 2019 review requested its data in a different manner to the previous reviews. Instead of participants providing data to UKHSA on a continuous basis, which was then reviewed for each 5-year period, diagnostic imaging data from a specific time period was requested, first for a limited pilot survey in 2018 and then for the main survey in 2019. The survey also provided a list of preferred projections, examinations, and procedures, rather than the choice being left entirely to the sender. This is in line with the approach used by other recent surveys, such as the UK CT survey (12). Participants were free to submit data for other exams, especially high dose or high frequency exams that they considered important.

There are some changes to the survey terminology used in this report. Most noticeably the term 'radiography system' is now used instead of 'radiography room' or 'X-ray room'; the term 'radiography system' meaning a specific X-ray generator and its detector(s). When an issue specific to fluoroscopy is being discussed, the term 'fluoroscopy system' is used. One reason for this change is the increased focus in this review on imaging performed by mobile systems, which frequently do not reside in a specific location. In this survey, the term 'plain screen radiography' has been shortened to 'plain radiography', as it was considered unlikely that the hospitals and clinics participating in this survey would still be using film-screen radiography systems.

Technological trends for the past decade influenced both the survey's design and the data received. The choice of dose indices, for which data was requested, was reviewed for this survey, and it was considered appropriate to cease setting NDRLs for Entrance Surface Dose (ESD).

Developments in other imaging modalities have influenced the use of plain radiography, and hence the data received for this survey. The growing availability and use of Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) scanners means that these modalities are the practical options for imaging more complex injuries, rather than performing multiple projection radiography examinations. A CT scan is the default method for imaging most head injuries as advised by the National Institute for Health and Care Excellence (NICE) (26,27). Alternatively, advances in ultrasound and increasing availability of MRI scanners mean that soft tissue imaging is now more frequently done by these modalities rather than plain radiography.

Technological trends have also influenced the collection and recording of diagnostic imaging data in the last decade, with increasing use and development of dose management systems and other data collection software platforms. A summary of the diagnostic imaging data recording methods used by participants is given in the Results chapter.

To encourage participation in the survey, the College of Radiographers (CoR) CPD certificate of Endorsement was obtained so that radiographers who took part in the survey could claim CPD credits (28).

Demographic information

Hospital and clinic representation

To monitor the range of facilities represented in the survey, information on the hospitals and clinics that participated was collated from reliable public sources. Hospitals and clinics were typified by sector (for example NHS England, NHS Wales, commercial, independent non-profit including Community Interest Companies (CIC), and so on), geographical location, bed capacity and population of the primary care catchment area.

Achieving nationally representative samples

To ensure the proposed NDRLs were representative of UK wide practice, the survey needed to acquire data from sufficient radiography systems from a broad range of healthcare organisations, located in diverse geographical regions and across the UK devolved nations.

As in previous reviews, proposed NDRL and typical values were expected to be based on data sets from at least 20 radiography or fluoroscopy systems, and from 10 or more hospitals.

This survey also required that exam data was submitted by at least 3 different survey contributing organisations. This is because medical physics groups often oversee radiology services for entire NHS trusts, boards, or organisations, and, in some cases, more than one. Without this requirement it might be possible for one survey participant to provide most of the data received for a specific exam. The number of survey participants, hospital regions, hospital organisations, hospitals and systems were collated and reviewed for each exam.

Patient and system sample size

Patient doses depend on patient size, especially the depth of tissue that the irradiating beam passes through, therefore any reference value needs to take this into account. IR(ME)R 2017, 2018 (as amended) (19,20) defines diagnostic reference levels as:

"… dose levels in medical radiodiagnostic or interventional radiology practices, or, in the case of radio-pharmaceuticals, levels of activity, for typical examinations for groups of standard-sized individuals or standard phantoms for broadly defined types of equipment."

ICRP publication 135 (17) states that DRLs should be based on data from 'standard size patients', which is taken to be the size typical of the patient population undergoing imaging. ICRP publication 135 stresses that some standardisation of patient size is especially important if the number of patients from whom data is collected is limited. Conversely, data based on larger patient numbers is treated as being representative of the patient population.

Patient weight is the most frequently used surrogate for patient size. ICRP publication 135 recommends some standardisation of weight for adult patients for data samples based on less than 50 people, and preferably for samples of less than 100 (17). It is suggested that a mean weight should be chosen that is close to the average weight in the population being considered. Previous UK general surveys encouraged all submissions to include weight data but only made it essential for system dose index data based on less than 10 patients.

Weight was standardised for most exams by using data from patients in a weight range of 50 to 90kg to obtain a mean weight of 70±5kg. For cardiac exams a higher mean weight of 80±5kg was accepted. The amount of weight data received by successive general surveys decreased from 70% of all patient DAP measurements in the 2000 survey (4) to 36% for the 2010 survey (7).

The mean adult weight (16 years and older) in England at the time of the 2019 survey was 79kg (29), (85kg for men, and 72kg for women). However, this may not be representative of the population which undergoes diagnostic imaging.

Consultation for the 2019 survey indicated that most radiography departments do not measure or record patient weight, and that many would not be able to participate in the survey if the provision of weight data was made essential. Therefore, the survey classified patient weight as 'very interesting' data, rather than as 'essential' data, whilst encouraging its inclusion.

Increased automation of data collection meant it was anticipated that larger samples of patient dose index values could be provided for most exams. Therefore, the preferred minimum patient sample size without weight data was increased from 10 to 20 patients for each exam on a given system, while stressing patient sample sizes should ideally be of at least 20 patients and preferably many more.

Survey data collection

The above discussion underlines the desire to receive survey data from as many participants, and for as many radiography systems, as possible. To this end, the survey aimed to be flexible in the data it accepted and the form in which it was provided.

A suite of 4 main Excel workbooks were provided for survey data entry, 2 for plain radiography, and 2 for combined simple fluoroscopy exams and simple IR procedures, with an appropriate workbook to be completed for each individual radiography or fluoroscopy system.

Two types of workbook were provided for each modality to give participants the option of entering system exam data either as examination dose summary data sets (for example if exam data had already been collated for the participant's own local dose audit), or as data sets of individual patients' doses and supporting data for each exam.

Bespoke versions of the plain radiography Excel workbooks were provided for recording Skeletal Survey data to enable information on up to 20 projections to be recorded.

The survey Excel workbooks can be found at National Diagnostic Reference Levels.

Guidance on use of the Excel workbooks is given on the front worksheet of each workbook. Information is requested for topics which include the hospital, data collection, and the radiology or fluoroscopy system used.

The data entry fields on worksheets are colour coded to assist in prioritising data entry, that is, to mark it as 'essential' data, 'very useful information', or 'supporting information'. Supporting information is non-essential information that is still of interest, should the participant wish to provide it. The essential data fields have been kept to a minimum and positioned to make providing the minimum necessary data as simple as possible.

Participants were requested to send quality assured data for diagnostic imaging performed between January 2017 and December 2019 for radiography systems still in current use. Where multiple data sets from different years for the same exam on the same system were provided, only the most recent data set from which the system median value could be determined was included in the analysis.

System exam summary data

The essential information for system exam summary data entries was each exam's name, a unique exam ID from the participant in case of queries, sample median and mean DAP values, DAP dose units and the patient sample size.

Patient record samples

For information provided as patient record samples, a named worksheet was provided for each of the requested examinations on which the data could be entered, ensuring that it included no information that could be used to identify individual patients.

For each patient record there are 3 essential data fields:

- DAP from the complete examination
- DAP units, unless these are the system's default dose units as entered on the system information worksheet
- a unique ID, containing no patient identifiers, for entry identification in the case of a query

Worksheets for plain radiography single projections have information fields for that individual projection. For plain radiography examinations, provision was made for entering data for up to 6 component projections, should the participant wish to do so. No projection fields were designated as essential.

For both types of data entry, data fields were also provided for entering similar information on fluoroscopy time and cumulative air kerma at the IEC reference point for fluoroscopy exposures, and for patient and exposure parameters.

While it was preferred that participants used the PHE Excel workbooks for sending their data to the survey, participants could use other means if they so wished, though preferably by electronic means, such as their own Excel form or similar style spreadsheets, or as comma separated values (csv) files.

The pilot survey, with invited participants, was conducted from 30 May to 31 August 2018, to test the survey design and to provide initial data that was used to test, refine and quality assure the data base and survey data recording methods. The main survey was launched on 17 April 2019, with data collection officially closed on 31 December 2019. Submission extensions were granted to participants who requested them.

Dose index selection

Following consultation with the UKHSA WP, and other stakeholders, it was agreed that DAP would be the essential dose index for all types of examination considered in this review and for the establishment of NDRLs. Other dose index parameters that some choose to use for some examinations are discussed below.

Historically in the UK, Entrance Surface Dose (ESD) was the main dose index used for recommending NDRLs for plain radiography single projections. However, consultation with stakeholders indicated that the recording of ESD to monitor patient exposure has significantly declined in the UK, and it was decided not to request ESD values for the 2019 survey.

For fluoroscopy and IR exams, the survey also requested Fluoroscopy Time and cumulative air kerma (CAK) at the IEC reference point (C_{dose}) (30) (sometimes called 'air kerma', 'dose at reference point' or 'skin dose') as well as DAP. However, the main data fields for these 2-dose indices were designated as 'very useful' information, rather than 'essential' (Table 1).

Table 1. Dose Index parameters requested by the General patient diagnostic dose survey

Parameter	Plain radiography	Fluoroscopy	Interventional radiology
Dose area product	Essential	Essential	Essential
Entrance surface dose	Not requested	Not requested	Not requested
Fluoroscopy time	Not appropriate	Very useful	Very useful
Cumulative air kerma at the IEC reference point	Not appropriate	Very useful	Very useful

Previous surveys have acquired fluoroscopy time data, and the reviews have recommended associated NDRL values. In this survey fluoroscopy time was designated as 'very useful', rather than as 'essential', because, while some continuity with previous surveys was desired, stakeholders had indicated that the use of fluoroscopy time to assess patient diagnostic dose had significantly decreased.

The survey provided an opportunity to gauge the usefulness of Cumulative air kerma at the IEC reference point, however stakeholders suggested it would not be routinely recorded and therefore it was designated as 'very useful' rather than 'essential'.

Exam selection

Exams requested for the surveys focused on those that are higher dose and frequently performed. Exams for which NDRL values had previously been recommended were considered, and the UKHSA WP and other stakeholders were consulted. The complete list of requested examinations is given in Appendix B, together with non-requested examinations for which significant data was received.

Information on the frequency with which plain radiography, fluoroscopy and IR exams were performed was obtained from the 2016 data of the NHS England Digital 'Diagnostic Imaging Dataset' (DID) (31), this being the most recent year for which fully approved data was available for initial survey development. The DID aims to record all diagnostic imaging performed at the request of NHS England. Each diagnostic image and IR procedure is identified by their National Interim Clinical Imaging Procedure (NICIP) (32) or Systematized Nomenclature of Medicine – Clinical Terms (SNOMED-CT) (33) code or both.

Plain radiography

For plain radiography, the 2016 NICIP and SNOMED-CT codes used by DID generally just indicate the body part or organ being imaged, with no information on the specific projection or examination performed or diagnostic objectives. Therefore, the requested plain radiography single projections and examinations were based on stakeholder consultation, and on projections and examinations included in previous reviews.

Requested plain radiography single projections and complete plain radiography examinations included those for the cervical, thoracic, and lumbar spine, and for the shoulder, chest, abdomen, hip, and pelvis (see Appendix B). Feedback from the WP and stakeholders resulted in the inclusion of frequently performed extremities (hand, foot, and knee projections), and 2 requested specialist radiography examinations: skeletal survey and leg length measurement (single leg). Later discussions determined that the survey should have requested leg length measurement (both legs), as single leg measurements are rare, but this was determined too late to alter the requested exam.

Following NICE designating CT as the appropriate imaging modality for most head trauma (26,27), plain radiography skull X-rays are far less frequently performed, and so were not requested for this survey. The slightly more commonly performed facial bone examination was included instead.

Fluoroscopy and IR

This review of fluoroscopy and IR focused on simple, commonly performed, exams. Complex fluoroscopy exams and IR procedures were outside the scope of this survey as these require more specialised studies and data analysis.

Requested fluoroscopy examinations included cerebral and femoral angiography, barium and water soluble contrast (WSC) exams and hysterosalpingography. Requested IR procedures included instillation of single and dual chamber pacemakers, of ureteric and oesophageal stents, and for inserting of a range of tubes and catheters. See Appendix B for a full list.

Fewer fluoroscopy and IR procedures are performed in the UK annually than for plain radiography or CT. This makes obtaining acceptable sample sizes for exams from these modalities far more of a challenge.

Mobile radiography and fluoroscopy

Consultation with the UKHSA WP and other stakeholders identified a need to benchmark exams performed using mobile radiography and fluoroscopy systems to aid with their optimisation. A specific request was made to include chest AP projections imaged using mobile X-ray systems for comparison with chest AP projections made using non-mobile systems. Generic mobile fluoroscopy exams with NICIP and SNOMED-CT coding titles based just on body areas were considered as the basis for NDRL values, but found to be too general, given the large range of potential diagnostic objectives for imaging each region. Therefore, data for 4 mobile imaging exams performed for specific diagnostic indicators was requested, mobile imaging of abdomen for laparoscopic cholecystectomy, of cervical spine for laminectomy, of lumbar spine for laminectomy and of orthopaedic hip pinning (see Appendix B).

Participants' data collection methods

The survey asked a range of questions about the methods used to collect and retrieve data for the survey to gauge the range of approaches used, and possibly inform data collection in future surveys. Participants' responses are summarised in the Results chapter.

Information was requested on the selection and rejection criteria used for including or excluding survey data.

Participants were asked if the survey dose index values and their units had been manually entered at any point, and, if so, whether the transcribed dose index data was quality assured. Radiology Information Systems (RIS) dose index data is usually input manually. This fulfils a practical purpose, providing a record that patient doses are monitored as required under Regulation 6, Schedule 2 (e) of IR(ME)R 2017,2018 (as amended) (19,20). However, manual dose entry can give rise to transcription errors, sometimes at a significant level (34). Some centres rectify this issue by quality assuring their manually transcribed dose index records. Others employ software platforms, for example dose management systems (DMS), that automate the transfer of dose index information, avoiding the need for manual transcription.

Radiography and fluoroscopy systems

Information was requested on makes, models and types of radiography and fluoroscopy systems, and to identify mobile systems, to have a record of the range of equipment represented in the survey.

Detectors

Makes, models and types of detectors used by the systems were requested.

Both radiography and fluoroscopy systems use direct digital detectors. In this report, to avoid any confusion about the modality being discussed, radiography direct digital detectors are termed digital detectors (DR), and fluoroscopy direct digital detectors will be termed flat panel detectors (FPD).

While most radiography systems use DR detectors, the indirect digital detectors, computed radiography (CR) detectors, do remain in use, with a few systems using both detector types.

For fluoroscopy, flat panel detectors are the usual current detector technology. However, systems employing indirect digital detectors, image intensifier (II) detectors, are still of practical use and widely used, especially with respect to mobile systems.

DAP calibration factors

Systems' DAP values are calibrated to be traceable to national standards. One method is to compare, for a given set of exposure conditions, the systems' DAP measurement with those of an independent DAP meter whose readings are traceable to national standards. Alternatively, traceable DAP values are obtained by combining the field size in centimetre squared (cm^2) of exposures with their air kerma measurements in gray (Gy), again made using instruments traceable to national standards. The survey asked if the DAP values provided for that radiography system had been corrected by the DAP calibration correction factor derived from the ratio of the traceable DAP values and the system's DAP values. As optional data the DAP calibration correction factor for the system was also requested, together with questions for fluoroscopy systems on if the calibration was performed above or below the table and if corrections were made for attenuation caused by the table.

Quality assurance of data

Excel workbooks received for the survey were logged and underwent both manual and automated quality control processes to ensure the validity of data. Checks were also performed to identify and exclude any data from patients aged under 16 years old or whose weight was given as 30kg or less, indicating that the patient was either a child or an adult whose low weight, possibly due to their medical condition, excluded them from this survey. Survey participants were consulted on any apparent inconsistences, or missing essential data, and records updated accordingly.

Data analysis also underwent separate quality assurance, using test data sets.

The automated processing of the workbooks also extracted the survey data and prepared it for numerical analysis. All values for each dose index were converted to be in consistent units, gray centimetre squared ($Gy.cm^2$) for Dose Area Product (DAP), seconds (s) for fluoroscopy time, and milligray (mGy) for cumulative air kerma at the IEC reference point.

Data analysis

The proposed NDRL and typical values for an exam are respectively based on the third quartile (75th percentile) and median of that exam's quality assured system median dose index values.

Exams' median dose index values were directly available for systems for which data was sent as system data summaries. For systems for which patient record data sets were sent, the data analysis program processed the received data sets to obtain their median values and a range of other statistical values such as mean and quartile values.

Having established complete data sets of system median dose index values for each named examination, outlying median values were reviewed and, in a few cases, excluded from further analysis following consultations with the survey participant.

Where data was provided for other numerical parameters, such as patient weight, this data was analysed using the same process.

The analysis was run with a range of different conditions imposed on the data sets used. The primary conditions were that system data sets used in an analysis should have patient sample sizes of at least 5,10, 20 or 30 patients. Further analyses were performed which included additional data sets of 5 or more patients for which weight data was provided which showed a mean patient weight in the standard mean range of 65 to 75kg or, for cardiac exams, a mean range of 75 to 85kg (7). Separate analyses were performed according to the systems' detector type.

The third quartile and median percentile values produced by these analyses (and other statistical measures) were compared to see the variation the range of conditions produced. This information was used in selecting which examinations had sufficiently robust data to propose as NDRLs.

The same analysis was performed for system mean dose index values (Appendix F).

Results

Survey responses were received from 43 participants, several of whom provided data on behalf of multiple trusts, health boards or organisations. People who were the primary contacts for the survey principally identified themselves as clinical scientists or medical physicists, but also included radiographers. Most participants stressed that additional colleagues from a range of professional backgrounds assisted with the survey.

Survey participation

Summary of data received

Data was received for diagnostic imaging performed on 714 radiography and fluoroscopy systems based in 169 hospitals and clinics from 54 NHS trusts, NHS boards, or other UK healthcare organisations. Appendix A lists the organisations that participated in the survey. Radiography system data was received for 475 systems based in 155 hospitals. Fluoroscopy system data from 239 systems was received from 67 hospitals. Plain radiography and fluoroscopy system data was provided by 54 hospitals, 101 hospitals sent only radiography system data, and 14 hospitals only fluoroscopy system data. The DAP data values received represent more than 1.4 million patient diagnostic studies: 1.35 million for plain radiography imaging and just under 90,000 for fluoroscopy examinations and interventional radiology procedures. Scaling Diagnostic Imaging Dataset (DID) statistics for NHS England for 2018 to 2019 financial year (35) to represent the entire UK population at the time of the survey, this represents approximately 5% of all plain radiography imaging performed annually and approximately 7.5% of annual fluoroscopy and IR imaging. As different teams quite commonly oversee plain radiography and the range of specialities that use fluoroscopy and IR, it was common for separate radiography and fluoroscopy survey responses to be received from the same organisation.

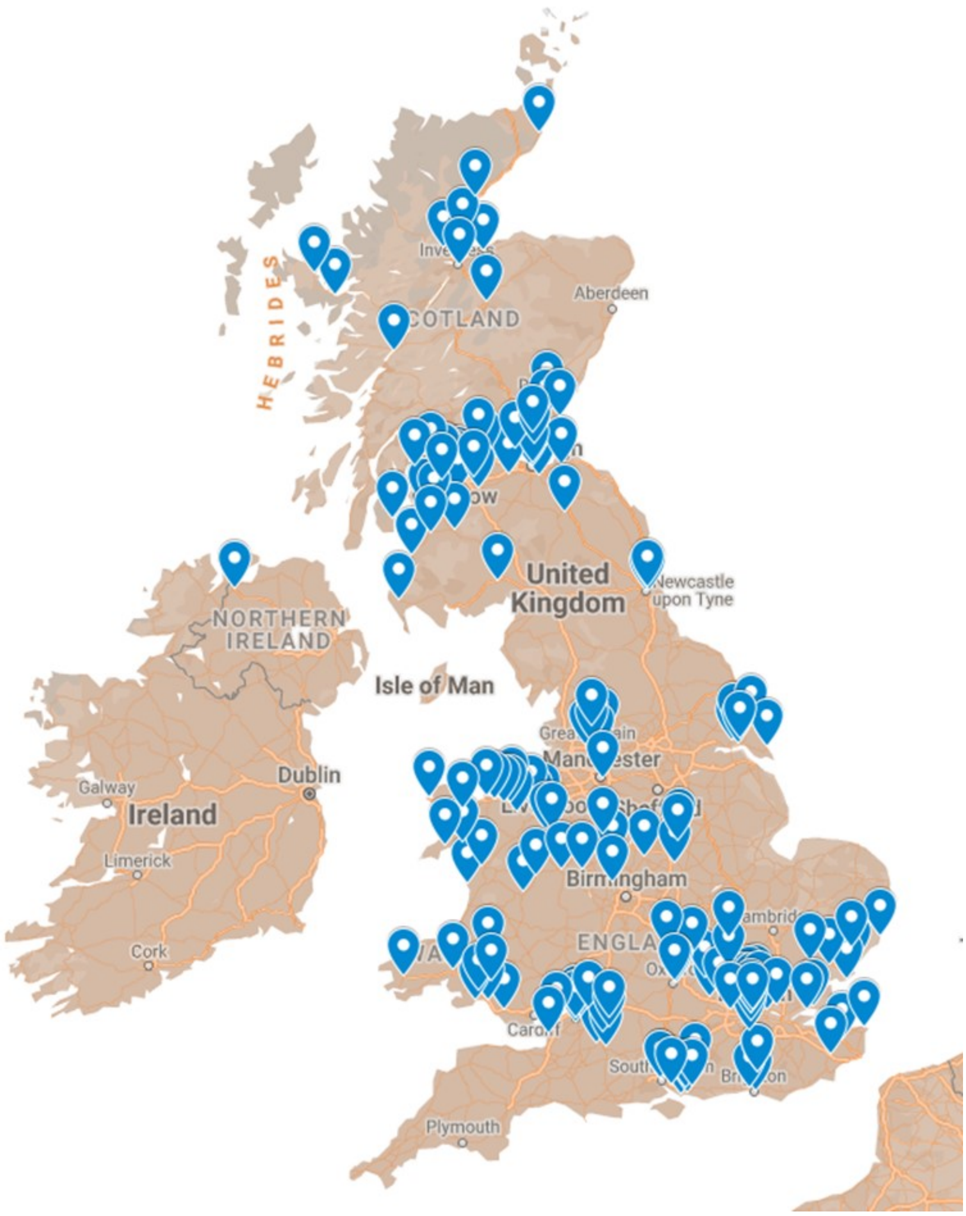
National and geographic response to survey

The geographical distribution of participating hospitals and clinics is shown in Figure 1. Physically, survey hospitals and clinics are reasonably well distributed across the UK.

All 4 of the UK nations participated in the survey, with Scotland and Wales being particularly well represented (Figure 1, Table 2). Data was received from one of the Northern Ireland health and social care trusts. For England, 12 of the 14 NHS England 'region local office' areas that existed in 2019 (36) were represented in the survey. However, the representation per region ranged from one hospital at one NHS trust to 20 hospitals based at 9 NHS trusts.

Table 2 shows survey participation in terms of participating NHS trusts (England and Northern Ireland) and NHS health boards (Scotland and Wales) from the UK nations, compared to the boards or trusts in each nation which are significantly involved in diagnostic imaging of adults (for example, mental health and ambulance trusts are excluded).

Figure 1. Geographic distribution of participating hospitals



Map Data ©2022 Google

The number of NHS England trusts that performed diagnostic imaging of adults has been taken as the number from which the NHS Digital Diagnostic Imaging Dataset (DID) requested plain radiography or fluoroscopy data in the financial year 2018 to 2019 (35), excluding specialist paediatric care trusts. The trusts and boards for Northern Ireland, Scotland and Wales were stated on their NHS national websites.

Table 2. Survey participation of UK NHS trusts and health boards, and of independent organisations

Organisation	Total number of trusts or boards	Number of trusts or boards in survey	Survey trusts or boards as % of total	Survey data by trusts or boards:		
				Radio-graphy systems	Fluoro-scopy systems	Both types of system
NHS England	148	35	24%	11	8	16
NHS Northern Ireland	5	1	20%	0	0	1
NHS Scotland	15	11	73%	1	0	10
NHS Wales	8	5	63%	4	0	1
Independent	Not known	2		1	1	0

Table 3 shows how the participating radiography and fluoroscopy systems are distributed between the 4 UK nations. Approximately 60% of survey radiography and fluoroscopy systems are based in England, about 30% in Scotland, just under 10% in Wales, and less than 1% in Northern Ireland.

Table 3. UK distribution of participating hospitals and radiography and fluoroscopy systems

	All systems		Plain radiography systems		Fluoroscopy systems	
UK nation	**Hospitals**	**Systems**	**Hospitals**	**Systems**	**Hospitals**	**Systems**
England	89	424	76	260	39	164
Northern Ireland	1	4	1	2	1	2
Scotland	49	222	49	156	23	66
Wales	27	61	27	55	3	6
Independent	3	3	2	2	1	1
Total	169	714	155	475	67	239

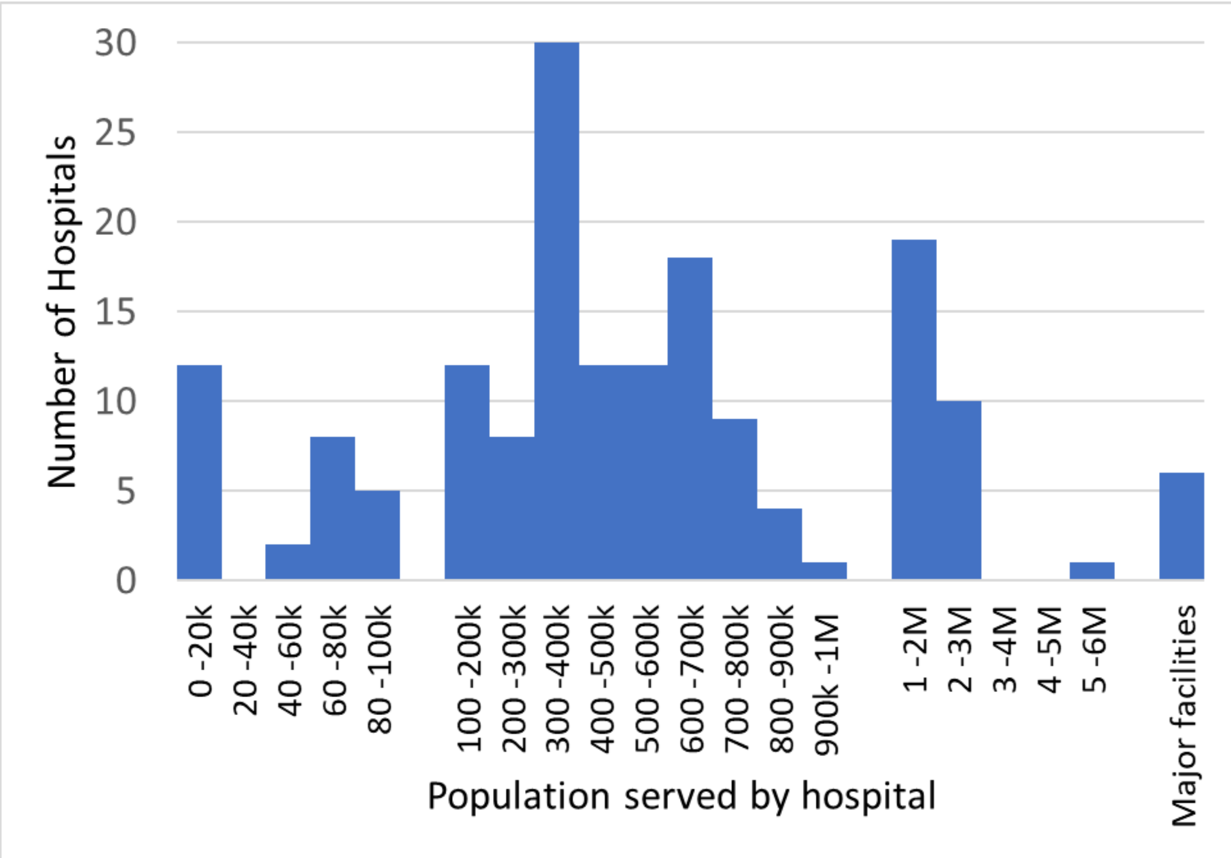
Independent healthcare providers and their hospitals and clinics are clearly underrepresented in this survey (3 hospitals and clinics, and 3 systems).

Several NHS trusts and boards included data from privately run clinics contracted to provide diagnostic imaging services for NHS patients. These independent clinics were usually community interest companies (CIC) whose primary purpose is to provide services to the NHS and have been treated as part of the contracting NHS organisation for the purposes of this survey.

Range of catchment populations and bed capacities of survey hospitals

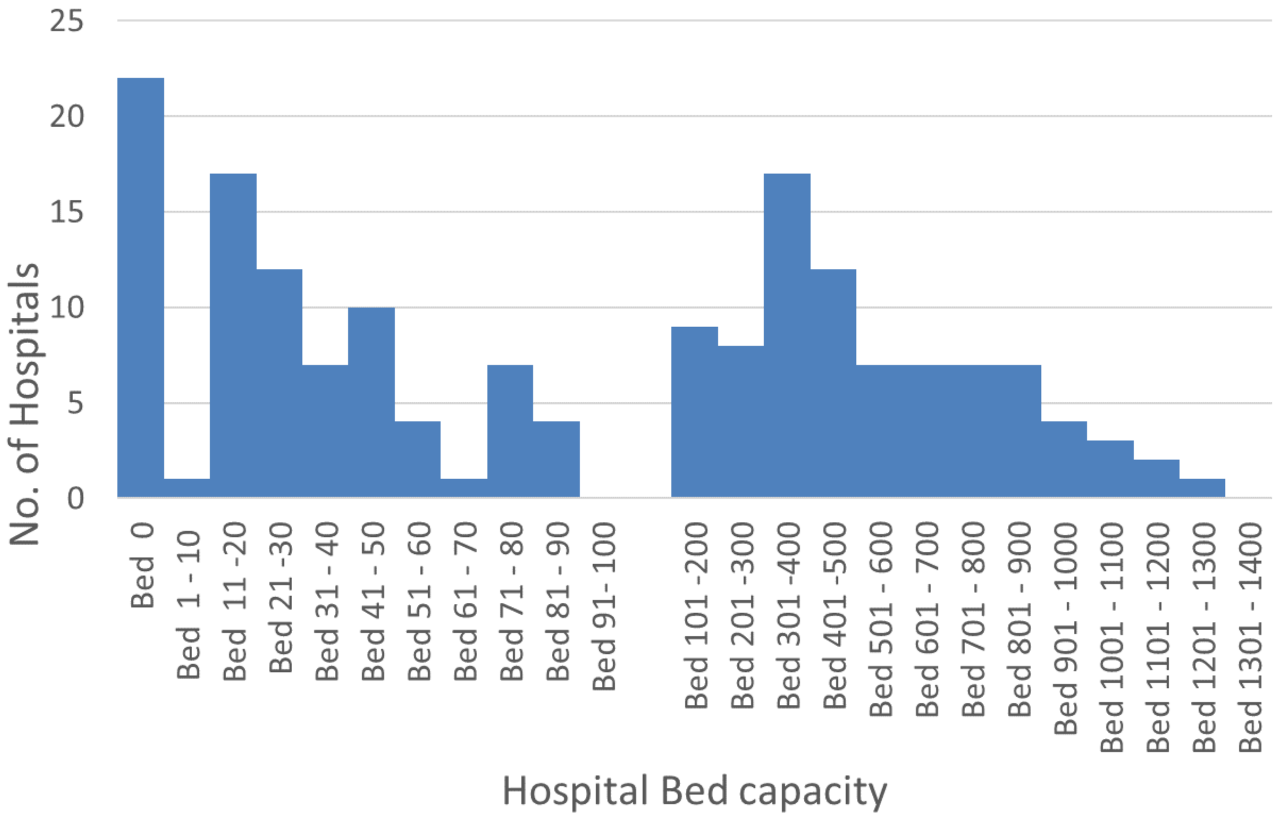
The diversity of participating hospitals was reviewed by comparing their estimated catchment populations and their bed capacities. Participants did not provide this information. Catchment population estimates were collated from a range of sources including official NHS websites, CQC reports, and online geographical data resources (37,38,39). Figure 2 shows that hospitals participating in the survey had catchment populations ranging from a few thousand to several millions. Centres that are known centres of excellence were treated as major facilities, serving a large fraction of the UK population.

Figure 2. Range of catchment populations for participating hospitals



Information on the bed capacities of participating hospitals and clinics was gathered from Binley's 2016 spring directory of NHS management (40), confirmed and supplemented by 2017 to 2019 information published on NHS Scotland (41) and NHS Wales (42) web sites, CQC reports, trust and health board websites and other credible public sources.

Figure 3. Bed capacity of participating hospitals and clinics



Note that this bed capacity data is reflective of the survey data collection period of 2017 to 2019. This was prior to the COVID-19 pandemic and is not affected by the increase in hospital bed capacities which that triggered.

Figure 3 shows that hospitals and clinics participating in the survey range from day clinics with no bed capacity to local hospitals with several tens of patient beds to large regional and national hospitals with bed capacities for hundreds of patients, and, in a few cases, more than a thousand.

The diversity of hospitals and clinics that participated in the survey, of varied geographical locations, range of catchment populations and bed capacities, and different hospital and healthcare environments, show that the survey received radiography systems data from a broad range of establishments encompassing a wide range of UK diagnostic imaging practice.

Data collection methods used by participants

All but 2 participants used the PHE Excel workbooks to provide the survey with their data. The data from the other 2 participants was transferred into that format to enable it to go through the automated process of QA checks, processing and uploading into the survey database.

A total of 729 PHE Excel workbooks were received, representing 714 radiography and fluoroscopy systems. Multiple workbooks were received for a few radiography systems for which data had been submitted in both the ‘system summary’ and ‘patient data’ formats, usually for different exams. For other systems, separate workbooks were sent for data from different calendar years, typically when it had transitioned to using new diagnostic imaging data collection software. Skeleton Survey data was sent in their own bespoke Excel workbooks to accommodate the large number of projections required for this examination.

In total, 490 workbooks were received for the 475 participating radiography systems, 324 providing data in the ‘system summary’ format and 166 in the ‘patient entry’ format.

For the 239 participating fluoroscopy systems 239 workbooks were received: 185 provided data in the ‘system summary’ format and 54 in the ‘patient entry’ data format. Data for one system was later withdrawn from the survey at the survey participant’s suggestion, following the withdrawal of that fluoroscopy system from use.

The one essential query on how survey data was collected asked if data was collected retrospectively or prospectively. By system, over 91% of received data was collected retrospectively (retrieved from existing diagnostic imaging records), 6% prospectively (recorded for the survey as the diagnostic imaging occurred) with 2% using both types of data collection, and less than 1% of systems providing no response to this query.

Most participants also replied to the other questions on survey data collection, despite these questions being voluntary. Information was received for over 96% of systems and from over 98% of hospitals. Table 4 sets out the reported use of various diagnostic imaging data collection software platforms, together with other means used to record data for the survey. Software platforms used included Radiology Information Systems (RIS), Picture Archiving and Communications Systems (PACS), General Patient Management Systems (GPMS), and Dose Management Systems (DMS). Diagnostic imaging data was typically collected using 2 or more of these options, for example PACS, RIS, and DMS systems. Some participants also chose to use their own bespoke electronic or paper forms for assembling information for the survey. Note that Table 4 reflects that a system’s survey data may have been gathered using more than one software platform.

Table 4. Sources and methods used for survey data collection

System	**All systems**		**Plain radiography systems**		**Fluoroscopy systems**	
Method	**By hospital**	**By system**	**By hospital**	**By system**	**By hospital**	**By system**
Response given	165	685	155	475	62	211
RIS	108	449	94	290	47	159
DMS	48	155	43	116	14	39
PACS	27	79	26	65	6	14
GPMS and others	7	30	6	18	4	12
Own electronic form	12	30	9	26	3	4
Own paper form	34	81	34	69	6	12

RIS was the system most used for retrieving survey data (65% of responding systems and hospitals), with DMS used to gather survey data for approximately 22% of systems and 28% of hospitals. Survey participants used DMS, RIS and other software platforms from a range of providers. Discussions were held with several DMS providers about creating a specific report format that could be directly imported into the PHE dose survey templates. This generated interest, however OpenRem was the only provider able to provide this facility within the required timescale.

While 20% of hospitals stated that paper forms were used in some capacity, they were used for only 12% of systems, most frequently for prospective data collection and, in some cases, in conjunction with other means of data collection.

Responses were received for 60% of systems (70% of hospitals) to the query on manual transcription of dose index values. Of those that replied, manual transcription was used at some point for about 75% of systems, the other 25% using entirely automated transcription.

Eighty per cent of hospitals replied to the enquiry "Was the survey data used elsewhere, such as in a local survey?" All but one of the replying hospitals stated that the data had been collected for another survey, or would, or was likely to be, used for another survey.

Data selection and exclusion criteria

There was a lower rate of response to queries on how data was selected for the survey. Responses were received from approximately 33% of hospitals providing fluoroscopy system data and from 40% of hospitals providing radiography system data. Supplementary information was provided through the comment boxes. While these are low response rates, the replies do give a flavour of the range of participants' approaches to the survey.

On how data was selected for the survey, most of those that replied stated that their approach was to submit a set number of results from adult patients for each exam, usually the first such entries in a given time interval, such as a calendar year. A smaller group used a method of randomly selecting suitable patient entries from the chosen time interval. There is no information of the methods used by the majority of hospitals that did not reply to this question and who may have used alternative approaches.

A small number of replies said that their data was based on exposures of adult patients who satisfied chosen physical requirements. The physical requirement was usually being of standard physique or the patient's weight being between 50kg and 90kg. In most of this small number of cases, data was collected prospectively, making it practical to check the patients' physique or weight. However, there were some cases where the data had been collected retrospectively and weight, or physique, information had been recorded.

Asked if individual patient entries were excluded on the grounds of inadequate image quality roughly 10% of all hospitals said data from such images was excluded, 25% said that image quality was not considered, and 65% of hospitals gave no response. Only about 14% of hospitals said that data would be excluded on the grounds of being from atypical or problematic examinations.

On data excluded on statistical grounds, 20% of all hospitals stated that patient entries identified as plain radiography statistical outliers were excluded, but only 10% of hospitals reported doing the same for fluoroscopy data. However, in preparing data for submission 13% of all hospitals trimmed the top and bottom 5% of patient dose index values from exam data sets. More hospitals (20% for fluoroscopy, 30% for plain radiography) reported through comment field entries that they trimmed the top and bottom of their patient dose index distributions by a percentage of their own choice. Note that the median of the distribution will be unchanged by this practice, but that it will reduce the distribution's interquartile range.

About half of hospitals that provided plain radiography data and a third of hospitals that provided fluoroscopy data responded to questions on the inclusion or exclusion of data based on individual patients' weight, BMI or physique. Therefore, most hospitals did not state if they considered patient weight when selecting survey data. The largest positive response, 23% of all hospitals, endorsed the statement that data from patients of extreme weight (low or high) was excluded. For both fluoroscopy and plain radiography, the next largest number of replies were to statements to the effect that neither patient weight, BMI nor stature had been considered when selecting data (13% of fluoroscopy system hospitals, 20% of plain radiography system hospitals). Only a couple of per cent of hospitals stated that specific patient weight or stature criteria were used in selecting or excluding data. These response rates can be compared with the actual amount of weight data received by the survey. Of the total of 4,837 exam data sets received by the survey, only 205 included weight data (4.3% of exam data sets). Alternatively, of the 1.44 million patient DAP values that contributed to the survey, supporting weight data was only provided for 9,000 (0.6% of participating patients). The query responses indicate that very few participants provided direct information on patient weight or stature, just under a quarter of respondents stated that they had taken patient weight or stature into account when selecting survey data, but that most participants probably had not.

Diagnostic imaging system information

Summary

Participants provided information on the participating radiography and fluoroscopy systems. Table 5 summarises the numbers of participating systems reported to have specific characteristics.

Responses were not received for all systems, even for essential entries. Therefore, the values for individual types of detector do not always add up to the values given for all systems. Four radiography systems used both DR and CR detectors and so are not included in the table. Additionally, the actual number of mobile fluoroscopy systems that contributed to the survey is higher than these stated values as, in a small number of cases, data from several mobile fluoroscopy systems of the same make and model was collated under the same RIS code and cannot be separated. However, for the purposes of this review they are treated as single mobile fluoroscopy systems. Therefore, the true total number of systems which the survey represents is marginally higher than that shown here.

Response to most radiography and fluoroscopy system queries was optional, and so the information gained is only indicative and may be biased in some cases.

Table 5. Summary of radiography and fluoroscopy systems from which survey data was received

Property	Radiography systems			Fluoroscopy systems		
	All systems	Digital radiography detector	Computed radiography detector	All systems	Flat panel detector	Image intensifier detector
Number of systems	475	344	119	238	137	97
Mobile systems	73	60	13	49	2	47
Built in DAP meter	322	245	75	134	90	44
Physical meter	188	118	70	61	46	15
Digital meter	70	67	1	41	23	18
AEC available [note 1]	247	177	68	Legal requirement [note 2]		
AEC not available	45	41	4	N/A	N/A	N/A
Antiscatter grid	162	134	27	179	113	66
No antiscatter grid	5	5	0	1	0	1

1. AEC: Automatic Exposure Control.

2. Regulation 15 (4)(a), Ionising Radiation (Medical Exposure) Regulations (IR(ME)R) 2017,2018 (as amended) (19,20).

The detector technologies currently in most common use are direct digital detectors, here termed Digital Radiography (DR) detectors for radiography systems and Flat Panel Detectors (FPD) for fluoroscopy systems to ensure that the modality being discussed is clear. However, indirect digital detectors are still used, with approximately 25% of participating radiography systems using Computed Radiography (CR) detectors, and about 40% of the fluoroscopy systems using Image Intensifier (II) detectors. The influence of detector type on dose is discussed in the Additional aspects section of this chapter, with further information presented in Appendix D.

In the survey, mobile systems accounted for roughly 15% of radiography systems and 20% of fluoroscopy systems, the mobile radiography systems predominantly using DR detectors (82%) and the mobile fluoroscopy systems II detectors (96%).

As all systems that participated in the survey provided DAP information, all systems evidently monitored the DAP of each patient exposure. About 64% of systems provided some information on the DAP meter used by the system. Of the systems for which information was received about two thirds were stated to use a physical DAP meter and the other third a digital DAP meter. Digital DAP meters assess DAP from exposure conditions via an algorithm contained in the system's software.

One of the few essential queries was if a DAP calibration factor, traceable to national standards, had been measured for the system and, if so, applied to the survey data. The response rate to this query was over 99%. Responses were received for 709 systems, of which 7 stated that the measurement had not been recorded, and 21 that it was not known if the factor was applied to DAP measurements. The remaining 681 systems stated that a traceable DAP calibration had been measured, with the factor applied to the system's DAP values for about 54% of those systems.

To the query for fluoroscopy systems on if DAP values had been corrected for couch attenuation, no reply was received from 60% of systems, and replies stated that no couch attenuation correction factor had been assessed for a further 30% of systems. Of the 10% of fluoroscopy systems for which it was stated that a couch attenuation factor had been assessed, half stated that it had not been applied to DAP values.

DAP calibration correction factors were provided for approximately 50% of radiography systems and 40% of fluoroscopy systems. For radiography systems the supplied calibration factors had a 5th to 95th percentile range of ± 12% and a 25th to 75th percentile range of ± 5%. For fluoroscopy systems, calibration factors had a 5th to 95th percentile range of ± 20% and a 25th to 75th percentile range of ± 8%. There was no obvious bias towards either negative or positive correction factors. There was no discernible link between the magnitude of calibration factors and whether they were applied to DAP values.

Table 6. Summary of radiography and fluoroscopy systems' stated default dose units and those used for reporting survey Dose Area Product (DAP) data

DAP units	mGy.cm²	µGy.m² or cGy.cm²	dGy.cm²	Gy.cm²	mGy.m²	cGy.m²	Gy.m²
Radiography systems							
Stated default units	11%	63%	17%	8%	1%	0.2%	-
Reporting units	7%	67%	7%	19%	-	-	-
Fluoroscopy systems							
Stated default units	13%	72%	1%	7%	5%	-	2%
Reporting units	5%	80%	2%	12%	-	-	2%

Systems' default DAP units were an essential entry for plain radiography and fluoroscopy systems. Table 6 shows that responses were dominated by use of micro-gray metres squared (µGy.m^2) and centi-gray centimetres squared (cGy.cm^2), dose units which are equivalent to each other. These units accounted for about two thirds or more of systems and were also the most used dose units for reporting survey DAP data. The remaining third of systems reported use of 6 different dose units. A few systems stated that their default dose unit was 'variable' (the system automatically selected the units used to report the dose) or were unsure as what was considered the default dose unit for that system (as opposed to the dose units which they used to report its data). A limited number of systems reported DAP information using different DAP units for different exams.

Information on the access to, and use of, Automatic Exposure Control (AEC) was provided for over 60% of radiography systems and 45% of fluoroscopy systems. For fluoroscopy systems it is a legal requirement to have an AEC system (19,20), so it was not surprising that no responses were received stating that a fluoroscopy system did not have one, but 9% of all plain radiography systems stated that they did not. Eight radiography systems reported the availability of AEC as 'not known'. The use or non-use of AEC and patient dose is discussed further in the Additional aspects section of this chapter.

The query on the availability of detector anti-scatter grids was replied to on behalf of about 40% of radiography systems and 75% of fluoroscopy systems. All but of 6 of the systems for which information was received were stated to have an anti-scatter grid. Five of the systems without an antiscatter grid were mobile DR detector radiography systems, the remaining system was a II detector fluoroscopy system designed for imaging extremities.

Information was gathered on when systems' X-ray tubes were installed or last changed, as tube output tends to vary most in new tubes and when they are about to fail. This information was requested so it could be taken into account for systems whose exam data showed evidence of a step change or seemed particularly variable around that time. No such cases were identified. X-ray tube installation dates were received for approximately a third of all systems, with a response rate of near 40% for systems using direct digital detectors, some of these being the systems' commissioning date, as opposed to about 20% for CR and II. Of those systems for which X-ray tube installation dates were provided, 72% had been installed in the 5-year period 2014 to 2019. The earliest X-ray tube installation dates received were 2007 for a FPD fluoroscopy system and 2001 for a CR radiography system.

Range of manufacturers represented in survey

Table 7 shows the information participants provided on the manufacturers of radiography and fluoroscopy systems. A broader range of manufacturers was reported for radiography systems than for fluoroscopy systems, with the top 3 manufacturers (in order), Philips Healthcare, Siemens Healthineers and Samsung Healthcare, accounting for 54% of participating radiography systems. The top 3 fluoroscopy system manufacturers (in order), Siemens Healthineers, Philips Healthcare and GE Healthcare, account for 80% of all participating fluoroscopy systems. For some systems, survey participants provided the name of the equipment supplier, rather than the manufacturer. These companies are included in Table 7.

The names of manufacturers of radiography system detectors were requested. Twelve manufacturers and suppliers were named, with Trixell Detectors, Fujifilm, Samsung Healthcare, Carestream Health and Canon Medical representing 80% of the detectors for whom this information was provided.

Some information on systems' detectors was received for 257 of the 475 participating radiography systems (54% of radiography systems), which indicated 115 systems had access to one detector, 110 to 2 detectors, 30 systems to 3 detectors, and 2 systems to 4 detectors. Almost half, 123, of the systems for which detector information was received used detectors from a manufacturer or supplier other than that named as the system manufacturer. But it was rare for systems to use detectors from more than one manufacturer.

Table 7. System manufacturer or distributor, as stated by participants

Manufacturer or supplier	Number of radiography systems in survey	Number of fluoroscopy systems in survey
AGFA HealthCare	11	1
Arcoma	2	
Canon Medical Systems Ltd (including Toshiba and DelfDI Canon)	22	6
Carestream Health	35	
Communications and Power Industries	1	
DMS Imaging	2	1
Fischer Imaging	1	
Fujifilm Healthcare	14	
GE Healthcare	39	22
Hologic		1
Konica Minolta	3	
Philips Healthcare	122	65
Samsung Healthcare	65	
Sedecal	1	
Shimadzu Corporation	24	
Siemens Healthineers	70	103
Solutions for Tomorrow	1	
Wolverson X-ray Ltd.	8	
Xograph Healthcare	10	
Ziehm Imaging		20
Stated as unknown	10	1
No entry	34	18

Patient data

Little data was received on patient characteristics. Patient age was best represented, with data received for 26% of survey patients, giving an average patient age of 62 years, as compared to 48 years for the adult English population (aged 16 or older) (43). A higher average age for adults undergoing diagnostic imaging is expected as people’s medical needs generally increase with age, but the actual value should be treated with caution as the ages of 74% of the survey's patients are unknown.

Weight data was received for only 4% of exam data sets and 0.6% of survey patients, with most survey participants using the provision of data based on larger patient sample groups to provide data representative of the patient population. For the small sample of patient weight that was received the mean patient weight was 74kg.

As weight data was available for such a small fraction of the received survey data it was decided not to use weight information when classing exam system data sets as typical of their patient populations. Instead, the criterion used was that the exam data sets from each system had a patient sample size of 30 or more. ICRP publication 135 (17) recommends a minimum patient sample size of 50 to be considered representative of standard physique. In this report a value of 30 has been chosen to maximise use of the received data while maintaining a reasonable sample size. In addition, only using system data sets of 50 or more patients would disproportionately exclude data from smaller hospitals and clinics especially for less commonly performed exams, and so impact on the diversity of the survey results.

Dose index data summary

Tables 8 and 9 show the total amount of data received for the different dose indices for different examination categories by the number of exams for which data was received, the total number of system exam data sets received, and the total number of patient dose index entries represented.

Table 8. Summary of Dose Area Product data received by survey

DAP data for the following exam groups	Exams represented	Number of exam data sets	Patient DAP entries
Plain radiography single projections	29	2,791	1,132,295
Plain radiography exams	21	910	215,749
Fluoroscopy exams	46	459	44,122
IR procedures	100	577	45,793
Total for all exam groups	196	4,737	1,437,959

Table 8 demonstrates that a significantly larger amount of patient DAP data was received for plain radiography single projections compared to either plain radiography examinations, fluoroscopy exams or interventional radiology (IR) procedures. The smaller amount of patient DAP data submitted for fluoroscopy and IR exams was for almost 3 times as many different exams as for the plain radiography data. This caused only a few fluoroscopy exams and IR procedures to receive sufficient DAP data to propose an NDRL value.

Table 9 shows how much data was received for other dose indices. The response for all of these dose indices, including for fluoroscopy time, was too low to recommend a NDRL for any individual exam. This data was useful for the survey in that it provided an indication of this data's current availability.

As a result, this report focuses on reporting exam DAP values. Some information on the received fluoroscopy time values is given to provide some continuity with fluoroscopy time values presented in previous reports (see Discussion chapter and Appendix E).

Table 9. Other dose indices data received for fluoroscopy and interventional radiology

Dose index parameter	Exams represented	Number of exam data sets	Patient dose indices entries
Fluoroscopy time	67	213	22,891
Dose area product			
– standard fluoroscopy	15	18	757
– acquisition	14	18	594
Cumulative air kerma (CAK) at the IEC reference point (C_{dose})			
– total dose from exam	17	27	2,475
– standard fluoroscopy	17	21	1,286
– acquisition	11	14	494

Plain radiography data

The plain radiography DAP data received contained information on 50 different exams, these being 29 specified single projections and 21 examinations (Table 8).

For this survey a plain radiography examination is defined as an examination that may require multiple radiography projections. This definition arose from the survey data, as data for some plain radiography examinations contained some patient studies of only a single projection and others composed of multiple projections. The chest exam is an example of this, for which many system data sets are mostly single chest PA exposures, a few single chest AP exposures, and a small fraction of examinations of 2 or more chest projections.

For plain radiography single projections, all 18 requested projections received sufficient data to propose NDRL DAP values for them. Data was received for an additional 11 projections. Unfortunately, insufficient data from too few sources was received to justify proposing NDRL values for any of them. Note that in the survey documents the lateral hip projection was wrongly named as the paediatric projection, frog leg lateral, but is named in this report as the adult hip lateral projection, hip horizontal beam lateral.

For plain radiography examinations, sufficient data was received for 9 of the 11 requested examinations to propose NDRL values. Insufficient data was received for the more specialist leg length measurement (single) and skeletal survey examinations. Data was also received for another 10 unrequested examinations. Sufficient data was received for foot and shoulder examinations to propose NDRL DAP values.

Fluoroscopy data

As stated, far less data was received for fluoroscopy and IR than for plain radiography. This was expected as far fewer exams and procedures are performed nationally.

For fluoroscopy, data was received for 46 named examinations including 7 generic mobile examinations. Sufficient data was formally received for only 3 of the 9 requested examinations to propose NDRL values, with NDRL values proposed for a further 2 examinations on the basis of supporting data from smaller system data samples and similar examinations. While, technically, sufficient data was received to propose an NDRL for generic mobile fluoroscopy imaging of the lumbar spine, discussions with the UKHSA WP concluded that the categorisation was too general, covering too broad a range of imaging requirements, for such a value to be of functional use. NDRL DAP values are proposed for 5 fluoroscopy examinations.

For IR procedures, information was received for a hundred named procedures, including the 17 requested procedures. In most cases insufficient data was received to recommend an NDRL, with 72 procedures receiving 5 or fewer system data sets, and only 15 procedures receiving 10 or more system data sets. In some cases of closely associated procedures, data was pooled to allow an NDRL DAP value to be proposed. NDRL DAP values are proposed for 8 IR procedures.

Dose area product values

Analysis of system exam DAP data for their median value distributions was performed to propose NDRL (third quartile of system median value distributions) and typical DAP values (median of system median value distributions). DAP values are reported in units of gray centimetres squared ($Gy.cm^2$).

A minimum patient sample size of 30 patients was set. The results obtained for lower minimum patient sample sizes provided useful supporting information, especially for exams for which a low number of system data set samples were received.

Table 10 (plain radiography single projections), Table 12 (plain radiography examinations), Table 14 (fluoroscopy examinations) and Table 16 (IR procedures) show the diversity of the data received for requested exams and for other exams for which the survey received data from multiple participants. For the listed exams, these tables give the number of:

- survey participants
- hospital regions represented

- NHS trusts, boards or private organisations represented
- individual hospitals and clinics
- systems
- all patients represented by all the exams' system DAP data

Note that some survey participants provided data for more than one organisation. In tables 10 and 12 the numbers of radiography systems using CR or DR detectors are given. Systems that use both CR and DR detectors are not included in this count, together with a few systems that did not give information on detector type. Tables 14 and 16 give the numbers of fluoroscopy systems using FPD detectors or II detectors. Again, a small number of systems did not provide information on detector type.

Tables 11, 13, 15 and 17 provide information on the exams' system median DAP distributions for the 4 categories of exams, including the 5th, 25th (first quartile), 50th (second quartile and median), 75th (third quartile), and 95th percentiles, and the interquartile range as an absolute value and as a percentage of the median value.

The median DAP distribution data for exams are displayed as box and whisker plots in figures 4 to 12, and as column charts in Appendix C.

To provide an approximate comparison with previous survey results (5,6,7) information on mean distributions of system exam DAP values is given in Appendix F, including the means of the exams' system mean DAP values and the error of the mean, instead of the interquartile range.

System DAP – plain radiography single projections

Plain radiography single projections are listed in alphabetical order in tables and figures, the projection names being given in full in Appendix B. Tables 10, 11 and F1 summarise the DAP system data sets of 30 or more patients received for plain radiography single projections. Figures 4 and 5 show box and whisker plots of the median DAP distribution data for higher dose and lower dose single projections respectively.

Table 10. Plain radiography single projections (adult): survey contributions of DAP data sets of 30 or more patients

Plain radiography single projections	Survey participants	Hospital regions	NHS boards, trusts etc.	Hospitals	All Systems [note 1]	CR systems [note 1]	DR systems [note 1]	Patients
Abdomen AP [notes 2,3,4]	28	12	33	68	188	24	155	67,194
Cervical spine AP [note 2]	18	10	19	40	115	11	100	14,703
Cervical spine LAT [note 2]	17	10	17	39	114	10	101	15,733
Chest AP [notes 2,3,5]	19	11	20	36	91	10	76	84,124
Chest mobile AP (ward) [notes 2,3,5]	17	10	20	33	72	12	59	79,183
Chest PA [notes 2,3,4]	27	13	39	110	301	61	230	491,643
Chest LAT [notes 3,4]	6	5	7	10	24	0	24	10,342
Foot (single) DP	10	8	12	23	62	6	50	27,148
Hand (single) PA	6	5	8	13	35	2	32	11,049
Hip (single) HBL	5	5	5	11	27	2	19	4,627
Knee (single) AP [note 3]	17	10	18	35	101	9	83	48,255
Knee (single) LAT [note 3]	16	10	17	33	95	8	78	47,260
Lumbar spine AP [notes 2,3,4]	22	12	25	53	140	21	111	28,201
Lumbar spine LAT [notes 2,3,4]	21	12	24	52	140	21	111	29,621
Pelvis AP view [notes 2,3,4]	27	13	37	98	237	54	174	91,301
Shoulder (single) AP [note 3]	20	11	24	64	165	24	132	40,776
Thoracic spine AP [notes 2,3,4]	16	11	18	35	84	12	68	9,831
Thoracic spine LAT [notes 2,3,4]	16	10	19	36	93	13	75	10,723

1. The sum of CR systems and DR systems do not always equal All systems as systems that used both types of detector system are not included, and this information is not available for a few systems.
2. 2010 Review (7): National reference dose (NRD) DAP value recommended.
3. 2010 Review (7): NRD ESD value recommended.
4. 2005 Review (6): NRD DAP value recommended.
5. These 2 projections, chest AP and chest AP mobile were not differentiated in previous surveys.

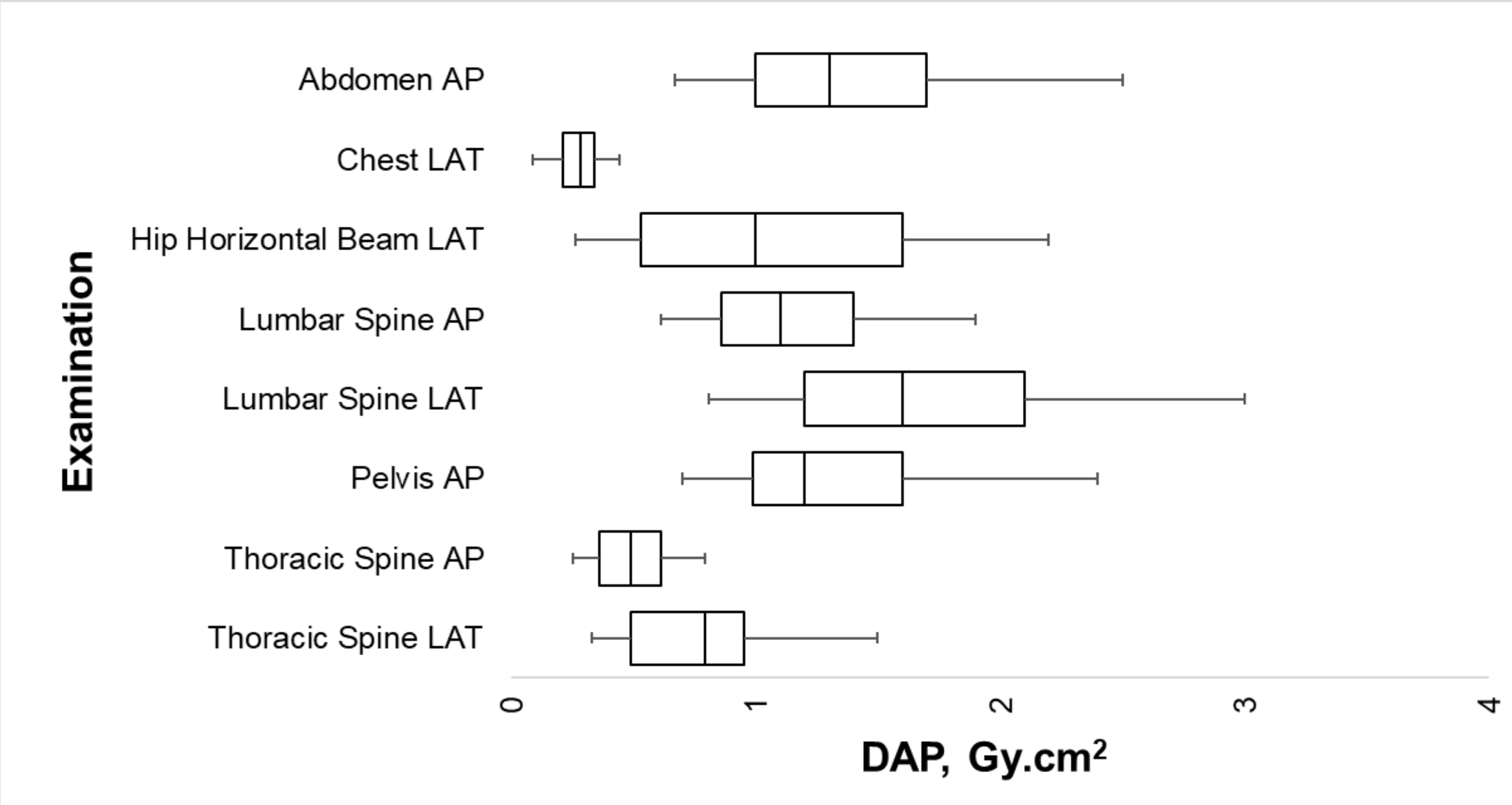
Table 11. Plain radiography single projections (adult): summary of system median DAP values (Gy.cm²) for data sets of 30 or more patients

Plain radiography single projections	Number of systems	Percentile, Gy.cm²					InterQuartile range 75th to 25th%ile	IQ range: % Median
		5th	25th	50th (median)	75th	95th		
Abdomen AP [notes 1,2,3]	188	0.67	1.0	1.3	1.7	2.5	0.73	57%
Cervical spine AP [note 1]	115	0.031	0.055	0.074	0.096	0.13	0.042	57%
Cervical spine LAT [note 1]	114	0.042	0.061	0.088	0.11	0.14	0.045	52%
Chest AP [notes 1,2,4]	91	0.025	0.049	0.072	0.092	0.13	0.043	60%
Chest mobile AP (ward) [notes 1,2,4]	72	0.047	0.070	0.091	0.11	0.15	0.042	46%
Chest PA [notes 1,2,3]	301	0.026	0.047	0.063	0.077	0.11	0.030	48%
Chest LAT [notes 2,3]	24	0.084	0.21	0.28	0.34	0.44	0.13	45%
Foot (single) DP	62	0.0047	0.0091	0.015	0.023	0.036	0.014	91%
Hand (single) PA	35	0.0062	0.011	0.015	0.022	0.038	0.010	68%
Hip (single) HBL	27	0.26	0.53	1.0	1.6	2.2	1.1	110%
Knee (single) AP [note 2]	101	0.012	0.033	0.048	0.054	0.072	0.021	44%
Knee (single) LAT [note 2]	95	0.014	0.034	0.046	0.056	0.074	0.022	48%
Lumbar spine AP [notes 1,2,3]	140	0.61	0.86	1.1	1.4	1.9	0.50	45%
Lumbar spine LAT [notes 1,2,3]	140	0.81	1.2	1.6	2.1	3.0	0.90	56%
Pelvis AP [notes 1,2,3]	237	0.70	0.99	1.2	1.6	2.4	0.60	49%
Shoulder (single) AP [note 2]	165	0.034	0.060	0.074	0.090	0.12	0.030	40%
Thoracic spine AP [notes 1,2,3]	84	0.25	0.36	0.49	0.61	0.79	0.25	51%

Plain radiography single projections	**Number of systems**	**Percentile, Gy.cm^2**					**InterQuartile range 75th to 25th%ile**	**IQ range: % Median**
		5th	**25th**	**50th (median)**	**75th**	**95th**		
Thoracic spine LAT [notes 1,2,3]	93	0.33	0.49	0.79	0.95	1.5	0.46	59%

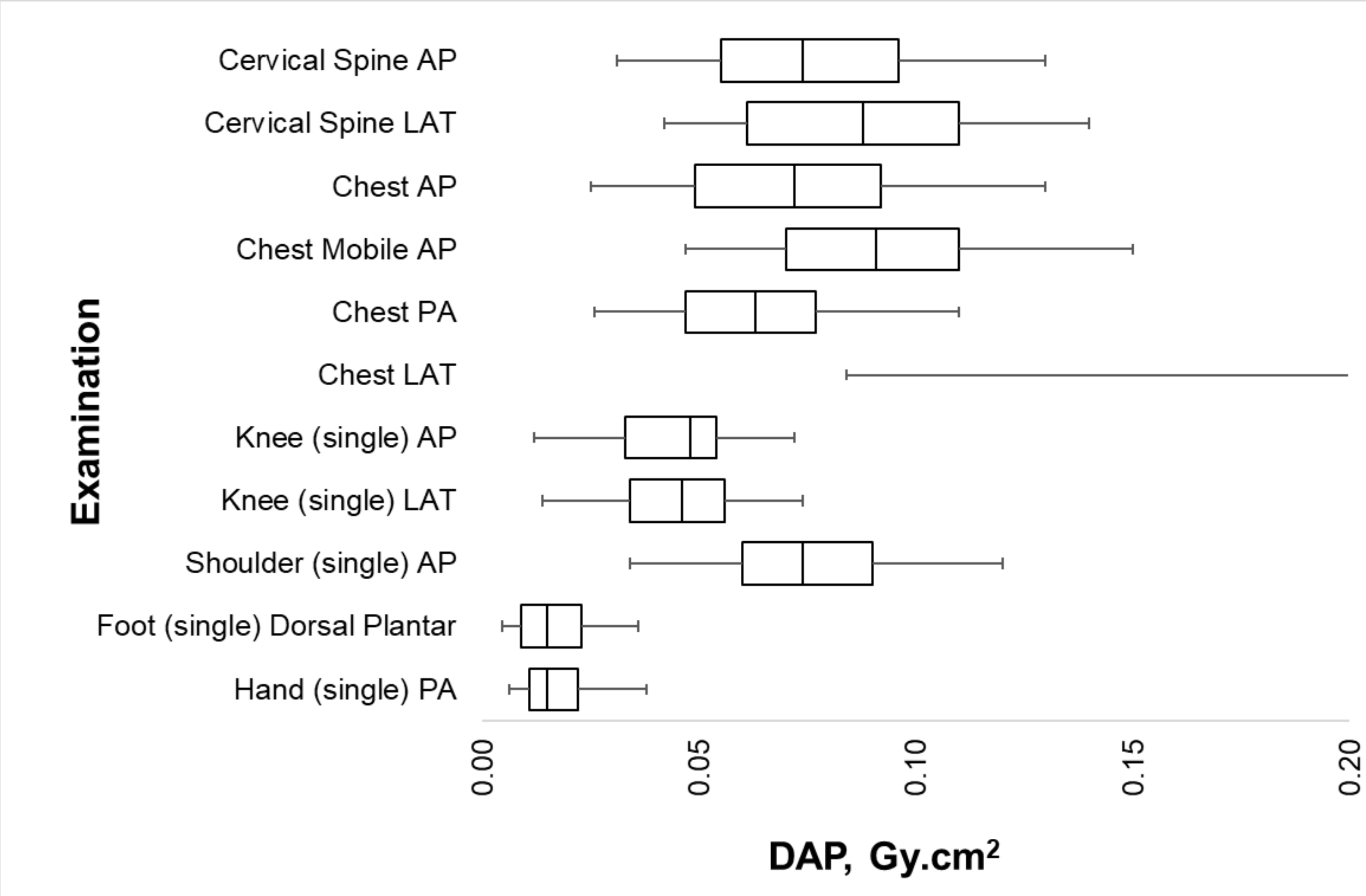
1. 2010 Review (7): National reference dose (NDR) DAP value recommended.
2. 2010 Review (7): NRD ESD value recommended.
3. 2005 Review (6): NRD DAP value recommended.
4. These 2 projections, chest AP and chest AP mobile were not differentiated in previous surveys.

Figure 4. Higher dose plain radiography single projections: system median DAP distributions, Gy.cm^2



Box: First, second, and third quartiles; Whiskers: 5th and 95th percentiles of system median distributions

Figure 5. Lower dose plain radiography single projections: system median DAP distributions, Gy.cm²



Box: First, second, and third quartiles; Whiskers: 5th and 95th percentiles of system median distributions

Chest lateral shown in full on Figure 4.

System DAP – plain radiography examinations

Plain radiography examinations are presented alphabetically in tables 12, 13 and F2. The tables summarise the DAP system data sets of 30 or more patients received for these examinations. Figures 6 and 7 show box and whisker plots of the median DAP distribution data for higher and lower DAP radiography examinations respectively. Two of the requested exams, leg length measurement (single leg) and skeletal survey, are included in the tables but not the figures as very little data was received for them.

The plain radiography examinations included in this survey are defined by the part of the body being imaged and can include one or more different projections, selected according to the patient's diagnostic needs. The data received by the survey suggests that for a given exam most systems use a comparable mix of projections for most patients. However, the data received from some systems for some exams reported atypical system median DAP values, with indications of either the use of a different combination of projections, or a usual projection combination being used for a larger than usual fraction of the sample. An MPE should ensure that any comparisons of local dose surveys to the proposed exam NDRL values are comparing similar exams.

Table 12. Plain radiography examinations (adult): survey contributions of DAP data sets of 30 or more patients

Radiography examinations	Survey participants	Hospital regions	NHS boards, trusts etc.	Hospitals	All Systems [notes 1]	CR systems [note 1]	DR systems [note 1]	Patients
Abdomen [note 2]	6 (6) [note 3]	6 (6)	6 (6)	17 (17)	37 (39)	13 (14)	23 (24)	9,498 (9,572)
Cervical spine	13	9	16	49	96	27	69	9,655
Chest [note 2]	8	8	9	29	62	24	37	83,864
Facial bones	9	8	9	12	19	1	16	2,509
Foot [note 4]	3	3	4	26	41	27	11	9,108
Hip (single)	8	6	9	27	57	14	42	9,452
Knee (single)	16	9	19	60	122	39	80	39,507
Leg length measurement (single leg)	3	3	3	3	4	0	4	337
Lumbar spine [note 2]	16	10	18	60	116	36	79	16,201
Pelvis	8	7	10	34	59	23	35	15,616
Shoulder [note 4]	3	3	4	26	39	27	10	8,474
Skeletal survey	1	1	1	1	1	0	1	35
Thoracic spine	10	8	12	23	41	5	36	3,645

1. The sum of CR systems and DR systems do not always equal All systems as systems that use both detector systems are not included, and this information is not available for a few systems.

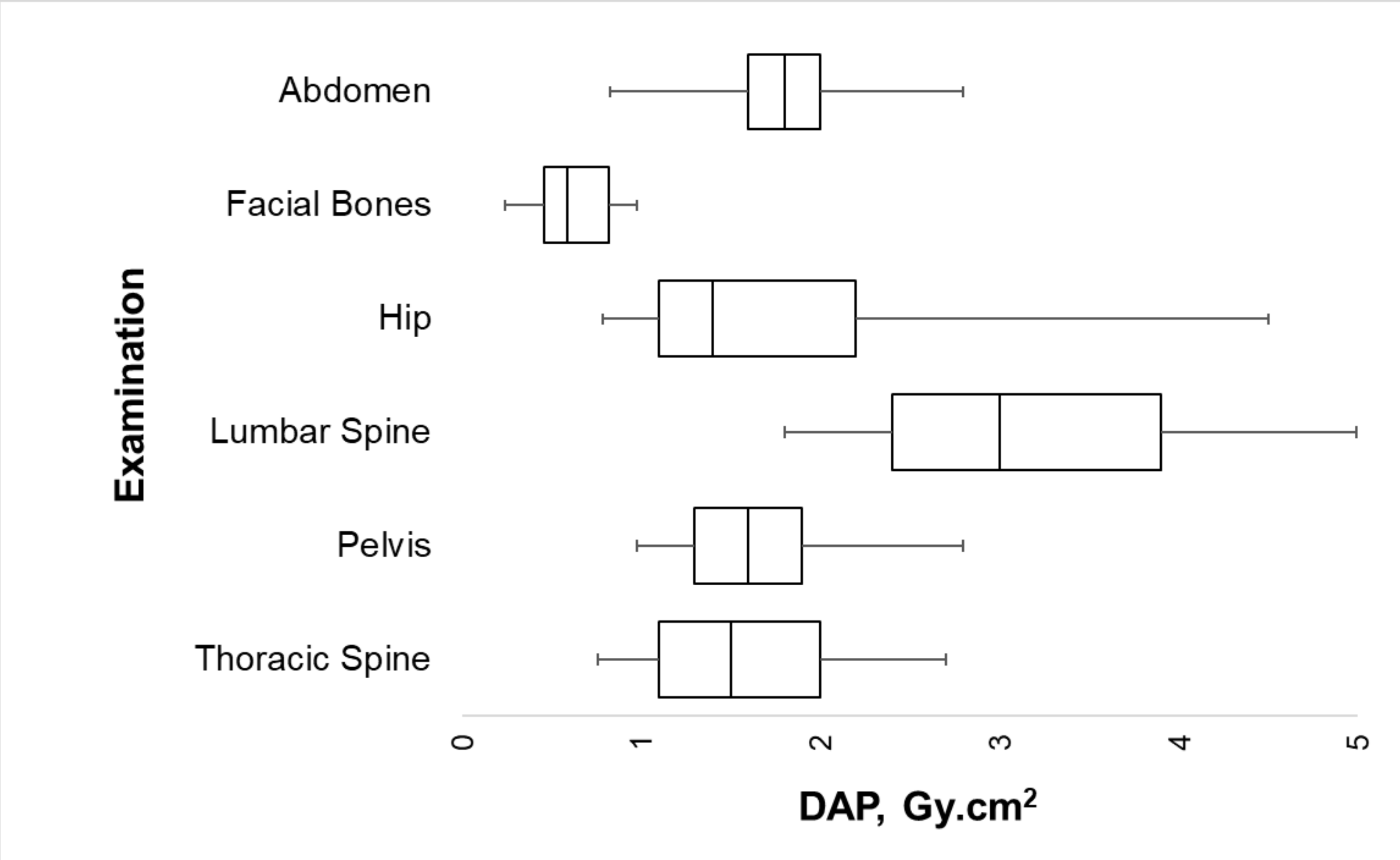
2. 2010 Review (7): National reference dose DAP value recommended.
3. Where the sizes of system median and mean data sets differ, the mean data set value is given in brackets.
4. Exam not on survey request list.

Table 13. Plain radiography examinations (adult): summary of system median DAP values ($Gy.cm^2$) for system samples of 30 or more patients

Radiography examinations	Number of systems	Percentile, $Gy.cm^2$					InterQuartile range: 75th to 25th%ile	IQ range: % Median
		5th	25th	50th (median)	75th	95th		
Abdomen [note 1]	37	0.83	1.6	1.8	2.0	2.8	0.43	24%
Cervical spine	96	0.11	0.14	0.18	0.24	0.33	0.10	58%
Chest [note 1]	62	0.040	0.061	0.076	0.12	0.38	0.061	81%
Facial bones	19	0.24	0.46	0.59	0.82	0.98	0.36	61%
Foot [note 2]	41	0.023	0.031	0.039	0.049	0.065	0.018	47%
Hip (single)	57	0.79	1.1	1.4	2.2	4.5	1.2	82%
Knee (single)	122	0.065	0.089	0.11	0.13	0.15	0.041	39%
Leg length measurement (single leg)	4	0.56	0.60	0.67	0.92	1.4	0.32	48%
Lumbar spine [note 1]	116	1.8	2.4	3.0	3.9	5.1	1.5	52%
Pelvis	59	0.98	1.3	1.6	1.9	2.8	0.54	33%
Shoulder [note 2]	39	0.082	0.13	0.17	0.20	0.28	0.066	39%
Skeletal survey	1	3.3	3.3	3.3	3.3	3.3	N/A	N/A
Thoracic spine	41	0.76	1.1	1.5	2.0	2.7	0.86	59%

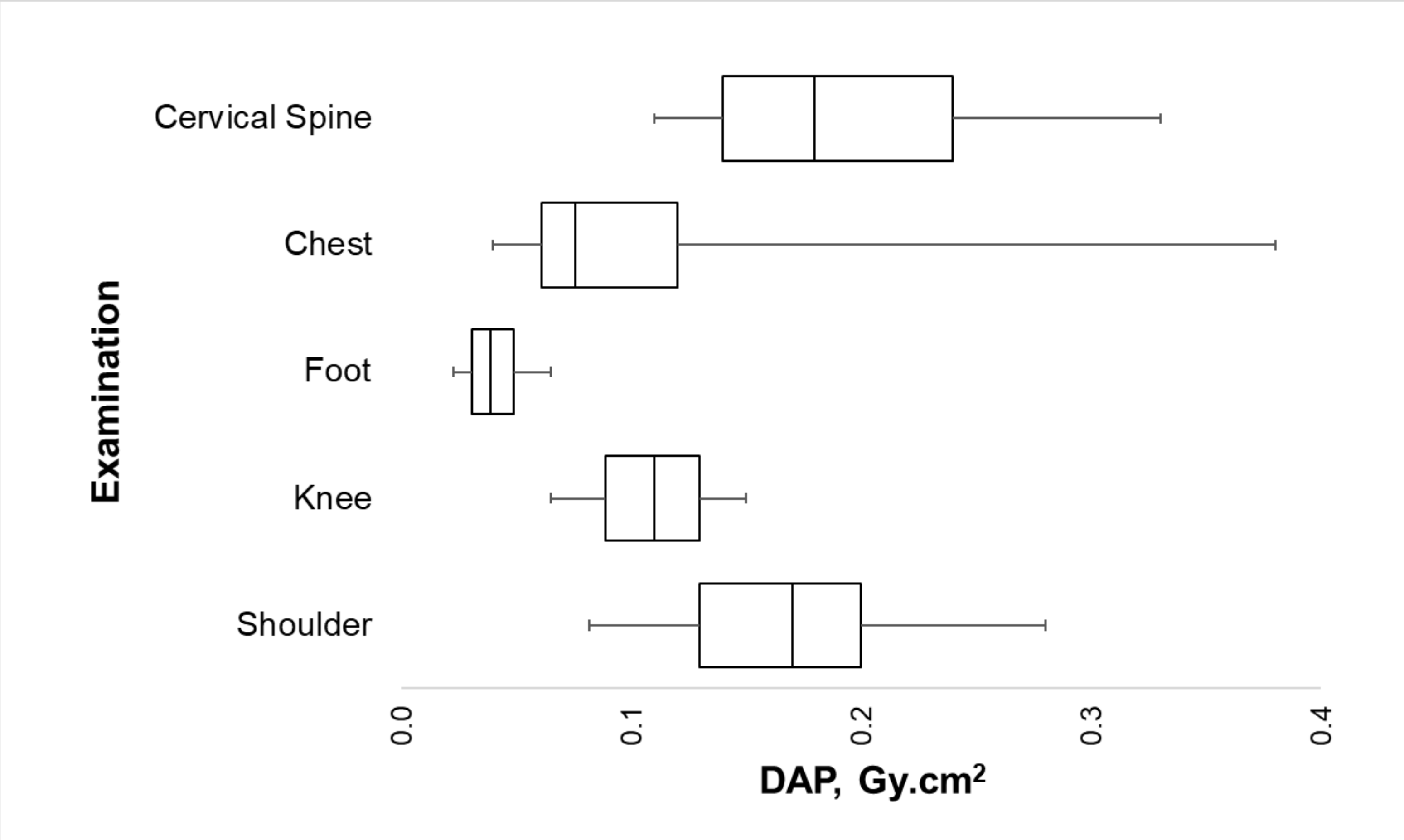
1. 2010 Review (7): National reference dose DAP value recommended.
2. Exam not on survey request list.

Figure 6. Higher dose plain radiography examinations: system median DAP distributions, Gy.cm^2



Box: First, second and third quartiles; Whiskers: 5th and 95th percentiles of system median distributions

Figure 7. Lower dose plain radiography examinations: system median DAP distributions, Gy.cm^2



Box: First, second and third quartiles; Whiskers: 5th and 95th percentiles of system median distributions

System DAP – fluoroscopy exams

As indicated above, far less data was received for the simple fluoroscopy examinations and simple IR procedures than for plain radiography. The fluoroscopy exam DAP data sets account for roughly 10% of all system exam data sets received for the survey, with the number of fluoroscopy patient DAP values accounting for only 3% of those received by the survey in total (see Table 8). However, data was received for a much larger number of named examinations (mostly unrequested), resulting in very few exams with sufficient data to propose NDRL or typical DAP values.

Tables 14, 15 and F3 summarise the information received for system exam DAP data sets of 30 or more patients for fluoroscopy examinations. Figures 8, 9 and 10 are box and whisker plots of the system median DAP data for higher, medium, and lower dose fluoroscopy examinations respectively.

Data was requested for 9 fluoroscopy examinations. Fluoroscopy examination data was also received for an additional thirty examinations. However, only 11 examinations, including 3 generic mobile imaging exams deemed too clinically unspecific to report, received 10 or more system exam data sets with a patient sample size of 30 or more. Few fluoroscopy examinations received sufficient data to enable NDRL DAP values to be proposed.

While insufficient data was received to recommend NDRL or typical DAP values for most of the fluoroscopy examinations listed in tables 14, 15 and F3, it was considered useful to include the data, to provide insight into the DAP values recorded for these examinations. The requested exam Angiography – Femoral (see Appendix B) is included in the tables but not the figures as very few system data sets were received.

Table 14 shows the diversity of contributions received. Table 15 shows the distribution of system median DAP values and Table F3 the distribution of system mean DAP values.

Table 14. Simple fluoroscopy exams (adult): survey contributions of DAP data sets of 30 or more patients

Fluoroscopy examinations	Survey participants	Hospital regions	NHS boards, trusts etc.	Hospitals	All systems	Systems with image intensifier detectors	Systems with flat panel detectors	Patients
Angiography – cerebral	8	6	8	8	8	0	8	1,424
Angiography – coronary [notes 1,2,3]	5 (6) [note 4]	4 (5)	5 (6)	6 (7)	11 (13)	0 (0)	11 (13)	5,818 (5,933)
Angiography – femoral [notes 1,2]	1	1	1	1	3	0	3	388
Arthrography – hip	5	4	5	5	6	2	4	654
Barium meal and swallow [notes 1,2]	7	6	7	7	7	1	6	521
Water soluble contrast enema [notes 1,2]	11	8	13	13	13	3	10	589
Barium swallow [notes 1,2,5]	24 (23)	11 (12)	29 (28)	44 (43)	46 (48)	17 (17)	27 (29)	11,339 (11,483)
Water soluble contrast swallow [notes 1,2]	9	7	9	13	15	4	11	1,441
Videofluoroscopy barium swallow [note 1]	18 (18)	10 (10)	18 (18)	28 (27)	28 (27)	7 (6)	21 (21)	2,913 (2,856)
Cystogram [note 3]	7	6	7	7	7	1	6	371
Hysterosalpingography [note 1,2]	16	10	18	20	23	6	17	2,622

Fluoroscopy examinations	Survey participants	Hospital regions	NHS boards, trusts etc.	Hospitals	All systems	Systems with image intensifier detectors	Systems with flat panel detectors	Patients
Percutaneous Transhepatic Cholangiography (PTC) [note 3]	5	5	5	5	6	2	4	281
Proctogram [notes 1,3]	6	6	6	7	7	3	4	972

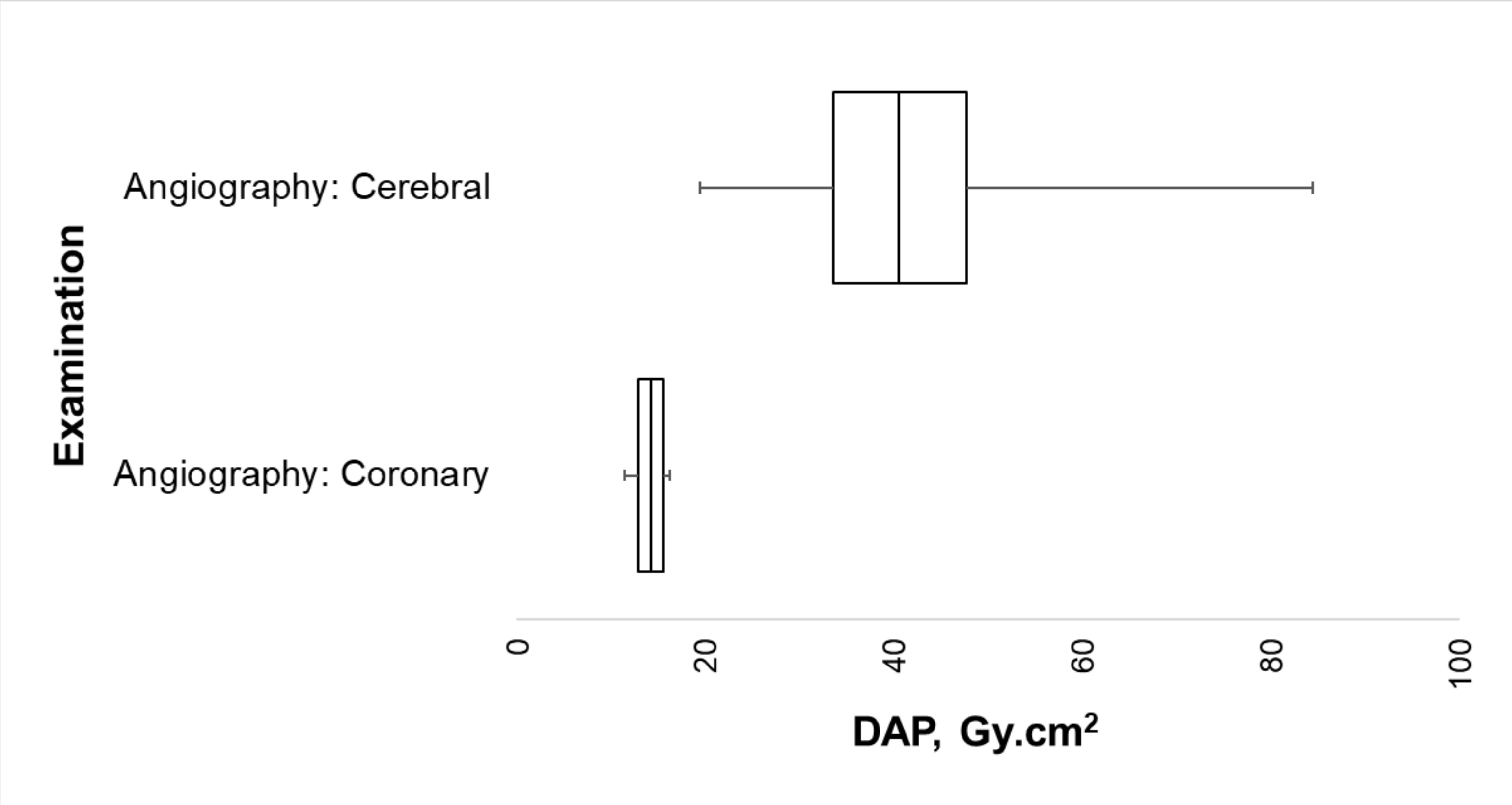
1. 2010 Review (7): National reference dose DAP value recommended (same NDR for equivalent barium and water soluble contrast exams).
2. 2005 Review (6): National reference dose DAP value recommended (same NDR for equivalent barium and water soluble contrast exams).
3. Exam not on survey request list.
4. Values in brackets refers to the mean values data set for that exam.
5. The sum of II systems and FPD systems does not equal All systems for this exam as information on detector type was not available for 2 systems.

Table 15. Simple fluoroscopy exams (adult): summary of system median DAP values (Gy.cm^2) for data sets of 30 patients or more

Fluoroscopy examinations	Number of systems	Percentile, Gy.cm^2					InterQuartile range 75th to 25th%ile	IQ range: % Median
		5th	25th	50th (median)	75th	95th		
Angiography – cerebral	8	19	34	41	48	84	14	35%
Angiography – coronary [notes 1,2,3]	11	11	13	14	16	16	2.7	19%
Angiography – femoral [notes 1,2]	3	3.9	4.9	6.3	7.1	7.6	0.75	22%
Arthrography – hip	6	0.029	0.047	0.44	0.88	1.1	0.83	190%
Barium meal and swallow [notes 1,2]	7	3.5	4.7	6.3	6.9	9.8	2.2	35%
Water soluble contrast enema [notes 1,2]	13	3.1	4.7	6.1	8.2	14	3.5	58%
Barium swallow [notes 1,2]	46	1.4	2.3	3.3	5.0	9.4	2.6	80%
Water soluble contrast swallow [notes 1,2]	15	1.5	2.2	3.9	5.3	8.7	3.1	80%
Videofluoroscopy barium swallow [note 1]	28	0.11	0.36	0.77	1.2	2.2	0.84	110%
Cystogram [note 3]	7	0.76	1.8	2.7	3.8	4.4	2.1	76%
Hysterosalpingography [notes 1,2]	23	0.12	0.22	0.37	0.55	0.88	0.33	89%
Percutaneous transhepatic cholangiography (PTC) [note 3]	6	2.4	3.0	4.1	5.9	10.5	2.9	69%
Proctogram [notes 1,3]	7	3.9	4.9	6.3	7.1	7.6	2.3	36%

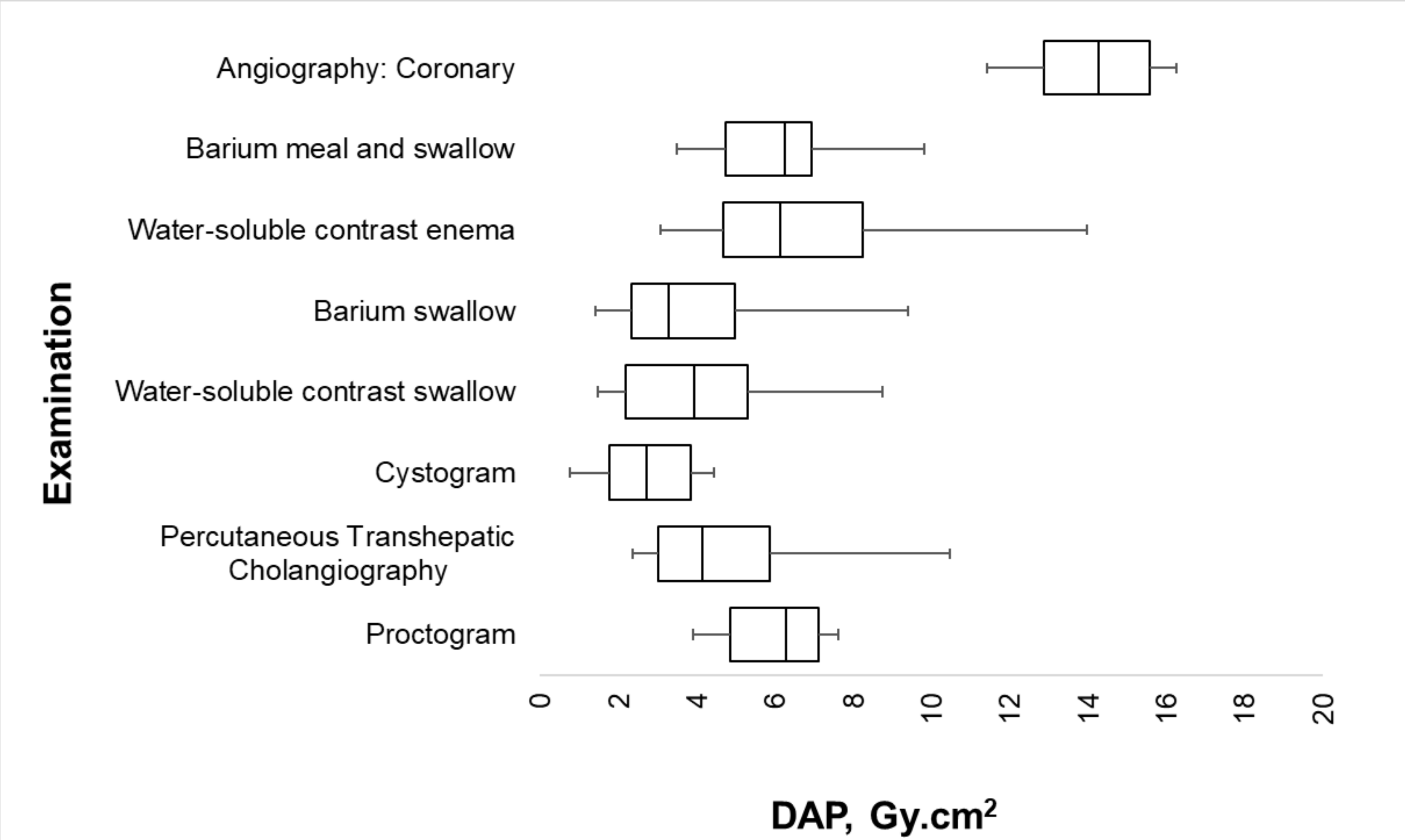
1. 2010 Review (7): National reference dose DAP value recommended (NDR same for equivalent barium and water soluble contrast exams).
2. 2005 Review (6): National reference dose DAP value recommended (NDR same for equivalent barium and water soluble contrast exams).
3. Exam not on survey request list.

Figure 8. Comparison of system median DAP for cardiac and cerebral angiography, Gy.cm²



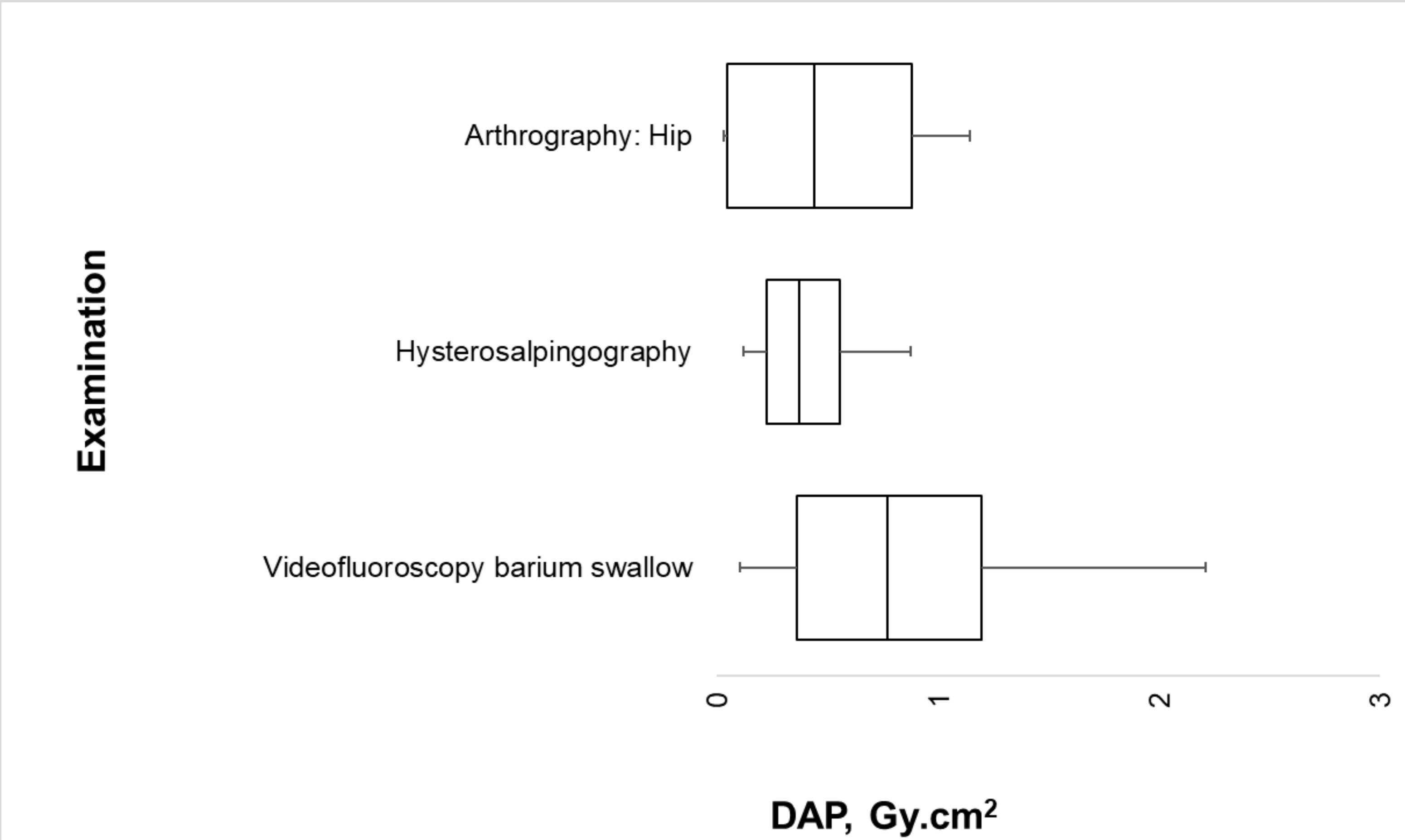
Box: First, second and third quartiles; Whiskers: 5th and 95th percentiles of system median distributions

Figure 9. Moderate dose fluoroscopy examinations: system median DAP distributions, Gy.cm²



Box: First, second and third quartiles; Whiskers: 5th and 95th percentiles of system median distributions

Figure 10. Lower dose fluoroscopy examinations: system median DAP distributions, Gy.cm²



Box: First, second and third quartiles, Whiskers: 5th and 95th percentiles of system median distributions

System DAP – interventional radiology procedures

Data was received for about 100 named IR procedures, roughly twice as many as named fluoroscopy examinations, from slightly more fluoroscopy systems but for a roughly equal number of patient DAP entries (Table 8). Only 9 named IR procedures received 10 or more system DAP data sets with patient sample sizes of 30 or more. For some closely associated procedures, such as pacemaker (permanent: single or dual chamber), pacemaker (permanent: single chamber) and pacemaker (permanent: dual chamber), data was pooled to provide a stronger data set. Instances where this has been done are noted below. Combining data from related exams could result in bimodal DAP value distributions. The combined exam data sets were reviewed but the received data did not show evidence of bimodal distributions.

Tables 16, 17 and F4 summarise DAP system data sets of 30 or more patient entries received for IR procedures, including the requested 4 mobile imaging exams or procedures for specific clinical objectives. Figures 11 and 12 are box and whisker plots of the system median DAP distribution data for higher and lower dose IR procedures respectively.

Where appropriate, the entries in tables 16, 17 and F4 have been grouped into types of procedure, such as heart implants or injections. This illustrates that typical DAP does differ significantly between superficially similar procedures. Implantation of biventricular heart devices cause DAP values roughly 5 to 10 times greater than those received from installing a single or dual chamber implant.

Table 16. Simple IR procedures (adult): survey contributions of DAP data sets of 30 or more patients

IR procedures	Survey participants	NHS regions	NHS boards, trusts etc.	Hospitals	All systems	Systems with image intensifier detectors	Systems with flat panel detectors	Patients
Angioplasty: superficial femoral artery [note 3]	4	3	4	6	8	0	8	399
Cardiac catheter ablation (RF)	6	5	6	6	11	0	11	2,179
Endoscopic Retrograde Cholangiopancreatography (ERCP)								
ERCP (diagnostic and interventional) [note 3]	16	7	19	26	29	15	14	4,571
Diagnostic ERCP	6	3	6	7	7	2	5	733
Interventional ERCP	4	1	4	5	6	1	5	841
Heart implants								
Pacemaker (single or dual chamber: permanent) [notes 1,2]	12	6	12	14	26	3	23	2,995
Defibrillator implant (ICD) [note 3]	4	4	4	4	5	0	5	267
Biventricular implantable cardioverter defibrillator [note 3]	4	4	4	4	5	0	5	227
Injections etc.								
Facet joint injection [notes 1,2]	6	6	7	7	11	5	6	703
Fluoro guided injection: hip [note 3]	4	3	4	5	7	4	3	755

IR procedures	Survey participants	NHS regions	NHS boards, trusts etc.	Hospitals	All systems	Systems with image intensifier detectors	Systems with flat panel detectors	Patients
Fluoro guided nerve root block [note 3]	3	3	3	4	6	1	5	758
Line insertions etc.								
Insertion of tunnelled central venous catheter [notes 1,2,4]	12	6	12	14	19	1	18	1,515
PICC line insertion	10	5	11	12	14	2	12	2,255
Radiologically inserted gastrostomy tube	8	7	8	8	9	2	7	646
Nephrostomy								
Nephrostomy [notes 1,2]	17	9	16	18	20	4	16	1,356
Nephrostomy tube replacement	11	8	11	11	12	1	11	655
Stents								
Stent (ureteric) [note 3]	8	5	8	8	10	5	5	683
Stent (ureteric antegrade)	4	4	4	4	5	0	5	315
Stent (ureteric retrograde)	4	4	4	4	5	5	0	364
Oesophageal stent [notes 1,2]	4	4	5	5	5	4	1	207
Mobile Imaging of IR procedures								
Mobile imaging of Abdomen for Laparoscopic cholecystectomy	2	2	2	4	4	0	4	196

IR procedures	Survey participants	NHS regions	NHS boards, trusts etc.	Hospitals	All systems	Systems with image intensifier detectors	Systems with flat panel detectors	Patients
Mobile imaging of cervical spine for laminectomy	2	2	2	2	2	1	1	470
Mobile imaging of lumbar spine for laminectomy	4	4	4	7	11	10	1	2,332
Mobile imaging of orthopaedic hip pinning	7	4	7	11	11	11	0	583

1. 2010 Review (7): National reference dose DAP value recommended.
2. 2005 Review (6): National reference dose DAP value recommended.
3. Exam not on survey request list.
4. A broadened procedure definition, which includes the previously reported Hickman Line procedure.

Table 17. Simple IR procedures (adult): summary of system median DAP values (Gy.cm^2) for system samples of 30 or more patients

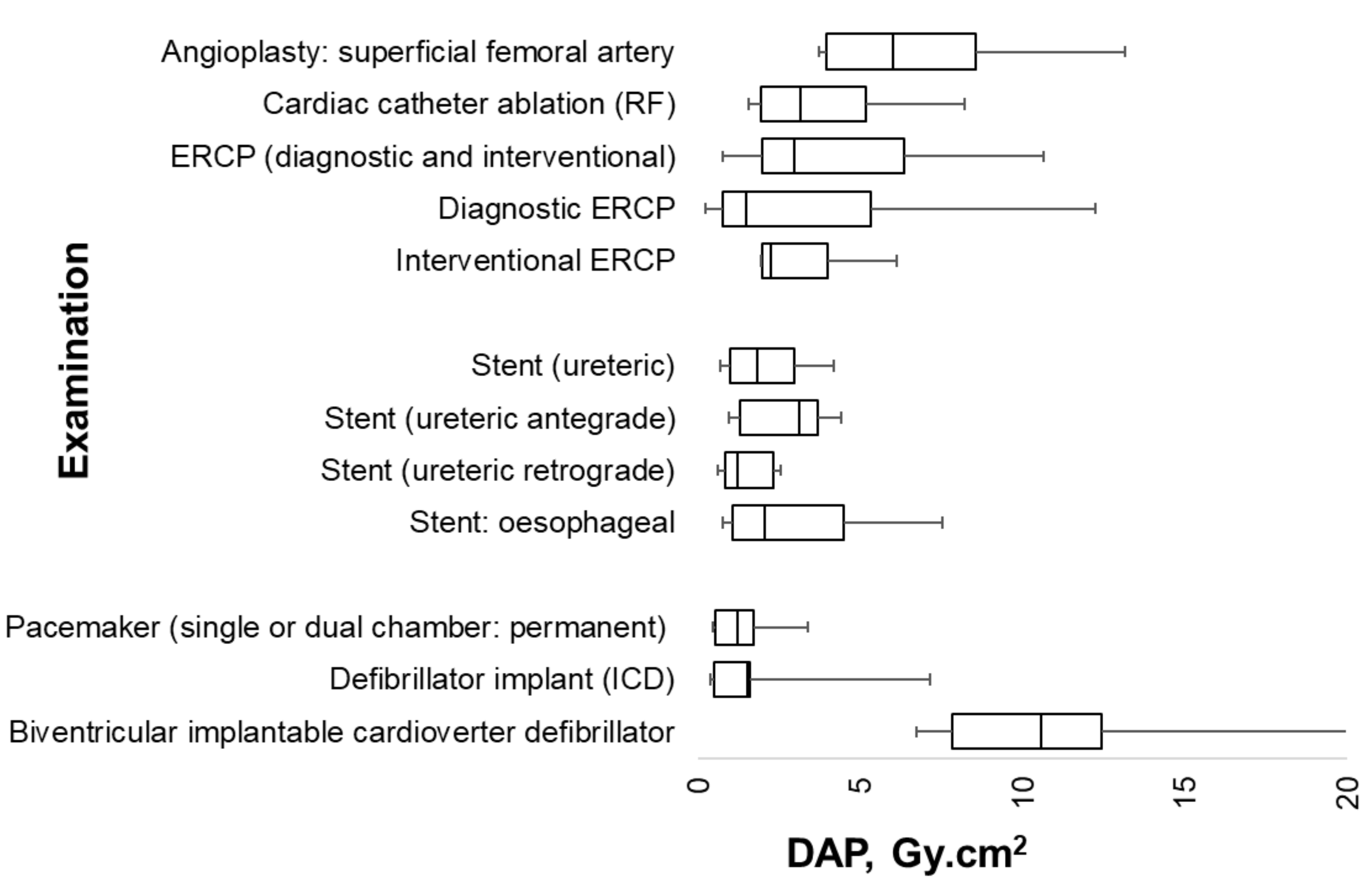
IR procedures	Number of systems	Percentile, Gy.cm^2					InterQuartile range 75th to 25th%ile	IQ range: % Median
		5th	25th	50th (median)	75th	95th		
Angioplasty: superficial femoral artery [note 3]	8	3.7	4.0	6.0	8.6	13	4.6	76%
Cardiac catheter ablation (RF)	11	1.6	2.0	3.2	5.2	8.2	3.2	100%
Endoscopic Retrograde Cholangiopancreatography (ERCP)								
ERCP (diagnostic and interventional) [note 3]	29	0.77	2.0	3.0	6.4	11	4.4	150%
Diagnostic ERCP	7	0.26	0.78	1.5	5.3	12	4.6	300%
Interventional ERCP	6	2.0	2.0	2.3	4.0	6.2	2.0	89%
Heart implants								
Pacemaker (permanent) single or dual chamber [notes 1,2]	26	0.47	0.56	1.2	1.7	3.4	1.1	94%
Defibrillator implant (ICD) [note 3]	5	0.40	0.51	1.5	1.6	7.2	1.1	72%
Biventricular implantable cardioverter defibrillator [note 3]	5	6.8	7.9	11	12	37	4.6	43%
Injections etc.								
Facet joint injection [notes 1,2]	11	0.15	0.28	0.60	1.3	1.8	1.0	170%
Fluoro guided injection: hip [note 3]	7	0.034	0.061	0.13	0.24	0.38	0.18	140%
Fluoro guided nerve root block [note 3]	6	0.50	1.0	1.3	1.6	2.7	0.60	48%

IR procedures	Number of systems	Percentile, Gy.cm^2					InterQuartile range 75th to 25th%ile	IQ range: % Median
		5th	25th	50th (median)	75th	95th		
Line insertions etc.								
Insertion of tunnelled central venous catheter [notes 1,2,4]	19	0.040	0.17	0.36	0.65	0.90	0.48	130%
PICC line insertion	14	0.028	0.042	0.19	0.31	0.34	0.27	140%
Radiologically inserted gastrostomy tube	9	0.21	0.50	0.62	1.3	2.2	0.75	120%
Nephrostomy								
Nephrostomy [notes 1,2]	20	0.39	0.69	1.0	1.5	2.5	0.77	75%
Nephrostomy tube replacement	12	0.16	0.30	0.32	0.52	1.5	0.22	68%
Stents								
Stent (ureteric) [note 3]	10	0.70	0.99	1.8	3.0	4.2	2.0	110%
Stent (ureteric antegrade)	5	0.97	1.3	3.1	3.7	4.4	2.4	76%
Stent (ureteric retrograde)	5	0.64	0.83	1.2	2.3	2.5	1.5	120%
Oesophageal stent [notes 1,2]	5	0.77	1.1	2.0	4.5	7.6	3.4	170%
Mobile Imaging of IR procedures								
Mobile imaging of abdomen for laparoscopic cholecystectomy	4	0.32	0.40	0.59	1.0	1.6	0.60	100%
Mobile imaging of cervical spine for Laminectomy	2	0.10	0.12	0.15	0.17	0.19	0.051	34%
Mobile imaging of lumbar spine for laminectomy	11	0.36	0.54	0.60	0.81	1.1	0.27	45%

IR procedures	Number of systems	Percentile, $Gy.cm^2$					InterQuartile range 75th to 25th%ile	IQ range: % Median
		5th	25th	50th (median)	75th	95th		
Mobile imaging of orthopaedic hip pinning	11	0.11	0.20	0.48	0.79	1.8	0.58	120%

1. 2010 Review (7): National reference dose DAP value recommended.
2. 2005 Review (6): National reference dose DAP value recommended.
3. Procedure not on the survey request list.
4. A broadened procedure definition, which includes the previously reported Hickman Line procedure.

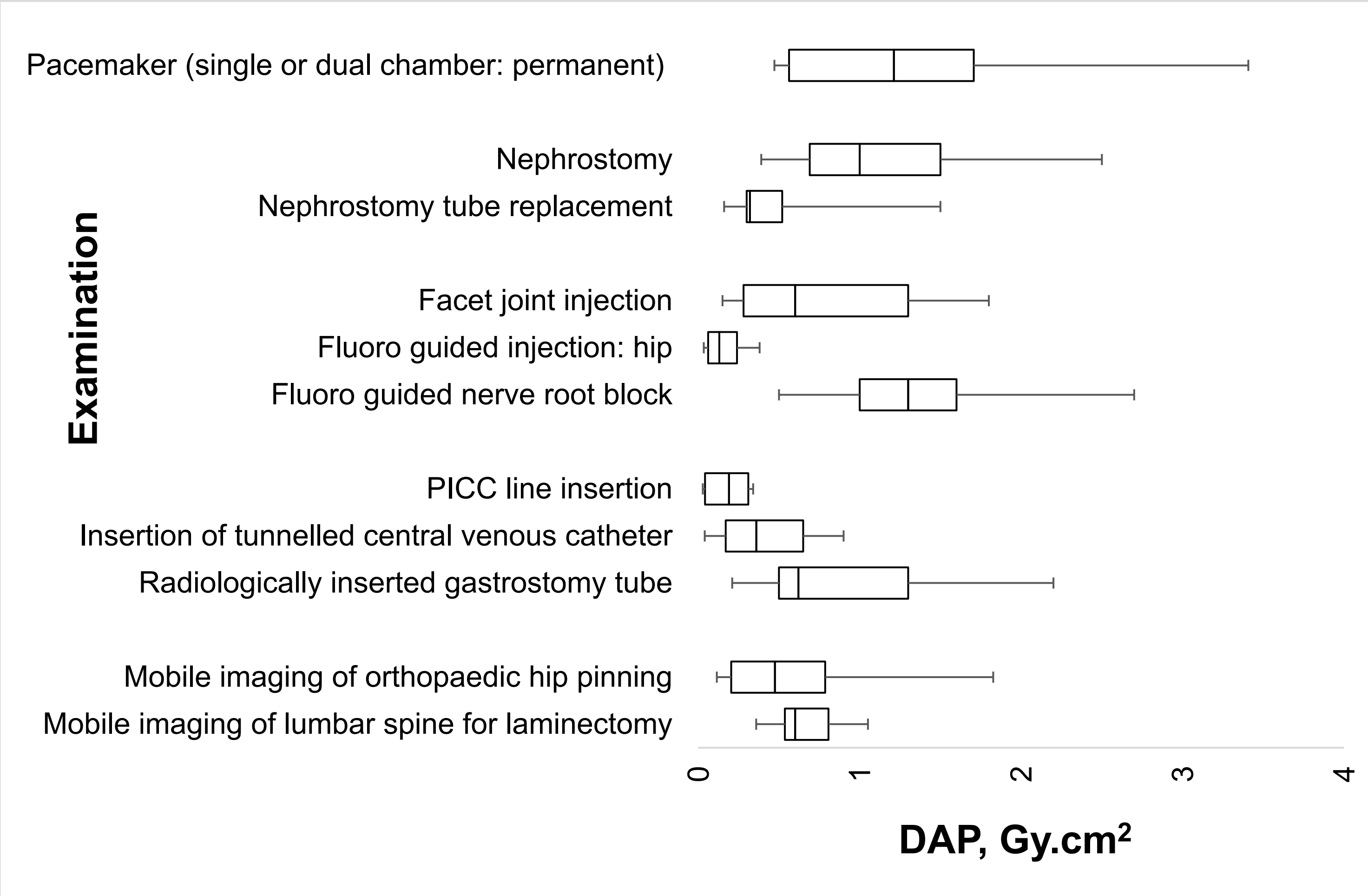
Figure 11. Higher dose 'simple' IR procedures: system median DAP distributions, Gy.cm²



Box: First, second and third quartiles; Whiskers: 5th and 95th percentiles of system median distributions

For Biventricular implantable cardioverter defibrillator, the 95th percentile (upper whisker value) is 37 Gy.cm²

Figure 12. Lower dose 'simple' IR procedures: system median DAP distributions, Gy.cm²



Box: First, second and third quartiles, Whiskers: 5th and 95th percentiles of system median distributions

Fluoroscopy time data

Very little fluoroscopy time data was received by the survey, with only 213 system exam data sets received in total for all fluoroscopy examinations and IR procedures (Table 9). This is insufficient for recommending NDRL or typical values for any fluoroscopy examination or IR procedure. However, Appendix E provides a summary of the limited fluoroscopy time data that was received. As fluoroscopy time data is so sparse, the information given is based on analysis of system exam data sets with a patient sample size of 10 or more patients to maximise the information provided.

Additional aspects

System DAP values are impacted by the technology of the radiography systems, such as detector technology and the use of AEC. The survey data was reviewed to find the extent to which these factors may influence system DAP values, and if they should be referenced when proposing NDRL or typical DAP values.

Detector systems

The survey received no data for diagnostic imaging performed using radiographic film nor were any enquiries received about providing such data. This may not mean that no diagnostic imaging using radiographic film is being performed in the UK but does suggest that it is now rare within a hospital or clinic setting. This completes the decline in use of film, with 98% of systems using film in the 2000 review, 55% of systems in 2005 review, decreasing to 3% in the 2010 review (Chapter 5, 2010 Review (7)).

Survey data was reviewed by detector type, comparing the exams' median and third quartile values of system median DAP values.

Computed radiography and digital radiography imaging systems

In the 2010 Review (7), CR detector systems accounted for 65% of participating radiography rooms, with DR systems (termed flat panel detectors in that report) accounting for 32% of radiography rooms.

2019 survey responses show that plain radiography systems now predominantly use DR detectors (72%) but that CR detectors (25%) are still in significant use, with a few systems using a combination of CR cassettes and wifi or tethered DR detectors (1%). The remaining 2% of survey systems did not provide detector information.

Table 18. Comparison of median and third quartile values of system median DAP distributions for CR and DR detectors for plain radiography single projections

Plain radiography single projections	Computed radiography			Direct digital radiography		
	No. of systems	Median Gy.cm^2	Third quartile Gy.cm^2	No. of systems	Median Gy.cm^2	Third quartile Gy.cm^2
Abdomen AP	24	1.7	2.2	155	1.2	1.6
Cervical spine AP	11	0.086	0.11	100	0.071	0.095
Cervical spine LAT	10	0.094	0.11	101	0.087	0.11
Chest AP	10	0.099	0.12	76	0.070	0.085
Chest AP mobile	12	0.14	0.16	59	0.083	0.10
Chest PA	61	0.076	0.091	230	0.058	0.074
Chest LAT	0	-	-	24	0.28	0.34
Foot (single) DP	6	0.014	0.017	50	0.016	0.025
Hand (single) PA	2	0.021	0.022	32	0.015	0.021
Hip (single) HBL	2	1.2	1.4	19	1.0	1.4
Knee (single) AP	9	0.048	0.074	83	0.046	0.055
Knee (single) LAT	8	0.052	0.059	78	0.044	0.056
Lumbar spine AP	21	1.1	1.2	111	1.1	1.4
Lumbar spine LAT	21	1.7	2.3	111	1.5	2.1
Pelvis AP	54	1.5	1.8	174	1.2	1.4
Shoulder(single) AP	24	0.071	0.085	132	0.074	0.089
Thoracic spine AP	12	0.62	0.74	68	0.44	0.59
Thoracic spine LAT	13	0.88	1.5	75	0.65	0.91

Table 18 compares median and third quartile values of system median DAP distributions for plain radiography single projections for CR and DR detector systems using exam data sets of 30 or more patients. The comparison is restricted to radiography projections to minimise confounding factors. For the plain radiography single projection data sets used in this comparison, 80% of systems had DR detectors, and 20% CR detectors.

For the projections in Table 18, DR detectors had median and third quartile system median DAP values an average of –18% and –13% lower than those of the CR detector systems. DR detector systems only had higher median and third quartile values for foot DP, lumbar spine AP, and shoulder AP projections. The CR foot DP, hand PA and hip HBL values should be treated with caution as they are based on very small sample sizes. The foot and shoulder projections are of peripheral parts of the body where the higher DR values may be due to the DR field of view not being restricted quite as much as for the CR detector systems. The 10% higher third quartile value for DR detector systems for lumbar spine AP is worth noting as this is the one projection that shows an increase in mean DAP since the 2010 review (7), as noted in the Discussion chapter and Appendix G.

Appendix D figures D1 to D18 compare the median DAP values for system exam data sets for CR and DR detector systems for a range of plain radiography single projections. The Appendix D figures and the DAP values in Table 18 show that system median DAP values from systems using DR or CR detectors usually overlap to a large degree. Therefore, while the median DAP values for DR detector systems are usually about 20% lower than the median DAP values for CR detector systems, there is a significant overlap of DAP values for systems using the 2 detector types. This indicates that it is not appropriate to set different NDRL values for plain radiography based on the type of detector used by radiography systems.

Flat panel and Image Intensifier detectors

For simple fluoroscopy and IR exams, about 60% of fluoroscopy systems used direct digital detectors (termed flat panel detectors (FPD) in this fluoroscopy system discussion), and 40% Image Intensifier (II) detectors. Almost a half (48%) of systems that used II detectors were identified as mobile systems, as opposed to less than 2% of FPD systems.

In the received data, the ratio of FPD to II detectors varied between the different areas in which fluoroscopy exams and IR procedures are used. The data sets for mobile imaging exams or imaging for limb bone fracture repairs by pinning were predominantly from systems using II detectors. In specialities such as cardiac and coronary exams, FPD systems were almost exclusively used. Care needs to be taken in the interpretation of this data as the number of system data sets received for most exams is low, even before being divided into systems using FPD or II detector systems.

Table 19 compares the medians and third quartiles of the system median DAP values for systems with FPD and II detectors for the fluoroscopy examinations and IR procedures for which the most data was received. In Appendix D, figures D19 to D29 compare the distribution of the system median DAP values for systems with FPD and II detectors for 10 exams (video-fluoroscopy barium swallow is shown twice using different DAP scales).

The median and third quartile system median DAP values in Table 19 do not show evidence of a consistent bias in median DAP values between exams done on systems using FPD or II detectors. This may be due in part to the low numbers of system data sets received for these examinations. It may be influenced by other factors. For instance, for the Stent: Ureteric data, almost all antegrade procedures were performed using FPD systems, and all retrograde procedures were performed using II detector systems data.

Table 19. Comparison of median and third quartile of system median DAP distributions for II and FPD detectors

Fluoroscopy examination or IR procedure	Image intensifier detector			Flat panel detector		
	No. of systems	Median Gy.cm^2	Third quartile Gy.cm^2	No. of systems	Median Gy.cm^2	Third quartile Gy.cm^2
Barium swallow	17	3.5	4.1	29	3.3	5.1
Water soluble contrast swallow	4	3.0	5.3	11	3.9	5.3
Videofluoroscopy barium swallow	7	0.56	1.3	21	0.95	1.2
Water soluble contrast enema	3	6.1	7.8	10	6.5	8.2
Hysterosalpingography	6	0.45	0.57	17	0.35	0.52
ERCP (diagnostic and interventional)	15	4.1	6.6	14	2.9	4.5
Pacemaker: permanent (single or dual chamber)	3	2.6	3.7	23	1.2	1.5
Insertion of tunnelled central venous catheter	1	0.040	0.040	18	0.37	0.66
PICC line insertion	2	0.18	0.25	12	0.19	0.31
Radiologically inserted gastrostomy tube	2	0.26	0.37	7	0.88	1.6
Nephrostomy	4	1.3	1.9	16	1.0	1.3
Nephrostomy tube replacement	1	0.47	0.47	11	0.31	0.53
Stent: Ureteric (antegrade and retrograde)	5	1.2	2.3	5	3.1	3.7

As no consistent trend is present in the survey data, and, as there is the considerable overlap of system median DAP values for systems using FPD and II detectors, there is no justification for recommending different NDRLs based on detector type used for fluoroscopy and IR procedures.

Automatic exposure control (AEC)

By law (19,20) all fluoroscopy systems are required to have AEC. It is not compulsory for plain radiography systems. The survey asked if radiography systems had AEC capability, and if AEC was used for specific plain radiography single projections. Where system exam data was submitted as patient data sets this information could be given for individual patient entries, the latter giving a view of how consistently AEC was used for specific projections on a given system.

Table 20. Information received on use of AEC for plain radiography single projections

Plain radiography single projections	No. of system data sets for which AEC info given	AEC used for most or all patients	System data sets where AEC not used
Abdomen AP	72	72	0
Cervical spine AP	54	18	36
Cervical spine LAT	56	13	43
Chest AP	40	9	31
Chest AP mobile	23	0	23
Chest PA	105	68	37
Chest LAT	13	13	0
Foot (single) DP	35	0	35
Hand (single) PA	27	0	27
Hip (single) HBL	8	7	1
Knee (single) AP	34	0	34
Knee (single) LAT	33	0	33
Lumbar spine AP	66	64	2
Lumbar spine LAT	67	66	1
Pelvis AP	92	86	6
Shoulder (single) AP	53	3	50
Thoracic spine AP	51	49	2
Thoracic spine LAT	51	50	1

Information on the availability and use of AEC was received for about 30% of the plain radiography single projection data sets, approximately 60% of those entries stating AEC was used for all or most patient projections, and about 40% stated AEC had not been used. Table 20 summarises the information received for specific plain radiography single projections. The number of system data sets for which AEC information was given is listed. The table includes information for all system data sets for which AEC information was given irrespective of system patient sample size.

Table 20 shows that for most projections there is a strong bias either towards using AEC or not using AEC. AEC is typically used for projections of the thicker or denser parts of the torso, such as abdomen, pelvis, lumbar and thoracic spine. AEC was typically not used for extremities and more peripheral parts of the body (hands, feet, knees, shoulder) or for chest AP mobile projections.

The projections for which there was more mixed use and non-use of AEC were cervical spine AP and lateral projections, and chest AP and PA projections. For the cervical spine projections and chest AP between 25% and 33% of systems did routinely use AEC. AEC was used for about 70% of chest PA projections.

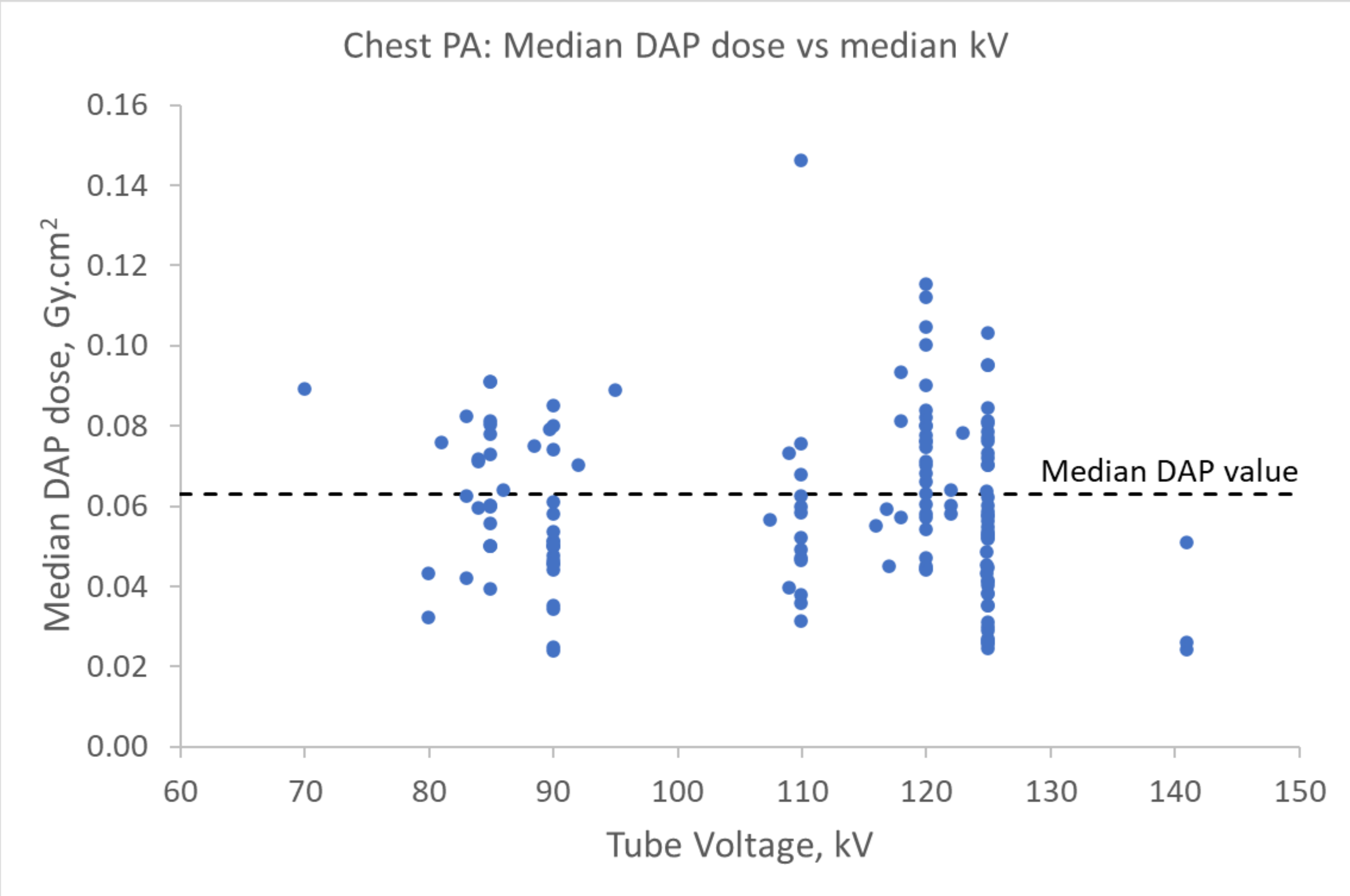
No trend was found between the use or non-use of AEC and system median DAP values, with no statistical difference seen between the mean system median DAP values for systems that used AEC and those that did not. Nor were these values statistically different from the median system median DAP value for all system data sets for that projection. In Appendix D, figures D30 to D33 show the distribution of system median DAP values for chest PA, chest AP, cervical spine AP and cervical spine lateral for systems that used AEC and systems that did not. In all 4 cases, the distributions of system median DAP values for systems which state AEC was used, and for those that said it was not, cover similar DAP ranges, and do not provide any justification for setting different NDRL values based on AEC use.

Chest PA projection: DAP versus tube voltage

Chest PA projection was, as expected, the exam for which the most data was received, with information from 340 radiography systems, representing just under 0.5 million patients. The exposure parameter for which the survey received the most information for chest PA was tube voltage, which was provided for 149 systems and ranged from 70 kV to 141 kV. Given the range of diagnostic objectives for imaging the chest, and the reasonable size of the data set, the chest PA system median DAP values were compared with the systems' median X-ray tube voltages to identify if any obvious trends were present.

Figure 13 shows system median DAP values plotted against median kV. The dashed black line is the median DAP value for all systems that provided chest PA data (0.063 Gy.cm^2), not just those that provided tube voltage data. Figure 13 shows no obvious trend in system median DAP value with voltage. The range of DAP values seen at the different tube voltages are generally very similar.

Figure 13. Chest PA projection: plot of system median DAP against X-ray tube voltage



Proposed NDRLs

Previous reviews in this series recommended national reference doses based on rounded third quartile dose index values of mean patient doses of nationally representative samples of radiography systems observed for common plain film radiography, fluoroscopy and IR exams. These national reference doses were then submitted to the Department of Health for approval as National Diagnostic Reference Levels (NDRL).

This review presents third quartile values of median patient doses, given to 2 significant figures, for common plain radiography, fluoroscopy and IR examinations from nationally representative samples of radiography and fluoroscopy systems as proposed NDRLs.

The change to using the system median dose index values, instead of mean dose index values, as used in previous national surveys, follows the recommendations of ICRP publication 135 (17). The effect of this change, as well as trends in mean DAP values over successive national surveys, is addressed further in the Discussion chapter, and in appendices H, I and G.

Proposed NDRL values are presented to 2 significant figures to avoid significant rounding errors that can be introduced for values close to 1, 0.1, 0.01 and so on. This practice is consistent with the approach used for 2019 review of CT NDRL values (12).

NDRLs aid in highlighting specific systems whose typical doses for given exams are higher than those generally found and may be worth investigating. When compared with local measurements characterising typical practice in each radiology department, they help to identify the systems and exam protocols requiring investigation and optimisation (21).

It is valid to propose NDRLs where there is demonstrated consistency of exam data, and the sample is representative of national practice. The NDRLs proposed in this report are based on system exam data sets of 30 or more patient exposures, usually from 20 or more radiography or fluoroscopy systems, 10 or more hospitals and always from 3 or more survey participants, hospital regions and healthcare organisations (for example, NHS trusts) for which this has been shown. This standard was chosen for the plain radiography single projections and plain radiography examinations considered by the survey as these are commonly performed, and this was a reasonably achievable sample size which had some continuity with the requirements of previous general surveys. It was a compromise with the ICRP publication 135 (17) recommended system sample size of 50 patients, and was made to aid the participation of smaller hospitals and clinics. For the less frequently performed fluoroscopy and IR procedures, the minimum number of systems represented for a 30 plus patient sample size has been relaxed in some cases. This was done where there was substantial additional supporting data from systems samples of 10 plus patients, which gave median and third quartile values consistent with those obtained from the 30 plus patient samples and where the survey indicated a substantial fall in typical dose since the 2010 review (7).

Plain radiography single projections

Revised or new NDRL DAP values are proposed for projections as listed alphabetically in Table 21.

Table 21. Proposed NDRL and Typical median DAP ($Gy.cm^2$) values for plain radiography single projections

Radiography projection	No. of systems	Typical (median)	NDRL
Abdomen anterior-posterior	188	1.3	1.7
Cervical spine anterior-posterior	115	0.074	0.096
Cervical spine lateral	114	0.088	0.11
Chest anterior-posterior	91	0.072	0.092
Chest anterior-posterior mobile (ward)	72	0.091	0.11
Chest posterior-anterior	301	0.063	0.077
Chest lateral	24	0.28	0.34
Foot (single) weight bearing dorsal-plantar	62	0.015	0.023
Hand (single) posterior-anterior	35	0.015	0.022
Hip (single) horizonal beam lateral	27	1.0	1.6
Knee (single) anterior-posterior	101	0.048	0.054
Knee (single) lateral	95	0.046	0.056
Lumbar spine anterior-posterior	140	1.1	1.4
Lumbar spine lateral	140	1.6	2.1
Pelvis anterior-posterior	237	1.2	1.6
Shoulder (single) anterior-posterior	165	0.074	0.090
Thoracic spine anterior-posterior	84	0.49	0.61
Thoracic spine lateral	93	0.79	0.95

Plain radiography examinations

NDRL DAP values are proposed for the plain radiography examinations listed alphabetically in Table 22. Care should be taken when using them to ensure that they are being compared with similar examinations. An NDRL value has been proposed for facial bones examination despite the value being based on only 19 system data sets of 30 or more patient studies as the median and third quartile values for 21 system data sets of 20 or more patient studies (0.59 and 0.79 $Gy.cm^2$ respectively) are similar.

Table 22. Proposed NDRL and Typical median DAP ($Gy.cm^2$) values for plain radiography examinations

Radiography examination	No. of systems	Typical (median)	NDRL
Abdomen	37	1.8	2.0
Cervical spine	96	0.18	0.24
Chest	62	0.076	0.12
Facial bones	19	0.59	0.82
Foot	41	0.039	0.049
Hip (single)	57	1.4	2.2
Knee (single)	122	0.11	0.13
Lumbar spine	116	3.0	3.9
Pelvis	59	1.6	1.9
Shoulder	39	0.17	0.20
Thoracic spine	41	1.5	2.0

Simple fluoroscopy examinations

NDRL DAP values are proposed for the fluoroscopy examinations given in Table 23.

Table 23. Proposed NDRL and Typical median DAP (Gy.cm^2) values for simple fluoroscopy examinations

Fluoroscopy examination	No. of systems	Typical (median)	NDRL
Barium swallow	46	3.3	5.0
Water soluble contrast swallow	15	3.9	5.3
Videofluoroscopy barium swallow	28	0.77	1.2
Water soluble contrast enema	13	6.1	8.2
Hysterosalpingography	23	0.37	0.55

The 2000, 2005 and 2010 reviews (5,6,7) recommended setting a single NDRL DAP value for pairs of similar barium contrast and water soluble contrast (WSC) exams, such as barium swallow and water soluble contrast (WSC) swallow, with the data from the 2 exams combined to derive it. However, the opinion of the UKHSA WP and stakeholders for the current review was that it was now appropriate to encourage separate optimisation of barium and WSC exams. To do that, it is appropriate to set separate NDRL values.

NDRL values are proposed for 2 exams, WSC swallow and WSC enema, for which fewer than 20 data sets of 30 or more patients DAP values were received. This is proposed as for both exams, DAP data was received for more than 20 systems for patient samples of 10 or more patients, and for 19 systems for patient samples of 20 or more patients. The median and third quartile values of the system median DAP value distributions showed consistency for the different minimum patient sample sizes. For instance, the WSC swallow median and third quartile values for system data sets of 20 or more patients were 3.2 and 5.3 Gy.cm^2 and for WSC enema 5.9 and 8.1 Gy.cm^2, close to the values given in Table 23.

Table 15 shows similar DAP distributions for WSC swallow and barium swallow. The proposed Typical and NDRL DAP values given in Table 23 are felt to be representative of these exams. Proposing these Typical and NDRL values also highlights the significant decrease in these exams' DAP values since the 2010 review (7) and encourages their separate optimisation.

The frequency of barium enema and WSC enema examinations have fallen significantly in the last decade, as other imaging methods have taken over. This drop in frequency caused barium enema not to be a requested examination for this survey. The survey received only one barium enema system DAP data set. That data set's mean and median DAP values fell well within the range of the received WSC enema DAP data. The data received by the survey for WSC enema (a requested exam) indicate a significant fall in DAP values for the exam since the 2010 review

(7). Therefore, it was felt appropriate to recommend a revised NDRL DAP value for WSC enema which better reflects present practice than does the 2010 Review NRD recommendation.

Simple interventional radiology procedures

NDRLs are proposed for the simple interventional radiology procedures given in Table 24.

Table 24. Proposed NDRL and Typical median DAP (Gy.cm^2) values for simple interventional radiology procedures

Interventional radiology procedures	No. of systems	Typical (median)	NDRL
ERCP (diagnostic and interventional)	29	3.0	6.4
Pacemaker: permanent (single or dual chamber)	26	1.2	1.7
Insertion of tunnelled central venous catheter	19	0.36	0.65
PICC line insertion	14	0.19	0.31
Radiologically inserted gastrostomy tube	9	0.62	1.3
Nephrostomy	20	1.0	1.5
Nephrostomy tube replacement	12	0.32	0.52
Stent: ureteric (antegrade and retrograde)	10	1.8	3.0

The NDRLs for 'ERCP (diagnostic and interventional)', 'Pacemaker: permanent (single or dual chamber)' and 'Stent: ureteric (antegrade and retrograde)' should be used with the awareness that these 3 exams contain data from 2 marginally different procedures. However, insufficient data was received for the individual procedures to propose NDRL DAP values for them separately. Proposing NDRL DAP values for the combined categories was considered warranted because there has been a significant fall in DAP values for all 3 procedures since the 2010 review (7).

Typical and NDRL values are proposed for 5 procedures for which less than 20 system data sets of 30 or more patient DAP values were received. These procedures are Insertion of tunnelled central venous catheter for which 19 system data sets were received, PICC line insertion, radiologically inserted gastrostomy tube, nephrostomy tube replacement, and Stent: Ureteric (antegrade and retrograde).

As was the case for fluoroscopy examinations, the justification for proposing Typical and NDRL values for these exams was the receipt of a reasonable number of system data sets with a patient sample size of 10 or more for each procedure and the consistency of median and third quartile values for system median DAP for the different minimum patient sample size system data sets. Further, in all cases, DAP values are significantly below those of the 2010 review (7), and it was felt important to reflect this decrease in the current proposed NDRLs.

Discussion

Trends in survey data

Key data from the 2019 survey was compared with that from previous UK national general surveys (5,6,7) to give some indication of national trends in doses and participation. These are presented in Appendix G, with summaries presented here.

System mean patient DAP values

For comparison with data from previous surveys, the 2019 data was also analysed using system mean values (Appendix F). Previous surveys had limited median data, so it was not possible to do the comparison based on system median values.

Table 25. Average percentage dose reduction between reviews of system mean dose index values

Survey comparison	Modality	Dose parameter	
		Mean, % decrease	Third quartile, % decrease
1995 to 2000	Single projections, all examinations, and procedures	16	20
2000 to 2005	Single projections, all examinations, and procedures	16	16
2005 to 2010	Single projections, all examinations, and procedures	5	10
2010 to 2019	Single projections	22	13
	Plain radiography and fluoroscopy examinations, and IR procedures	40	35

Table 25 summarises the average change per exam of the mean and third quartile system mean dose index values between successive surveys since 1995 (7). Appendix G gives more detailed information on the trends for DAP values for specific examinations in successive surveys since 2000 (5,6,7).

The comparisons given in Table 25 are approximate. Key differences in the survey data which may affect the comparisons are the transition through successive surveys from smaller system data sets, curated for patient weight, to larger data sets without weight data, and also that the comparisons up to 2010 includes the trends for DAP, ESD and fluoroscopy time, whereas 2010 to 2019 only compares DAP values.

For the comparison of the 2010 and 2019 surveys, a separate entry is given for plain radiography single projections because of the difference in their percentage decrease compared to that of the other examinations and procedures. However, all the modalities show a continuation of the general downward trend in average mean dose index values per exam for adult patients that has been seen since the 1995 review (7). This suggests a trend indicating continued improvements in such factors as optimisation of exposures.

For DAP values for plain radiography, there is a larger average percentage decrease for complete exams than for projections. One explanation could be that the increased access to CT and MRI imaging for complex cases has resulted in fewer plain radiography examinations that require a large number of projections.

For fluoroscopy exams and IR procedures, the decrease in mean DAP values per exam not only suggests increased implementation of dose optimisation practices, but also gains from advances in imaging and operative technology.

The exams which are exceptions to the general trend of decreasing mean system mean DAP are considered in Appendix G. For plain radiography single projections (figures G1, G2, Table G1) these are lumbar spine AP, lumbar spine lateral, and chest lateral. For plain radiography examinations (figures G3, G4, Table G2) the only minor, and statistically non-significant, dose increases are for the high frequency, but low dose, foot and shoulder examinations.

For fluoroscopy examinations and IR procedures for which reasonably robust 2019 data is available, figures G5 to G7 and Table G3 show system mean DAP values generally decreasing. In cases where the 2019 survey data is limited there are instances of both apparent dose increases (for example, nephrostogram) and of large decreases in dose (for example, angiography – femoral) which it may be useful to explore further by collecting more substantial data samples.

Table G3 records an increase in the third quartile system mean DAP value of water soluble contrast (WSC) swallow between the 2010 and 2019 surveys. However, this increase is not supported by other evidence, with the mean value for WSC swallow in Figure G5 unchanged from the 2010 survey, and its third quartile system median DAP values comparable with that of barium swallow (Table H3). Student's unpaired 2-tailed t-test indicates no statistical difference between the 2010 and 2019 survey mean DAP values for barium meal and swallow, barium swallow and WSC swallow.

Comparison of mean fluoroscopy times from 2010 and 2019 surveys

Comparison of fluoroscopy time mean system mean and third quartile system mean values for the 2010 and 2019 surveys are shown in Table E7 in Appendix E. The 2010 survey (7) data is more statistically robust than that of the 2019 survey, with the system mean values based on many more fluoroscopy systems. However, for most exams or procedures the 2019 mean and third quartile values of the system mean values are of the same order, or less than, the 2010 values.

Survey demographics

Trends in the number of participating hospitals, and of radiography and fluoroscopy systems in the General survey, together with the total number of patient DAP values contributed for specific exams, are shown in Appendix G (figures G8 to G22). Factors which may have influenced some of these measures of participation are noted. Most significantly, the patient sample sizes for exams have, in general, increased, probably due to the automation of dose data collection. Exceptions to this are usually where the use of specific examinations or procedures have diminished.

Comparison of system mean and median DAP values

ICRP Publication 135 (17) recommended the adoption of DRL values and NDRL values based on system median dose index values rather than system mean dose index values. ICRP publication 135 states that this recommendation was because NDRLs based on system median dose index values (50th percentiles) are considered to represent typical practice more closely than those based on system mean dose index values. This is because outlying dose index values have a greater effect on the system mean dose index value than on the system median dose index value.

The change to proposing NDRLs based on system median dose index values has caused a step decrease to all the NDRL DAP values proposed by this survey, compared to the values that would have been proposed based on system mean DAP values. Appendix H gives information for each exam for which NDRL values are proposed, showing that all have lower third quartile system median values than third quartile system mean values. The average difference between median and mean values for these exams were −16% (range −9% to −32%) for the 18 plain radiography single projections, −21% (range −3% to −36%) for the 11 plain radiography examinations, −20% (range −11% to −48%) for the 5 simple fluoroscopy examinations, and −44% (range −23% to −60%) for the 8 simple IR procedures.

Appendix I illustrates the overall change in values used for recommending NDRL between the 2010 and 2019 surveys, reflecting the influence of all factors contributing to the data, that is, not only reduction in doses but also the influence of the change from mean to median and changes in data collection methods. These show an average decrease in DAP values of −30% for plain radiography single projections and, typically, decreases of more than 50% for most plain radiography and fluoroscopy examinations, and for IR procedures,

Imaging equipment

Direct digital radiography (DR and FPD) has continued to grow in comparison to the use of indirect digital radiography (CR and II). For plain radiography projections, a comparison of DAP values from this survey with the 2010 survey (7), gives generally larger decreases in patient DAP values for systems using DR detectors than CR detectors. A similar comparison is not possible for fluoroscopy systems based on detector type, mainly because the 2010 survey received very little data from systems that used direct digital detectors for some exam categories such as barium and water soluble contrast medium studies.

However, the 2019 survey shows that CR and II are still used by a significant fraction of systems and for a substantial fraction of diagnostic imaging exams. The presence of CR with X-ray tube installation dates as early as 2002 indicates that there are older systems in use. The continued replacement of older systems with new systems using contemporary technology provides additional opportunities for reducing patient dose without sacrificing diagnostic capabilities. This implies that there is potential for further reductions in patient doses.

Diagnostic imaging data software platforms

The information gathered on the data collection methods used by survey participants showed Radiology Information Systems (RIS) were the main means used to collate data for this survey. Approximately 3 times as many radiography systems and 4 times as many fluoroscopy systems used RIS rather than Dose Management Systems (DMS) to collate the survey data. While both RIS and DMS can be used to effectively conduct patient dose optimisation programs it is expected that the use of DMS for conducting dose surveys will increase as experience in their use is established. Both software platforms may assist with the further automation of dose surveys.

Alternative dose indices

Dose Area Product (DAP) was designated as the essential dose index parameter for this survey, and used to propose NDRLs. The survey also requested data on other dose index parameters, fluoroscopy time and cumulative air kerma at an IEC reference point, as 'very useful information'. The limited data received for these, and other dose index parameters, are discussed below.

Fluoroscopy time data was requested as 'very useful information'. Table 9 shows that only 213 system exam fluoroscopy time data sets were received by the survey as opposed to the approximately 600 system exam DAP data sets received for unrequested exams. This is probably because, currently, many centres do not routinely collect fluoroscopy time data. This may be because standard use of RIS only allows the recording of one type of dose index parameter. The recording of fluoroscopy time values, and of other dose indices, may increase with the further adoption of automated data collection and analysis, as recommended by ICRP Publication 135 (17).

Cumulative air kerma at the IEC reference point data (also known as ‘air kerma’, ‘Dose at a reference point’, or ‘Skin dose’), which was also requested as ‘very useful information’, was provided by a very small group of participants, with insufficient data to report any values in this report.

The survey also received highly limited samples of Exposure Index and Deviation Index data, entered in the ‘Other information of interest’ data entry fields.

The lack of data the survey received for other dose indices, combined with the present variation in the measurement scales used by radiography and fluoroscopy systems to record some of these dose indices, indicates that it is not yet appropriate to adopt any of these parameters as NDRL candidates. IEC (30) have set official international definitions for both cumulative air kerma at the IEC reference point and ‘Exposure Index’, but many radiography and fluoroscopy systems are still not using these internationally agreed definitions to measure these dose indices. This issue should be reviewed once most systems have adopted reporting these parameters using the agreed international definitions.

No Entrance Surface Dose (ESD) data was received by the survey.

Promoting the use of NDRLs for specific clinical indicators

ICRP and other international bodies such as the European Society of Radiology promote diagnostic reference levels (DRL), and hence NDRLs, based on imaging performed for a specific clinical objective. ICRP term this the ‘clinical task’, while the European Society of Radiology uses the terms ‘clinical indication’ or ‘clinical DRL’ (17).

UK CT NDRL values have been based on requested exams performed for specific clinical indications (9,10,12) since the legal adoption of NDRLs.

For the general X-ray, simple fluoroscopy and IR survey, clinical indicators were explicitly stipulated for the requested mobile fluoroscopy examinations and were inherent for some fluoroscopy examinations and IR procedures through their titles, for example, Insertion of tunnelled central venous catheter. To date, clinical indicators have not been used for UK plain radiography NDRLs, for either single projections or for examinations. Consideration will be given to adopting clinical indicators for some plain radiography NDRLs, and to using more specific definitions for some fluoroscopy and IR NDRLs.

Comparison with other countries’ NDRL values

Not all countries publish DAP NDRL values for plain radiography single projections and examinations. Countries which have introduced NDRLs relatively recently have, very logically, tended to focus on establishing NDRL values for CT exams, as the higher dose modality. Other nations such as Japan, Indonesia and Iran have chosen to set ESD NDRL values for plain radiography single projections (44,45,46). The American Association of Physicists in Medicine gave limited guidance for ESD for Chest PA and Abdomen AP in Table 1 of the 2018 document ACR–AAPM–SPR Practice Parameter for Diagnostic Reference Levels and Achievable Doses in Medical X-Ray Imaging (47) which are based on measurements of a standard phantom rather than patient imaging. DRLs for fluoroscopy are also suggested, again using phantom measurements.

Table 26 compares the DAP typical and NDRL values for some of the plain radiography single projections proposed by this review to typical and NDRL DAP values recently established by Germany (48,49), the Republic of Ireland (50) and for Malta (51). The German NDRLs values given are taken from Table 1 of the Bundesanzeiger Federal Gazette January 2023 publication (48). These NDRL values differ marginally from the 75th percentile values of the 2019 publication (49), whose 50th percentiles are used for the German typical values in Table 26. Table 26 entries can be compared with Netherland's adult NDRL and achievable dose values (median) for DR detector systems, provided in the Nederlandse Commissie voor Stralingsdosimetrie 2012 report 'Diagnostische referentieniveaus in Nederland' (52) of 0.12 and 0.06 $Gy.cm^2$ for chest PA, and 3 and 1.5 $Gy.cm^2$ for pelvis AP.

Table 26. A comparison of plain radiography single projection DAP NDRL values (Gy.cm^2) of UK, Germany, Ireland and Malta

Country	Proposed UK		Germany		Ireland		Malta	
Plain radiography single projection	Typical: median	NDRL	Typical: median [note 1]	NDRL [note 2]	Typical: median	NDRL	Typical: median	NDRL
Abdomen AP	1.3	1.7	1.6	2.0	1.39	1.7	0.96	1.8
Cervical spine AP	0.074	0.096	-	-	0.13	0.16	0.12	0.18
Cervical spine LAT	0.088	0.11	-	-	0.14	0.19	0.08	0.13
Chest AP	0.072	0.092	-	-	0.10	0.12	-	-
Chest AP mobile	0.091	0.11	-	0.15	0.13	0.16	-	-
Chest PA	0.063	0.077	0.09	0.12	0.08	0.12	0.10	0.15
Chest LAT	0.28	0.34	0.28	0.40	-	-	0.40	0.80
Foot (single) DP	0.015	0.023	-	-	0.04	0.06	-	-
Hand (single) PA	0.015	0.022	-	-	0.04	0.06	-	-
Lumbar spine AP	1.1	1.4	1.4	2.0	1.2	1.6	1.92	3.8
Lumbar spine LAT	1.6	2.1	2.3	3.3	1.56	2.24	1.66	2.9
Pelvis AP	1.2	1.6	1.7	2.3	-	-	1.2	2.4
Thoracic spine AP	0.49	0.61	0.77	1.0	0.53	0.76	0.53	0.99
Thoracic spine LAT	0.79	0.95	0.86	1.2	0.92	1.8	0.82	1.6

1. German typical values taken from reference (49).
2. German NDRL values taken from reference (48).

Table 27 compares the proposed UK, German (48,49) and Maltese (51) typical and NDRL DAP values for the fluoroscopy examinations, barium swallow, videofluoroscopy barium swallow and the IR procedure ERCP. The Bundesanzeiger Federal Gazette article (48) lists the ERCP DAP NDRL as 2000 cGy.cm^2 in the table of interventional procedures, but in the journal RoFo (49), ERCP is listed in the table of fluoroscopy examinations as having 50th and 75th percentile values of 1000 and 2600 cGy.cm^2 respectively, hence the double entry in Table 27.

Table 27. A comparison of fluoroscopy examination and IR procedure DAP typical and NDRL values (Gy.cm^2) of UK, Germany and Malta

Country	Proposed UK		Germany		Malta	
Examination or procedure	**Typical: median**	**NDRL**	**Typical: median**	**NDRL**	**Typical: median**	**NDRL**
Barium swallow	3.3	5.0			3.81	6.24
Videofluoroscopy barium swallow	0.77	1.2			0.64	1.22
ERCP (diagnostic and interventional)	3	6.4	10	26 (48) 20 (49)		

Table 28. A comparison of plain radiography single projection DAP NDRL values (Gy.cm^2) of proposed UK values and EUCLID review of European NDRL values

	Proposed UK	European NDRL summary		
Plain radiography single projection	**NDRL**	**Most common NDRL value**	**Range**	**Ratio: max ÷ min**
Abdomen AP	1.7	3	2.0 to 8.0	4
Chest PA	0.077	0.16	0.12 to 1.0	8.3
Chest LAT	0.34	0.6	0.25 to 1.0	2.7
Lumbar spine AP	1.4	2.3	1.5 to 10	6.7
Lumbar spine LAT	2.1	4.2	2.75 to 8.0	2.9
Pelvis AP	1.6	3	1.5 to 7.0	4.7
Thoracic spine AP	0.61	1.3	0.97 to 2.2	2.3
Thoracic spine LAT	0.95	1.7	1.2 to 3.2	2.7

The report, '2018 European Study on Clinical Diagnostic Reference levels for X-ray Imaging (Euclid) Deliverable 2.1: Report and review on existing clinical DRLs' (53) provides a summary in its Table 16 of the basis of DRL values for adult X-ray examinations in European countries. In the same document Table 18 gives a summary of the more common plain radiography single projection NDRL DAP values in mGy.cm^2. These are compared with the proposed UK 2019 survey NDRL values in Table 28.

As many of the European NDRLs included in the EUCLID survey predate 2018 by several years, it is not surprising that most of the European ‘most common NDRL values’ are higher than this review’s proposed values.

This limited comparison of countries’ DAP NDRL, mostly focused on values for plain radiography single projections, shows that the values proposed by this review are similar to, or slightly lower than, those that have been recently introduced in other countries.

Conclusion

The review proposes revised NDRL DAP values for 18 plain radiography single projections, 11 plain radiography examinations, 5 simple fluoroscopy examinations and 8 simple IR procedures. In accordance with the recommendations of ICRP publication 135 (17), the proposed NDRL values are based on third quartile values of system median DAP distributions, rather than the previously used third quartiles of system mean distributions.

The proposed NDRL values are lower than current NDRLs for most exams with the reduction varying widely according to exam. Plain radiography single projection NDRLs are lower by an average of 30%, plain radiography examinations are typically reduced by about 50%, with decreases for fluoroscopy examinations and IR procedures ranging from 30% to 90%.

The reduced NDRL values are influenced by the change to using system median values, resulting in a typical decrease of 10% to 50%, and by other changes in data collection methodology.

Taking into account all the changes in data collection analysis and methodology, the general trend in DAP values suggests an overall decrease in dose to patient per exam. A comparison of the system mean distributions of the 2019 and the 2010 surveys (7) demonstrates that in almost all cases the 2019 third quartile values are lower. However, there are exams for which the 2019 survey values are higher. The lumbar spine AP and lumbar spine lateral projections may warrant special investigation. Other cases have mitigating factors, such as being low dose imaging of an extremity (foot examination), or a value from a relatively small sample of system mean DAP values with median DAP values that are less suggestive of a real increase in patient dose (WSC swallow).

The reduction in patient DAP values, and subsequent recommended NDRLs, observed by the 2019 survey, is the result of the continuing UK programme of optimising radiography and fluoroscopy diagnostic imaging carried out by the medical physics and radiology communities. Evidence suggests that this trend will continue with further reductions gained without sacrifice of image quality as older equipment currently in use gets replaced. It will also be aided by active engagement across medical physics and radiology professions in optimisation which, it is hoped, this, and other dose surveys and audits, encourages and promotes.

The influence of increasing automation of data collection has been seen both in the increase in the average sample size of the received system data sets, and the increased number of exams for which individual radiography systems typically provide data. It is hoped that the advantages this brings to data collection, together with other technological advances, can be harnessed to further automate aspects of conducting dose surveys, so increasing the practicality of conducting them at more frequent and regular intervals. This is a non-trivial challenge with respect to data quality control and assurance, and with respect to staff resources required both by participants and survey organisers, but it is one worth pursuing.

A disadvantage of retrospective data collection being the primary means of data collection is the current non-availability of patient weight information. Patient weight data decreased from being provided for approximately 70% of all DAP values in the 2000 survey (5), to 36% in the 2010 survey (7), to 0.6% of DAP values in the 2019 survey, representing only 5% of the survey's system data sets. This issue is of particular importance for paediatric dose surveys, where such information is essential for most exams.

The use of plain radiography and fluoroscopy has decreased for some specific diagnostic objectives as the use of other modalities is now preferred, as newer technology becomes more widely available and in compliance with national guidance (26,27).

The response to this survey indicates that for plain radiography, fluoroscopy, and IR, at present, DAP was the principal dose index for which data was submitted, and for which NDRL values could be set. One cause of this may be because a large fraction of participants drew their data from their RIS platform, and RIS typically permits only one type of dose index to be recorded. Increased use of DMS and changes to RIS platforms may well increase the automatic recording of other dose indices, and hence enable the establishing of both DRLs and NDRLs for additional dose indices. This situation should be kept under review, especially when it becomes the norm for radiography systems to record dose indices such as Exposure Index using the internationally agreed dose scales.

In compliance with the guidance of ICRP (17) and IAEA (54), future national reviews of patient diagnostic dose will be conducted to monitor national performance and to provide appropriate NDRL values as the use of plain radiography, fluoroscopy, and interventional radiology continues to evolve.

Acknowledgements

The reviews and surveys on which UK NDRL recommendations rely are entirely based on the voluntary participation of diagnostic imaging teams and their colleagues across the UK. We would like to thank all the staff in all the hospitals and clinics that carried out or assisted with the collection of information for the survey, its quality assurance and entry into the survey Excel workbooks. These are all non-trivial tasks and without them the survey and review could not have taken place. Participants are thanked for taking part in the survey and for their prompt responses to queries on data quality assurance and analysis.

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Appendix A: Participating organisations

The names of participating organisations are recorded as stated at the time of the survey.

Barking, Havering, and Redbridge University Hospitals NHS Trust

Queen's Hospital, Romford

Barts Health NHS trust

Barts Heart centre, St Bartholomew's Hospital, London

Newham University Hospital, London

Royal London Hospital, London

St Bartholomew's Hospital, London

Whipps Cross University Hospital, London

Bedfordshire Hospitals NHS Foundation Trust

Bedford Hospital, Bedford

Luton and Dunstable University Hospital, Luton

Betsi Cadwaladr University Health Board

Abergele Hospital, Abergele

Alltwen Hospital, Tremadog

Bryn Beryl Hospital, Pwllheli

Colwyn Bay Community Hospital, Colwyn Bay

Deeside Community Hospital, Aston

Denbigh Community Hospital, Denbigh

Dolgellau and Barmouth District Hospital, Dolgellau

HMP Berwyn, Wrexham

Holywell Community Hospital, Holywell

Llandudno General Hospital, Llandudno

Mold Community Hospital, Mold

Royal Alexandra Hospital, Rhyl

Tywyn and District War Memorial Hospital, Tywyn

Wrexham Maelor Hospital, Wrexham

Ysbyty Glan Clwyd, Rhyl

Ysbyty Gwynedd, Bangor

Ysbyty Penrhos Stanley, Holyhead

Brighton and Sussex University Hospitals NHS Trust

Hove Polyclinic, Hove

Princess Royal Hospital, Haywards Heath

Royal Sussex County Hospital, Brighton

Sussex Orthopaedic Treatment Centre, Haywards Heath

Buckinghamshire Healthcare NHS Trust

Amersham Hospital, Amersham

Buckingham Community Hospital, Buckingham

Stoke Mandeville Hospital, Aylesbury

Wycombe Hospital, High Wycombe

Care UK

Havant NHS Diagnostic Centre, Havant

St. Mary's NHS Treatment Centre, Portsmouth

Cwm Taf Morgannwg University Health Board

Princess of Wales Hospital, Bridgend

East Kent Hospitals University NHS Foundation Trust

Kent and Canterbury Hospital, Canterbury

Queen Elizabeth The Queen Mother Hospital, Margate

William Harvey Hospital, Ashford

East Lancashire Hospitals NHS Trust and Integrated Radiological Services (IRS) Ltd

Accrington Victoria Community Hospital, Accrington

Burnley General Teaching Hospital, Burnley

Clitheroe Community hospital, Clitheroe

Rossendale Primary Care Centre, Rossendale

Royal Blackburn Hospital, Blackburn

East Suffolk and North Essex NHS Foundation Trust

Aldeburgh Community Hospital, Aldeburgh (Suffolk Community Healthcare)

Clacton and District Hospital

Colchester Hospital, Colchester

Fryatt Hospital, Harwich (Anglia Community Enterprise CIC)

Halstead Hospital, Halstead

Ipswich Hospital, Ipswich

Greater Glasgow and Clyde NHS Board

Clydebank Health Centre, Clydebank

Gartnavel General Hospital, Glasgow

Glasgow Royal Infirmary, Glasgow

Inverclyde Royal Hospital, Greenock

New Victoria Hospital, Glasgow

Queen Elizabeth University Hospital, Govan

Royal Alexandra Hospital, Paisley

Shettleston Health Centre, Glasgow

Stobhill ACH, Glasgow

Vale of Leven Hospital, Alexandria

West Glasgow Ambulatory Care Hospital, Glasgow

Hull and East Yorkshire Hospitals NHS Trust

Bransholme Health Centre, (Hull City Health Care Partnership CIC)

Castle Hill Hospital, Hull

East Riding Community Hospital, Beverley

Hornsea Cottage Hospital, Hornsea

Hull Royal Infirmary, Hull

Withernsea Community Hospital, Withernsea

Hywel Dda University Health Board

Glangwili General Hospital, Carmarthen

Llandovery Hospital, Llandovery

Withybush General Hospital, Haverfordwest

Manchester University NHS Foundation Trust

Manchester Royal Infirmary, Manchester

National Centre for Sport and Exercise Medicine

National Centre for Sport and Exercise Medicine – East Midlands

NHS Ayrshire and Arran

Arran War Memorial Hospital, Isle of Arron (North Ayrshire Community Health Partnership)

Ayrshire Central Hospital, (Irvine North Ayrshire Community Health Partnership)

East Ayrshire Community Hospital, Cumnock (East Ayrshire Community Health Partnership)

Girvan Community Hospital, Girvan (Sothern Ayrshire Community Health Partnership)

University Hospital Crosshouse, Kilmarnock

University Hospital Ayr, Ayr

NHS Borders

Borders General Hospital, Melrose

NHS Dumfries and Galloway

Dumfries and Galloway Royal Infirmary, Dumfries

Galloway Community Hospital, Stranraer

NHS Fife

Adamson Hospital, Cupar

Glenrothes Hospital, Glenrothes

Queen Margaret Hospital, Dunfermline

St Andrews Community Hospital, St Andrews

Victoria Hospital, Kirkcaldy

NHS Forth Valley

Forth Valley Royal Hospital, Stirling

Stirling Care Village, Stirling

NHS Golden Jubilee National Hospital

Golden Jubilee National Hospital, Clydebank

NHS Highland

Aviemore Medical Centre, Aviemore

Belford Hospital, Fort William

Caithness General Hospital, Wick

County Community Hospital, Invergordon

Dr MacKinnon Memorial Hospital, Broadford

Lawson Memorial Hospital, Golspie

Nairn Town and County Hospital, Nairn

Portree Community Hospital, Portree

Raigmore Hospital, Inverness

Ross Memorial Hospital, Dingwall

NHS Lanarkshire

Monklands Hospital, Airdrie

Wishaw General Hospital, Wishaw

University Hospital Hairmyres, East Kilbride

NHS Lothian

East Lothian Community Hospital, Haddington

Lauriston Building, Edinburgh

Leith Community Treatment Centre, Leith

Midlothian Community Hospital, Bonnyrigg

Royal Infirmary of Edinburgh, Edinburgh

St John's Hospital, Livingston

Western General Hospital, Edinburgh

NHS Tayside

Ninewells Hospital, Dundee

North Bristol NHS Trust

Cossham Hospital, Bristol

North Somerset Community Hospital, Clevedon (North Somerset Community Partnership CIC)

Southmead Hospital, Bristol

Yate West Gate Centre and Minor Injuries Unit, Bristol (Sirona Care and Health CIC)

North Middlesex University Hospital

North Middlesex University Hospital, Haringey

Nottingham University Hospitals NHS Trust

Nottingham City Hospital

Queen's Medical Centre, Nottingham

Oxford University Hospitals NHS Foundation Trust

Churchill Hospital, Oxford

Horton Hospital, Banbury

John Radcliffe Hospital, Oxford

Nuffield Orthopaedic Centre, Oxford

Portsmouth Hospitals NHS Trust

Fareham Community Hospital, Fareham (Southern Health NHS Foundation Trust)

Gosport War Memorial Hospital, Gosport (Southern Health NHS Foundation Trust)

Petersfield Community Hospital, Petersfield (Hampshire and Isle of Wight Healthcare NHS Foundation Trust)

Queen Alexandra Hospital, Portsmouth

Powys Teaching Health Board

Montgomery County Infirmary, Newtown

Victoria Memorial Hospital, Welshpool

Ystradgynlais Community Hospital, Swansea

Royal Brompton and Harefield NHS Foundation Trust

Royal Brompton Hospital, London

Royal Brompton and Harefield Hospitals Specialist Care, London

Royal Free London NHS Foundation Trust

Barnet General Hospital, Barnet

Chase Farm Hospital, Enfield

Edgware Community Hospital, Edgware

Finchley Memorial Hospital, North Finchley (Central London Community Healthcare NHS Trust community hospital, hospital service provided by RFL NHS Foundation Trust)

Royal Free Hospital, London

Royal Free London NHS Foundation Trust Private Patients Unit

Hadley Wood Hospital, Barnet

Royal United Hospitals Bath NHS Foundation Trust

Chippenham Community Hospital, Chippenham (Great Western Hospitals NHS Foundation Trust)

Frome Community Hospital, Frome (Somerset NHS Foundation Trust)

Melksham Community Hospital, Melksham (Salisbury NHS Foundation Trust)

Royal Wolverhampton NHS Trust

Royal United Hospital, Bath

Trowbridge Community Hospital, Trowbridge (Great Western Hospitals NHS Foundation Trust)

Warminster Community Hospital, Warminster (Salisbury NHS Foundation Trust)

Royal Wolverhampton NHS Trust

New Cross Hospital, Wolverhampton

Southend University Hospital NHS Foundation Trust

Canvey Clinic, Canvey Island

Southend University Hospital, Southend-On-Sea

St George's University Hospital NHS Foundation Trust

St George's University Hospital, London

Swansea Bay University Health Board

Morriston Hospital, Swansea

Neath Port Talbot Hospital, Port Talbot

Singleton Hospital, Swansea

The Hillingdon Hospitals NHS Foundation Trust

Hillingdon Hospital, Uxbridge

Mount Vernon Hospital, Northwood

The Newcastle upon Tyne Hospitals NHS Foundation Trust

Freeman Hospital, Newcastle upon Tyne

Molineux Street NHS Centre

Royal Victoria Infirmary, Newcastle upon Tyne

The Royal Marsden NHS Foundation Trust

The Royal Marsden Hospital, Chelsea

The Royal Marsden Hospital, Sutton

The Shrewsbury and Telford Hospital NHS Trust

Princess Royal Hospital, Telford

Royal Shrewsbury Hospital, Shrewsbury

University Hospital Southampton NHS Foundation Trust

Princess Anne Hospital, Southampton

Royal South Hants Hospital, (Southampton NHS Property Services Ltd and Care UK)

Southampton General Hospital, Southampton

University Hospitals Bristol NHS Foundation Trust

Bristol Haematology and Oncology Centre, City of Bristol

Bristol Royal Infirmary, City of Bristol

South Bristol Community Hospital, Bristol

University Hospitals of Derby and Burton NHS Foundation Trust

Queen's Hospital, Burton-on-Trent

University Hospitals of North Midlands NHS Trust

Royal Stoke University Hospital, Stoke-on-Trent

The County Hospital, Stafford

Western Health and Social Care Trust, NI

Altnagelvin Area Hospital, Londonderry

Weston Area Health NHS Trust

Weston General Hospital, Weston-Super-Mare

Appendix B: Projections, examinations and procedures

Plain radiography projections

Requested

Abdomen Anterior-Posterior (AP) view

Cervical spine AP view

Cervical spine Lateral (LAT) view

Chest AP view

Chest mobile X-ray AP (ward) view

Chest Posterior-Anterior (PA) view

Chest LAT view

Foot (single) weight bearing Dorsal-Plantar (DP) view

Hand (single) PA view (palm on plate)

Hip (single) Horizontal Beam Lateral (HBL)

Knee (single) AP view

Knee (single) LAT view

Lumbar spine AP view

Lumbar spine LAT view

Pelvis AP view

Shoulder (single) AP view

Thoracic spine AP view

Thoracic spine LAT view

Additional: limited data received

Facial bones Occipito-Mental (OM) view (also called Waters view)

Facial bones Occipito-Mental view acquired at 30 degrees from horizontal (OM30 view)

Hip (single) AP view

Shoulder (single) Axial view

Plain radiography examinations

Requested

Abdomen complete exam

Cervical spine complete exam

Chest complete exam

Facial bones complete exam

Hip (single) complete exam

Knee (single) complete exam

Leg length measurement (single leg)

Lumbar spine complete exam

Pelvis complete exam

Skeletal survey complete exam

Thoracic spine complete exam

Additional

Foot (single) complete exam

Hand (single) complete exam

Shoulder (single) complete exam

Fluoroscopy examinations

Requested

Angiography – cerebral

Imaging of blood vessels of the cerebral (brain) blood vessels using contrast medium.

Angiography – femoral

Imaging of the femoral arteries in the legs, sometimes including part of the lower torso (groin), using a contrast medium, typically to investigate the legs' blood supply.

Arthrography – hip

Imaging to enable injection into the hip joint. The injection may be a contrast medium to enable imaging of the hip joint, or of steroid medication to reduce inflammation and so hopefully alleviate pain. Ultrasound may now also be used to image the injection and MRI for examination of the joint.

Barium meal and swallow

Imaging of the pharynx, oesophagus, stomach, and duodenum after swallowing barium sulphate suspension as a contrast medium to look at the lining of the oesophagus and stomach.

Barium swallow

Imaging of the pharynx, and full length of the oesophagus to the stomach after swallowing barium sulphate suspension as a contrast medium. Used to check for physical abnormalities such as the presence of cancer. There is a higher DAP value associated with this examination than videofluoroscopy barium swallow as a far longer section of the digestive tract is imaged.

Hysterosalpingography (HSG)

Imaging of the uterus, especially the fallopian tubes, following an injection of contrast medium through the cervix.

Videofluoroscopy barium swallow

Video-imaging of the mouth, pharynx, larynx and oesophagus to approximately the level of the jugular notch at the top of the rib cage after swallowing barium sulphate suspension as a contrast medium. Performed to investigate the kinetics of swallowing and for speech therapy.

Water soluble contrast enema

Imaging 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. Use of an iodine-based contrast medium can also enhance the visibility of vascular structure and organs.

Water soluble contrast swallow

Imaging of the pharynx, and full length of the oesophagus to the stomach after swallowing iodinated water soluble contrast medium, performed in preference to a barium swallow if there is a risk of leakage from the gastro-intestinal tract. Use of an iodine-based contrast medium can also enhance the visibility of vascular structure and organs.

Additional

Angiogram – coronary

Imaging of blood vessels which supply blood to heart muscles using a contrast medium.

Cystogram

A procedure using a contrast medium to image the urinary bladder and its function.

Nephrostogram

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.

Percutaneous transhepatic cholangiography (PTC)

Injection of contrast medium into a bile duct to image the biliary system. Often associated with an IR procedure such as the introduction of a catheter, balloon dilation of the bile duct, removal of gallstones, placement of a stent, or drainage through a catheter. Care is therefore required in dose audits to ensure the procedure is correctly documented, and that only the diagnostic examination took place.

Proctogram

Anal-rectal imaging of defecation for diagnosing the cause of issues or symptoms.

Sialogram

Imaging of the salivary system using iodine contrast medium injected into a dilated orifice of a salivary gland

T-tube cholangiogram

Imaging of the biliary system performed post-operatively after the removal of the gallbladder by injecting contrast medium through a T-tube catheter placed in the common bile duct during surgery. (The T-tube catheter is so called for its shape, and is not to be confused with a tympanostomy tube which is used in ear surgery)

Interventional radiology procedures

Requested

Diagnostic endoscopic retrograde cholangiopancreatography (ERCP – diagnostic)

Diagnostic examination of the biliary tree (a system of vessels that directs secretions from the liver, gallbladder, and pancreas into the duodenum), and of the pancreatic ducts using water soluble contrast medium. (Technically a fluoroscopy exam but placed here for convenience.)

Interventional endoscopic retrograde cholangiopancreatography (ERCP – interventional)

Interventional procedures in the biliary tree and pancreatic ducts including stone removal, tissue sampling, endoscopic papillary balloon dilation, drainage, and the placement of biliary and pancreatic stents.

Cardiac catheter ablation

Performed in cases of heart arrhythmia to identify the source of the arrhythmia by passing catheters through blood vessels into the heart to record and stimulate the heart's electronic activity. Once the area of heart muscle that is causing the arrhythmia is identified it is destroyed using heat (radiofrequency ablation) or freezing (cryoablation).

Facet joint injection

Injection of local anaesthetic (for pain relief) and/or steroid (to reduce inflammation) into the facet joints of vertebra usually in the lumbar region of the spine using fluoroscopic imaging for accurate insertion of the injection.

Radiologically inserted gastrostomy (RIG) tube

This procedure inserts a gastrostomy tube (small feeding tube) through the skin directly into the stomach using fluoroscopic imaging to guide the procedure. It is performed to achieve feeding access in patients with tumours of the head and neck or oesophagus. RIG is an alternative method of tube positioning to that used for percutaneous endoscopic gastrostomy (PEG) where a gastroenterologist uses an endoscope inserted into the patient’s stomach to image the lining of the stomach while illuminating the equivalent position on the patient’s skin to determine the position of the tube.

Insertion of tunnelled central venous catheter (TCVC)

Under local anaesthetic, a tunnelled central venous catheter is inserted under the skin typically in the neck but also groin, chest or back. Some distance from that entry point the catheter is inserted into a vein through which the catheter is then threaded to usually end in the vena cava in the heart. Outside of the body the catheter may have up to 3 inlets (lumens) to deliver drugs (for example, chemotherapy, long-term antibiotics), fluids, blood products or to use for drawing blood samples. Both fluoroscopy and ultrasound can be used to guide the insertion of the catheter. An X-ray may be taken after the procedure to ensure correct placement. Includes the Hickman line insertion procedure which was included in previous general surveys. By having the entry of the catheter into the vein tunnelled away from its insertion point through the skin, the catheter may be retained for weeks to months, rather than exchanged weekly or more frequently.

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.

Nephrostomy tube replacement

Nephrostomy tubes require changing regularly, at intervals from every few weeks to every few months. A guide wire is inserted into the existing nephrostomy tube under fluoroscopic guidance with use of a contrast medium. The old tube is removed, the new tube inserted, and its position checked.

Oesophageal stent

An interventional procedure in which a stent or stents are inserted into the oesophagus to open a stricture usually caused by cancer but also by other conditions of the oesophagus.

Pacemaker (permanent)

Permanent implantation of a single or dual chamber cardiac pacemaker which usually involves the surgical implantation of the pacemaker into a small pocket created by the surgeon between the skin of the upper chest and the chest muscles. The pacemaker's pacing leads are inserted into a vein and guided to their correct positions in the appropriate heart chamber using fluoroscopic imaging. A single chamber pacemaker paces the right ventricle only, whereas a dual chamber pacemaker also paces the right atria. The procedure takes place under local anaesthetic. Alternative methods may be used for children or if additional heart surgery is being performed.

Peripherally inserted central catheter (PICC) line insertion

PICC line insertion is similar in some regards to a tunnelled central venous catheter, but with the line inserted into a large vein in the arm, usually above the elbow, the catheter then being threaded through veins to terminate just above the heart. Like the TCVC, the PICC line is one catheter tube inside but may branch into 2 to 3 fine tubes outside the body, to allow different treatments to be administered at the same time. A PICC line may be left in for weeks to months. A PICC line may be installed on the ward or in a treatment room. Its placement may be made using fluoroscopy or ultrasound. A chest X-ray may be used to check the correct positioning of the end of the catheter.

Stent (ureteric antegrade)

In antegrade ureteric stent insertion the ureteric stent (thin flexible tube) is inserted through an incision in the lower back and so into the kidney and down the full length of the ureter to the bladder. It holds the ureter open to allow urine to drain, relieving obstructions such as cancer and kidney stones. If stenting the ureter is not feasible a nephrostomy may be performed.

Stent (ureteric retrograde)

Retrograde ureteric stent insertion uses a cystoscope (thin endoscopic camera) to insert the ureteric stent (thin flexible tube) on a guide wire through the urethra and bladder into the ureter to line it from the kidney to the bladder. It holds the ureter open to allow urine to drain, relieving obstructions such as cancer and kidney stones. If stenting the ureter is not feasible a nephrostomy may be performed.

Additional

Angioplasty – superficial femoral artery

Angioplasty is used to treat narrowing of, and blockages in, the superficial femoral artery. A catheter is guided by fluoroscopy to the site of the blockage or narrowing. A balloon is inflated to widen the artery and, if necessary, a stent deployed to support the widened artery before deflating the balloon and removing it and the catheter. May also be termed Percutaneous transluminal angioplasty (PTA) of the femoral artery.

Biventricular pacemaker

Installed in a similar manner to a single or dual chamber pacemaker with the following differences. A biventricular heart pacemaker uses 3 leads to pace both the right and left ventricles of the heart, compared to dual chamber pacemakers that use 2 leads to pace the right atrium and the right ventricle of the heart, and the single chamber pacemaker that paces either the right atrium or the right ventricle. Instillation of the leads and their electrodes to both the right and left ventricles of the heart is a much longer procedure than just placing electrodes on the right side of the heart and results in significantly higher DAP value to the patient (roughly a factor of 10).

Biventricular implantable cardioverter defibrillator

Installed in a similar manner to a single or dual chamber pacemaker with the following differences. A biventricular ICD differs from a standard ICD by monitoring both the right and left ventricle for arrhythmia and then providing stimulation to restore sinus rhythm. Like a biventricular pacemaker its instillation takes significantly longer than a usual ICD because leads and electrodes need to be positioned and installed on both sides of the heart, causing a higher dose to the patient.

Defibrillator implant (ICD)

A permanent automated implantable cardioverter defibrillator (ICD) is inserted in a similar manner to a permanent pacemaker, the defibrillator being fitted into a pouch made between the skin and muscles of the upper chest with a lead inserted into the right ventricle to monitor heart rhythm, usually through the subclavian vein. When sustained ventricular tachycardia or ventricular fibrillation is detected the defibrillator sends a shock or shocks to stimulate the heart back to sinus rhythm. Note that the acronym AICD has been trademarked by the Boston Scientific corporation.

Diagnostic and interventional endoscopic retrograde cholangiopancreatography (ERCP – diagnostic and interventional)

Combined reporting of diagnostic examinations and interventional procedures of the biliary tree and of the pancreatic ducts (see above).

Fluoro guided injection – hip

Fluoroscopic imaging of the hip to enable injection of contrast media, steroids, analgesics and so on. See also Arthrography – hip. Ultrasound may also be used to image the injection.

Fluoro guided nerve root block

An injection of local anaesthetic, steroid or contrast agent around a nerve in the spine. The procedure is used to confirm the source of spinal pain by temporarily numbing a nerve root in the spine to determine if this provides pain relief. It is now being used as a therapeutic procedure as well as for diagnosis. CT fluoroscopy can also be used for performing guided nerve root blocks.

Percutaneous transluminal angioplasty (PTA) of the femoral artery

See: Angioplasty – superficial femoral artery

Mobile fluoroscopy or IR procedures

Requested

Mobile imaging of abdomen for laparoscopic cholecystectomy

Laparoscopic cholecystectomy is keyhole surgery to remove the gallbladder. It is usually performed on persons suffering from pain from, or complications from, gallstones. Intraoperative fluoroscopy is used to enable surgeons to visualise the biliary tree as the operation takes place. Postoperative fluoroscopy imaging is performed to identify, or rule out, postoperative complications. Ultrasound may also be used to image the procedure.

Mobile imaging of cervical spine for laminectomy

A cervical laminectomy is performed to relieve pressure on the spinal cord in the neck, or nerves linking to it, due to a stenosis (narrowing) in the vertebrae. The lamina is the piece of the vertebrae at the rear of the neck that encloses the spinal cord, from which the spiny process emerges. The lamina and the spiny process is removed to relieve the pressure on the spinal cord. Fluoroscopic imaging is used to assist the accurate performance of the required surgery. MRI and CT can also be used for imaging.

Mobile imaging of lumbar spine for laminectomy

A lumbar laminectomy is performed to relieve pressure on spinal cord in the lumbar region of the spine, or nerves linking to it, due to a stenosis (narrowing) in the vertebrae. The lamina is the piece of the vertebrae at the rear of the spine that encloses the spinal cord, from which the spiny process emerges. The lamina and the spiny process is removed to relieve the pressure on the spinal cord. Fluoroscopic imaging is used to assist the accurate performance of the required surgery. MRI and CT can also be used for imaging.

Mobile imaging of orthopaedic hip pinning

A hip fracture is a break at the upper end of the femur close to the hip joint of the femur and pelvis. The break may be treated either by hip pinning or by hip replacement. Hip replacement is favoured for younger patients and where the blood supply to the head of the femur has not been severely compromised, causing bone necrosis. Fluoroscopic imaging is used to check that the break is correctly pinned.

Additional

Generic mobile fluoroscopy imaging:

- mobile fluoroscopy of hip

- mobile fluoroscopy of lumbar spine
- mobile fluoroscopy of sacrum
- mobile fluoroscopy of abdomen
- mobile fluoroscopy of cervical spine
- mobile fluoroscopy of thoracic spine
- mobile fluoroscopy of pelvis

Appendix C: System median DAP histograms

Figures C1 to C52 show system median DAP histograms for plain radiography single projections, plain radiography and fluoroscopy examinations and IR procedures based on system data sets of 30 or more patient investigations (shown as blocks).

Plain radiography single projections

Figures are given for all plain radiography single projections for which the survey received data from 10 or more radiography systems representing 30 or more patients (figures C1 to C18). Projection names are given in full in Appendix B.

The 2019 survey third quartile median DAP values are shown as a solid line. The third quartile mean DAP values of the 2010 review (7), generally adopted as the 2010 NDRLs, are given as a dashed line where available. If the value is above the DAP range shown, it is given as a footnote to the figure.

Extremities

Figure C1. Foot (single) weight bearing DP projection

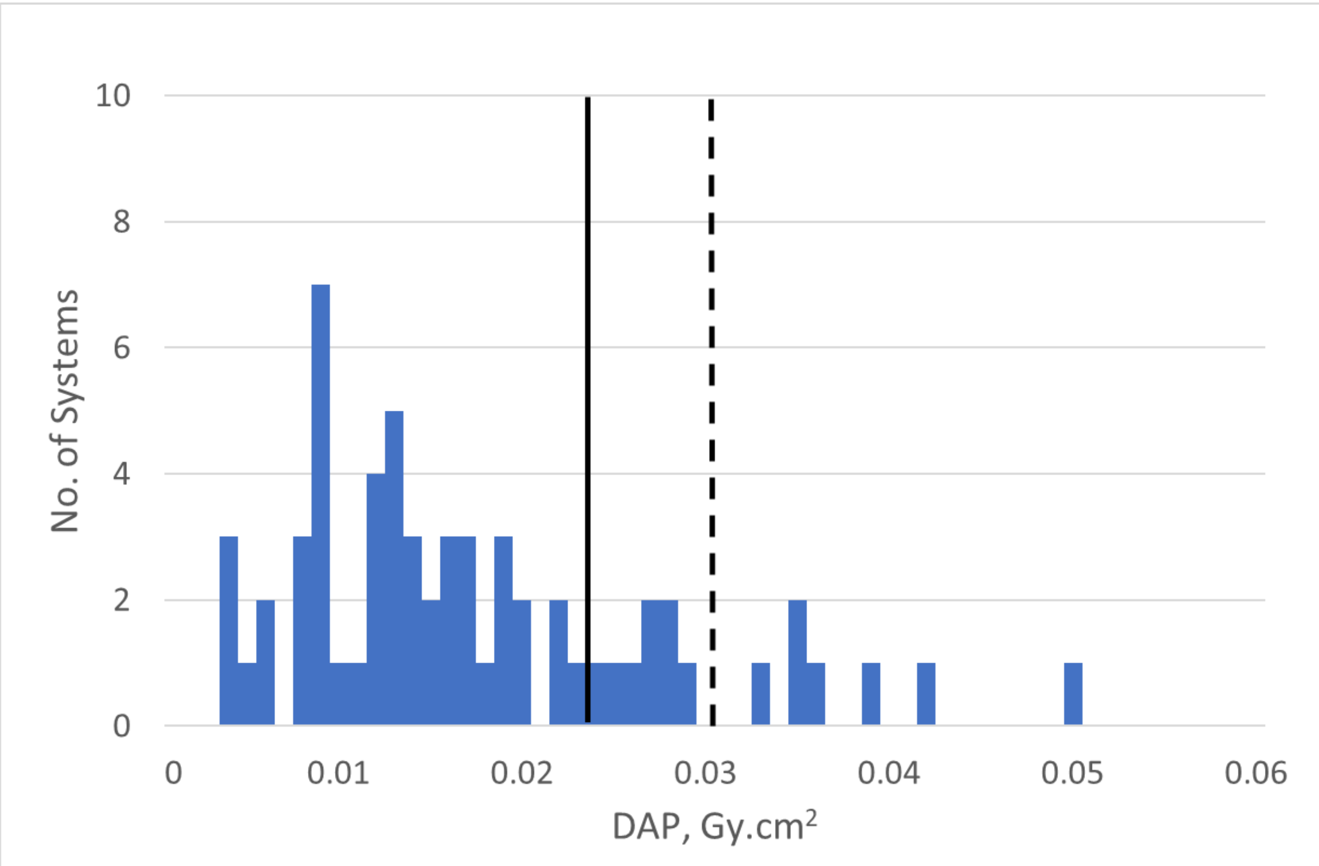


Figure C2. Hand (single) PA projection

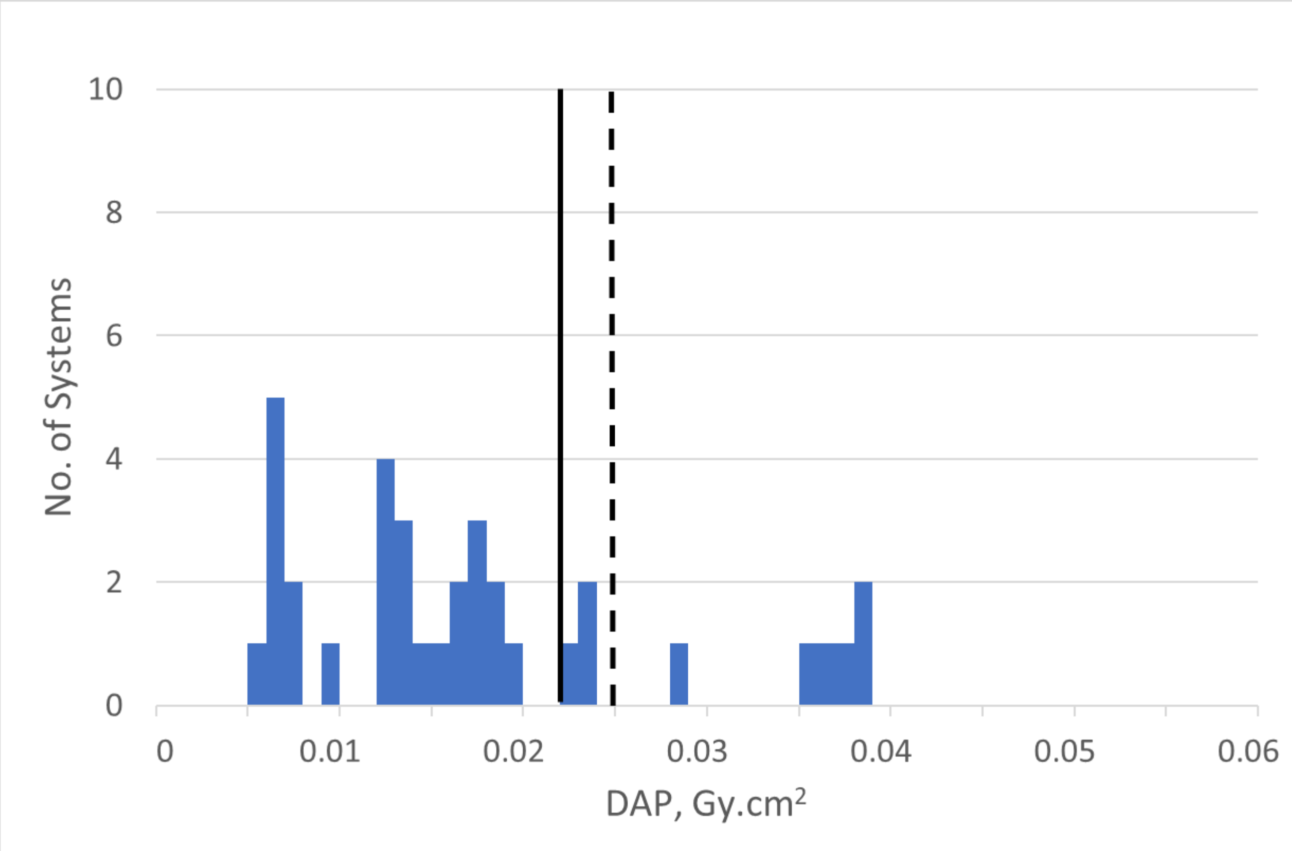


Figure C3. Knee (single) AP projection

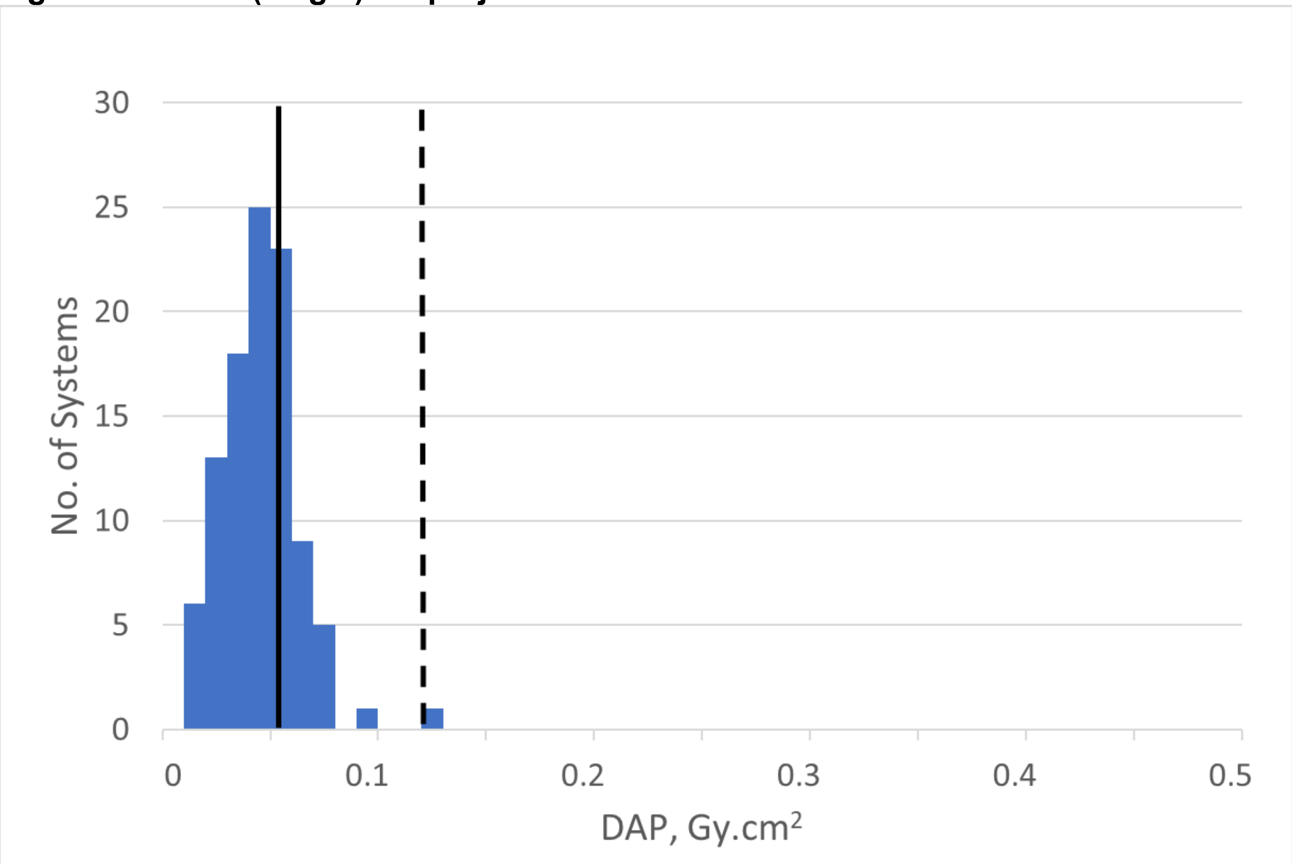
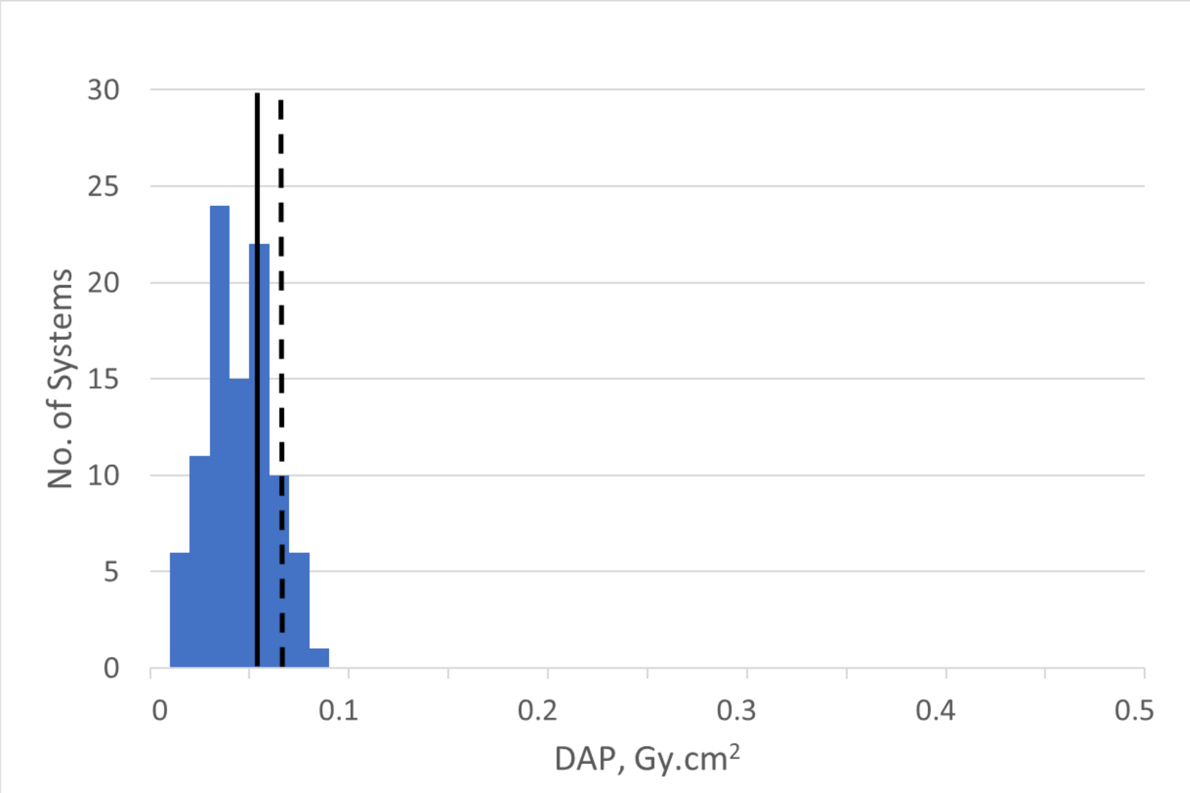


Figure C4. Knee (single) lateral projection



Cervical spine and shoulder

Figure C5. Cervical spine AP projection

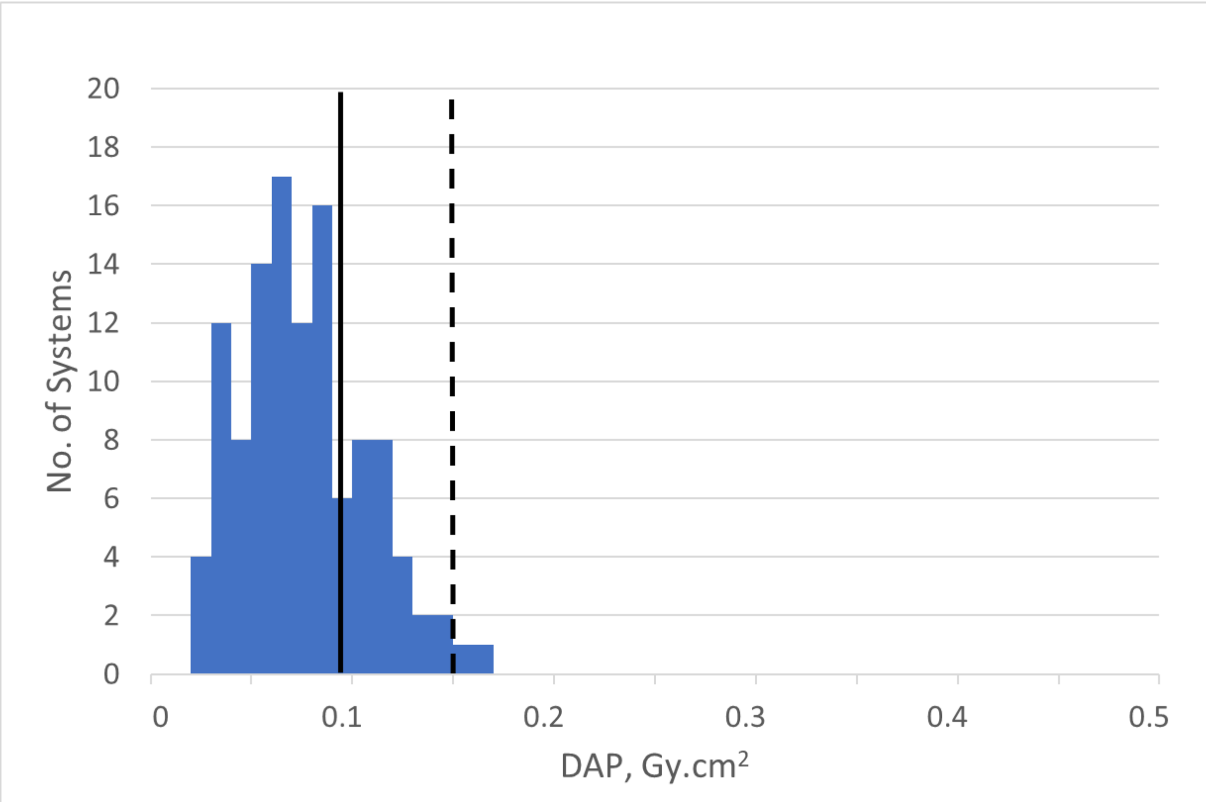


Figure C6. Cervical spine lateral projection

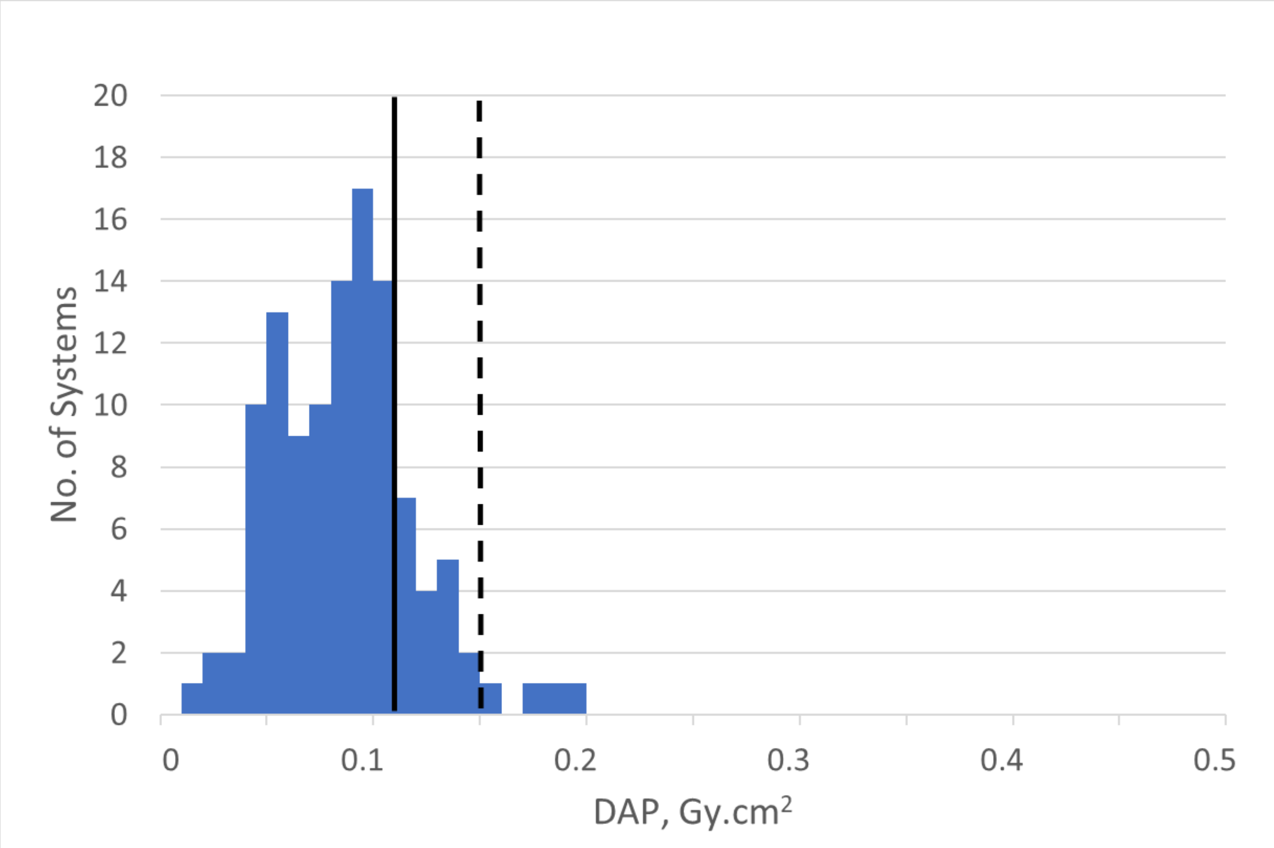
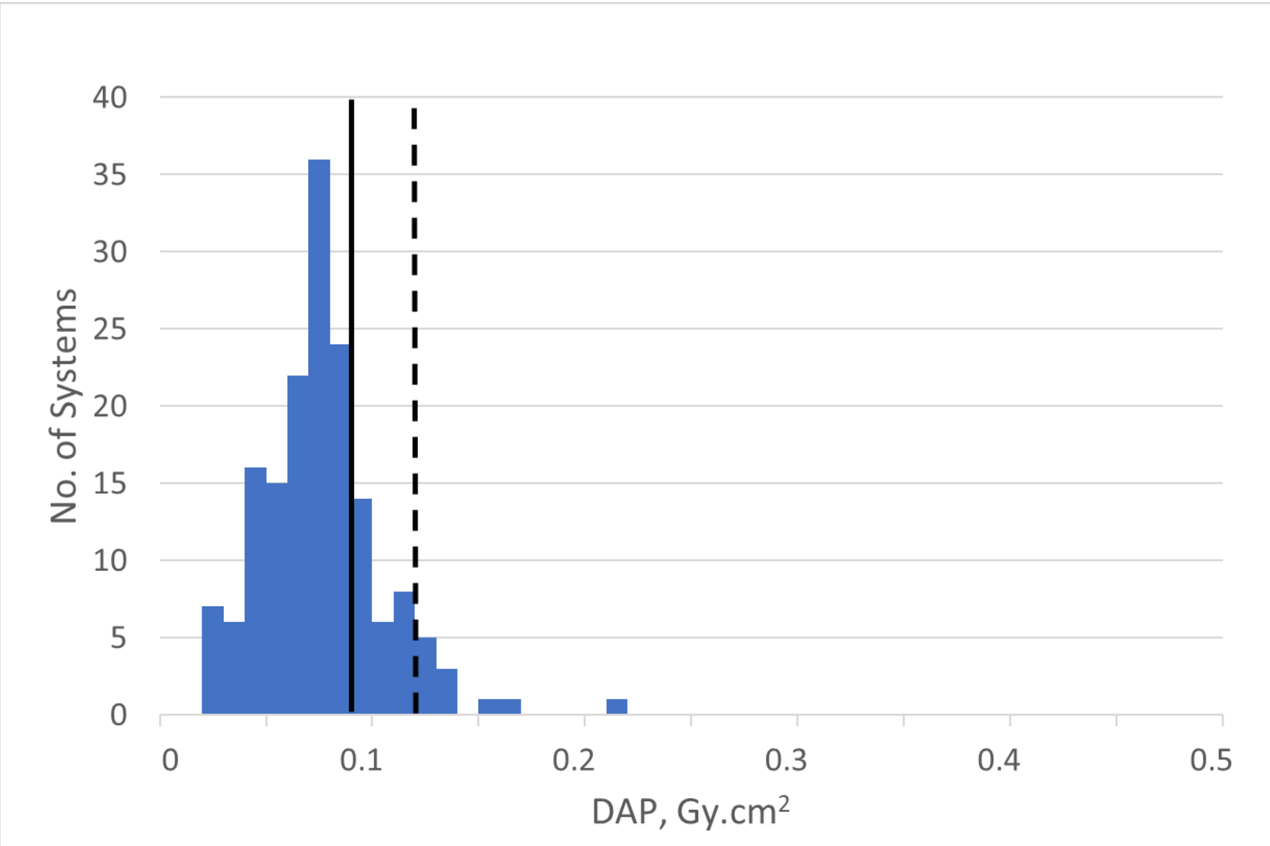


Figure C7. Shoulder (single) AP projection



Chest projections

Figure C8. Chest AP projection

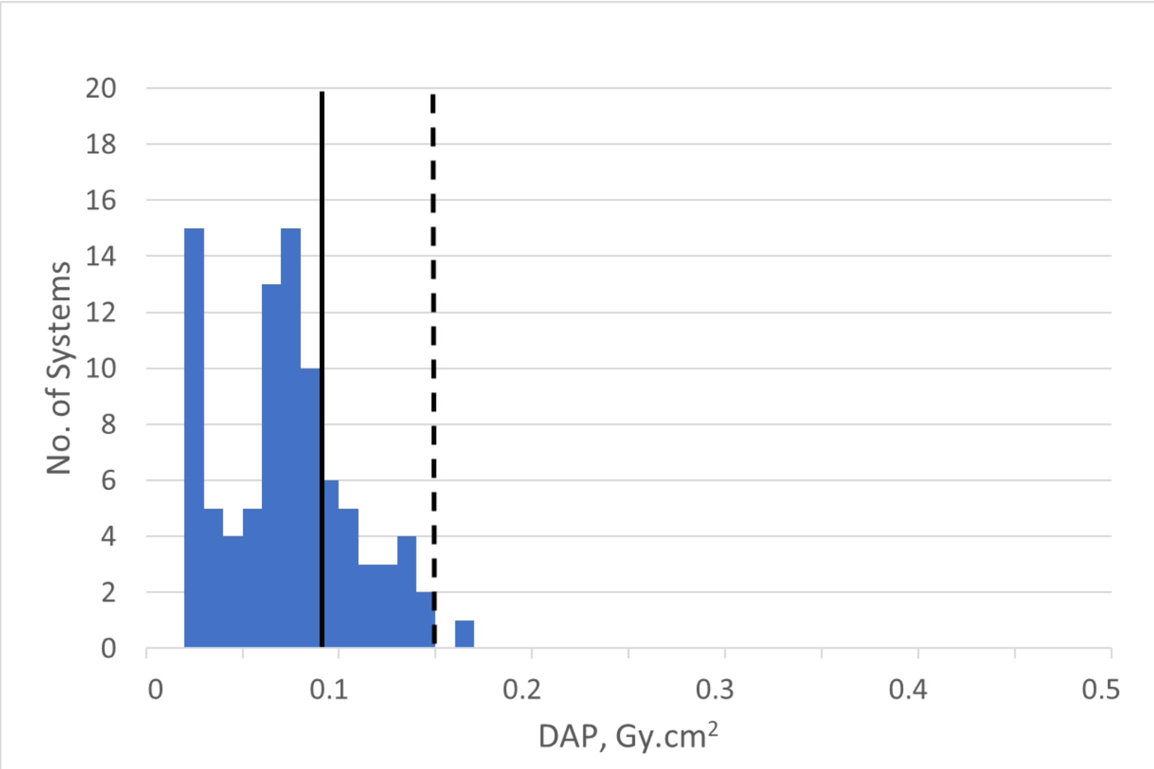


Figure C9. Chest AP projection: mobile system

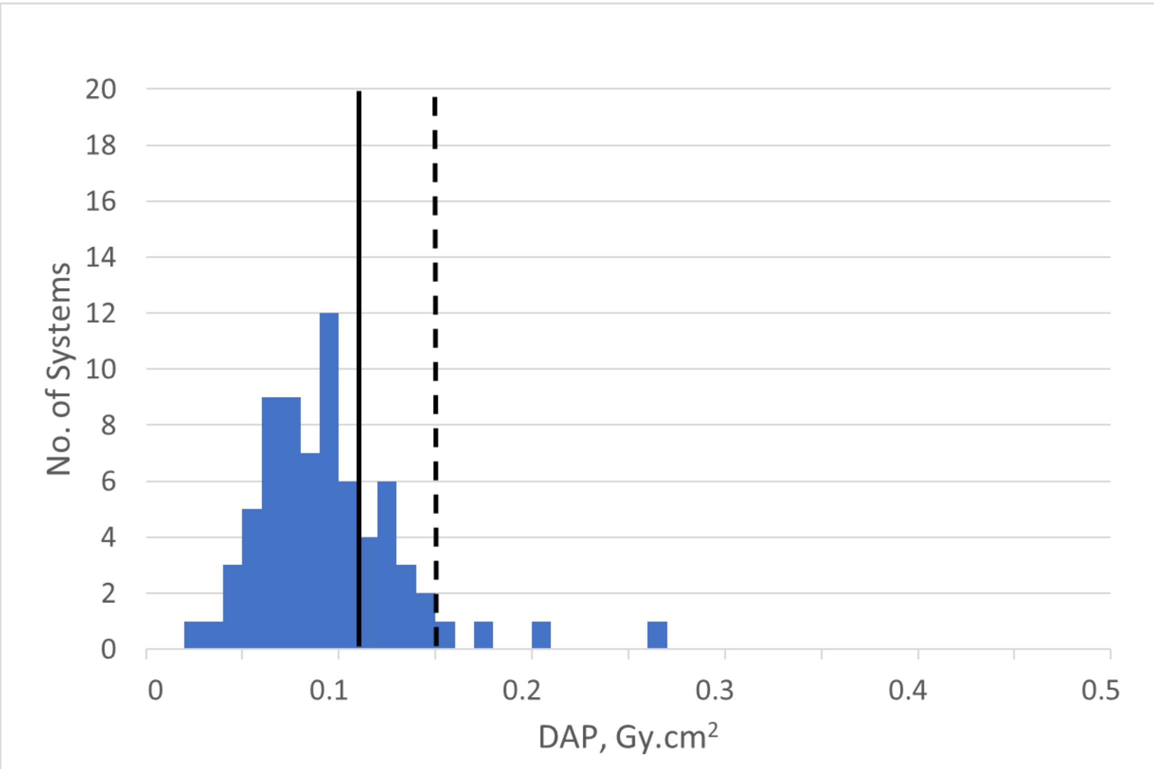


Figure C10. Chest PA projection

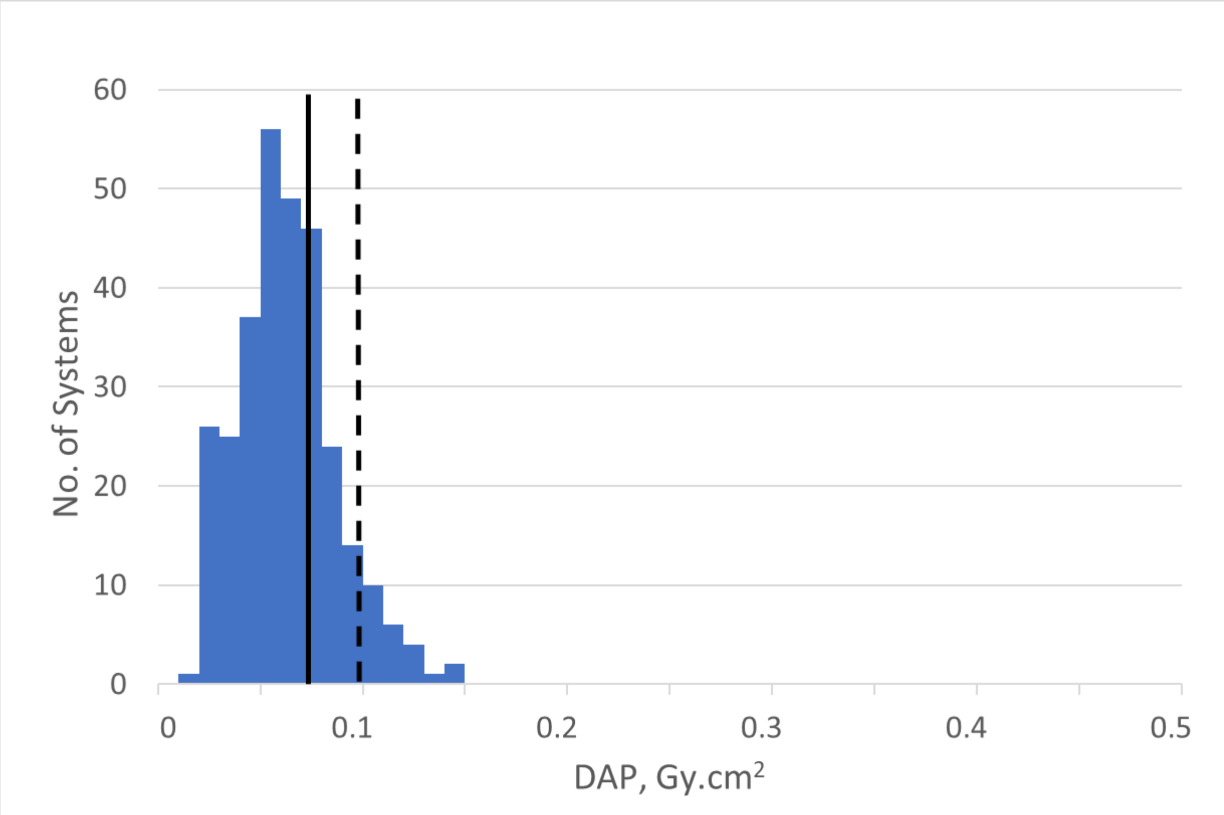
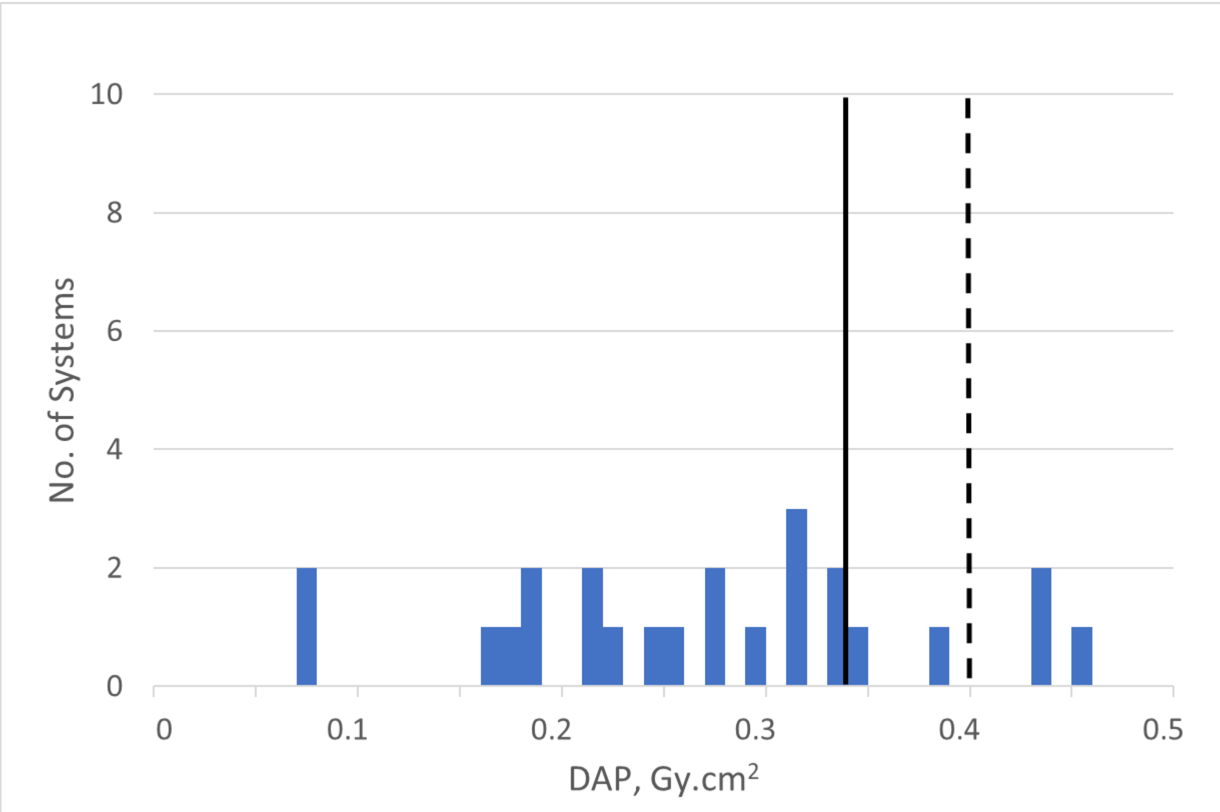


Figure C11. Chest lateral projection



Abdomen, pelvis and hips

Figure C12. Abdomen AP projection

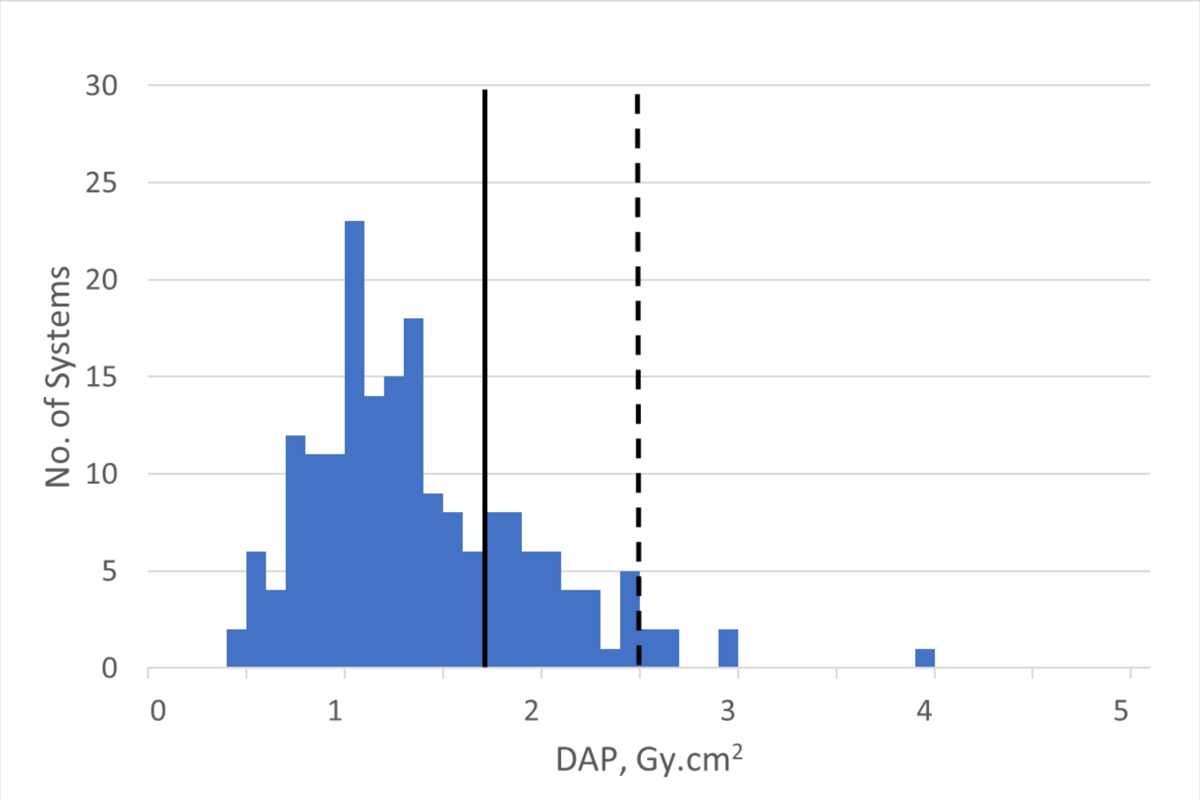


Figure C13. Pelvis AP projection

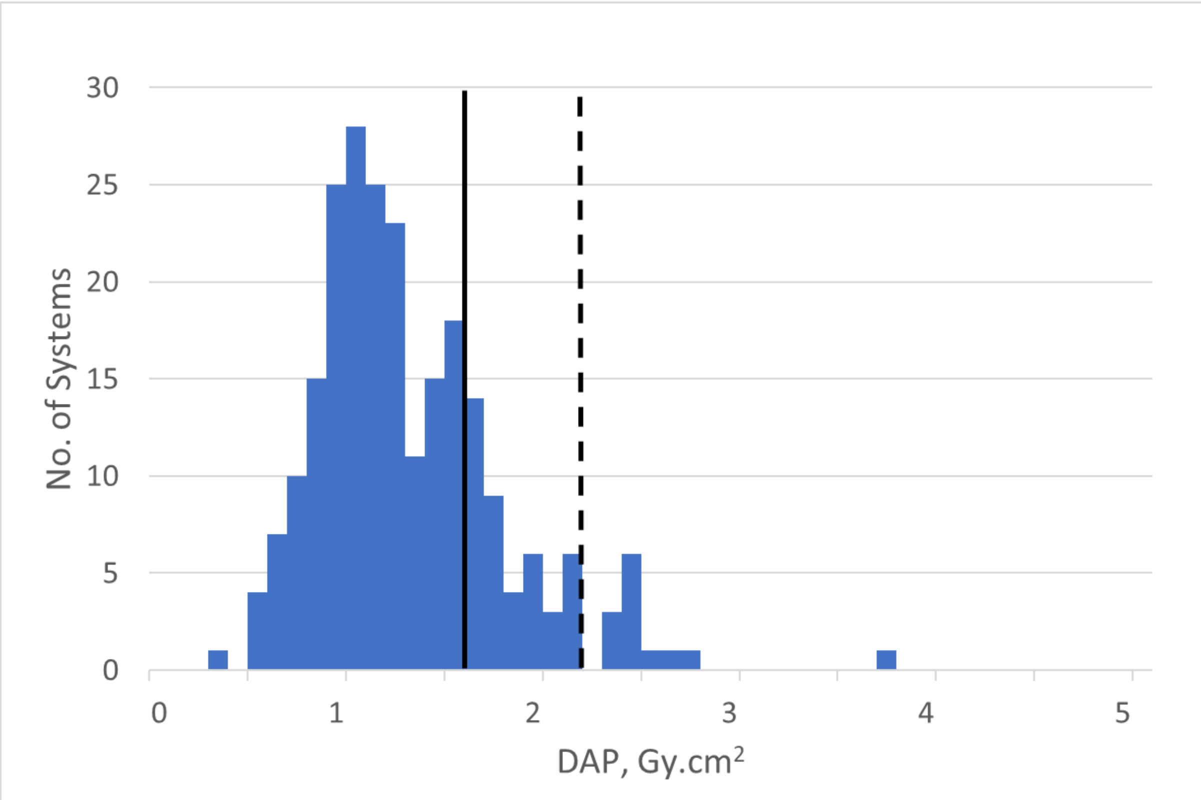
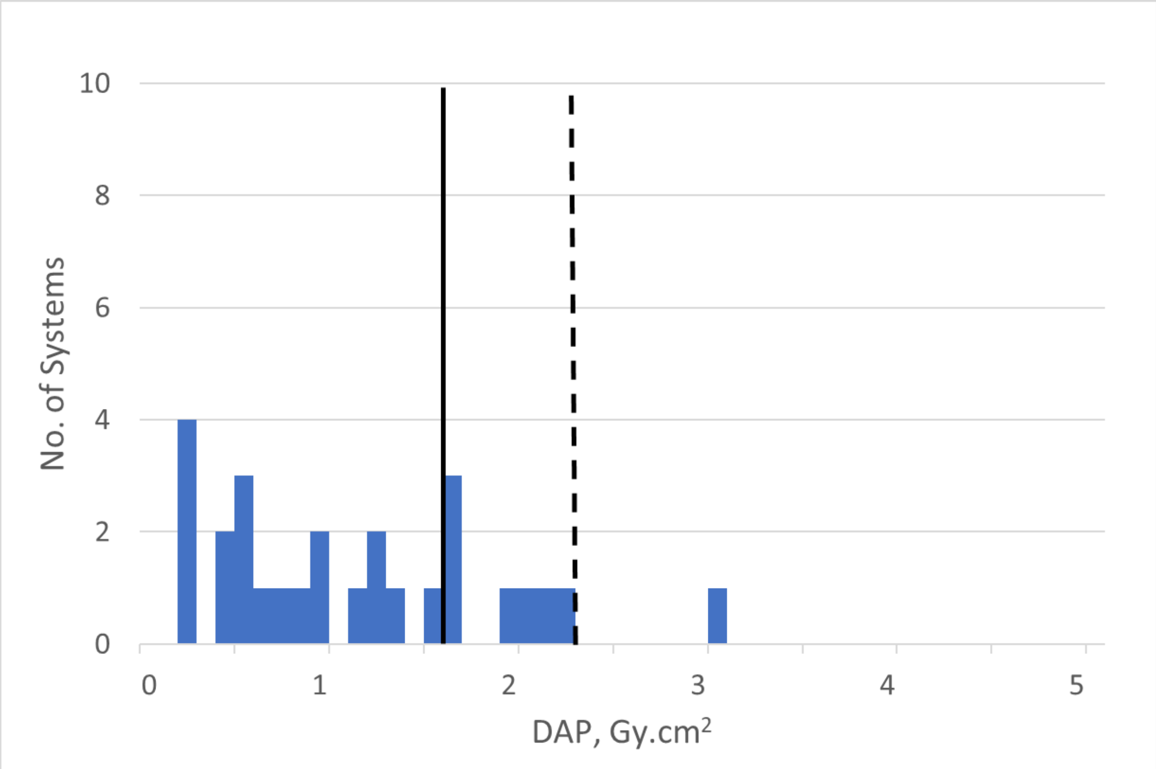


Figure C14. Hip (single) horizontal beam lateral projection



Thoracic and lumbar spine

Figure C15. Thoracic spine AP projection

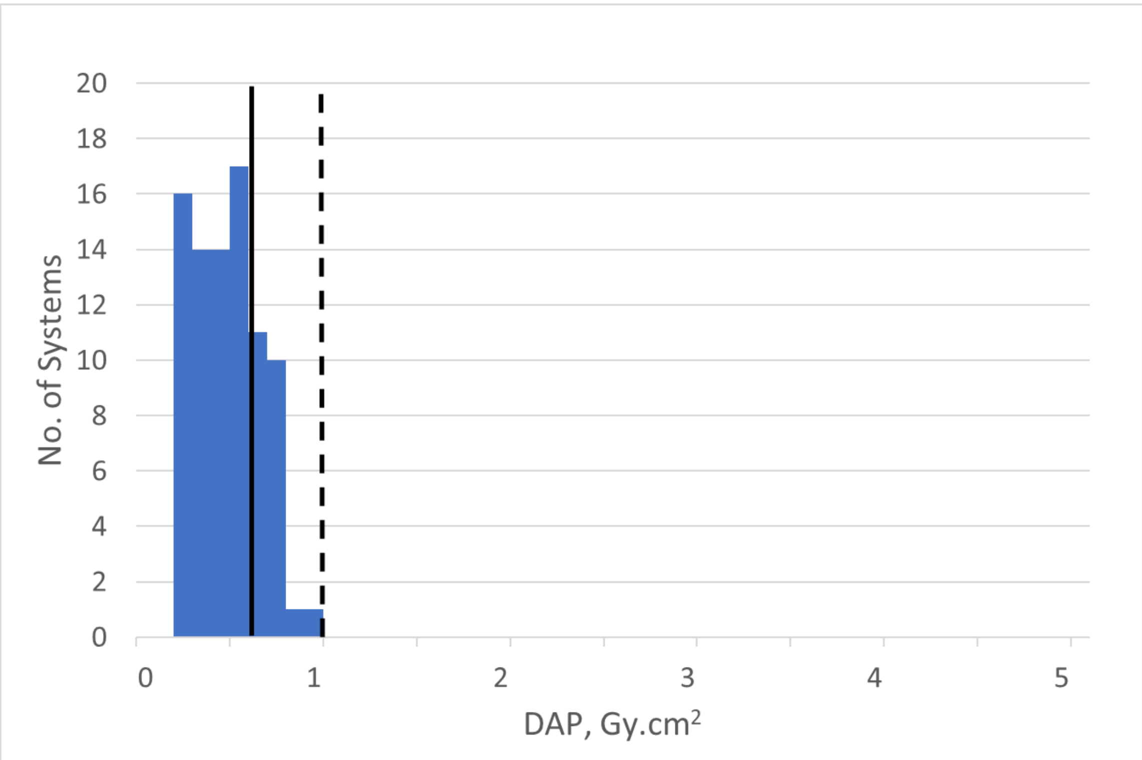


Figure C16. Thoracic spine lateral projection

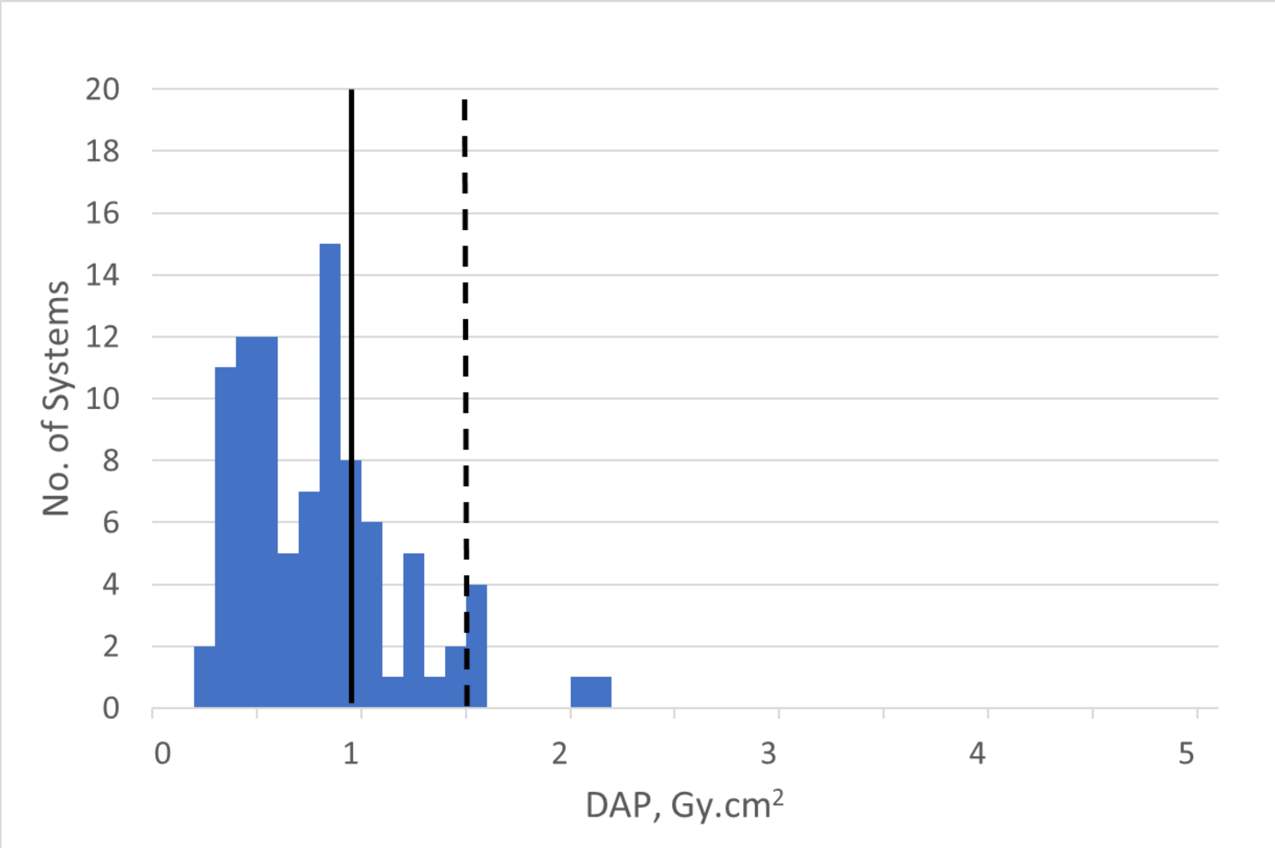


Figure C17. Lumbar spine AP projection

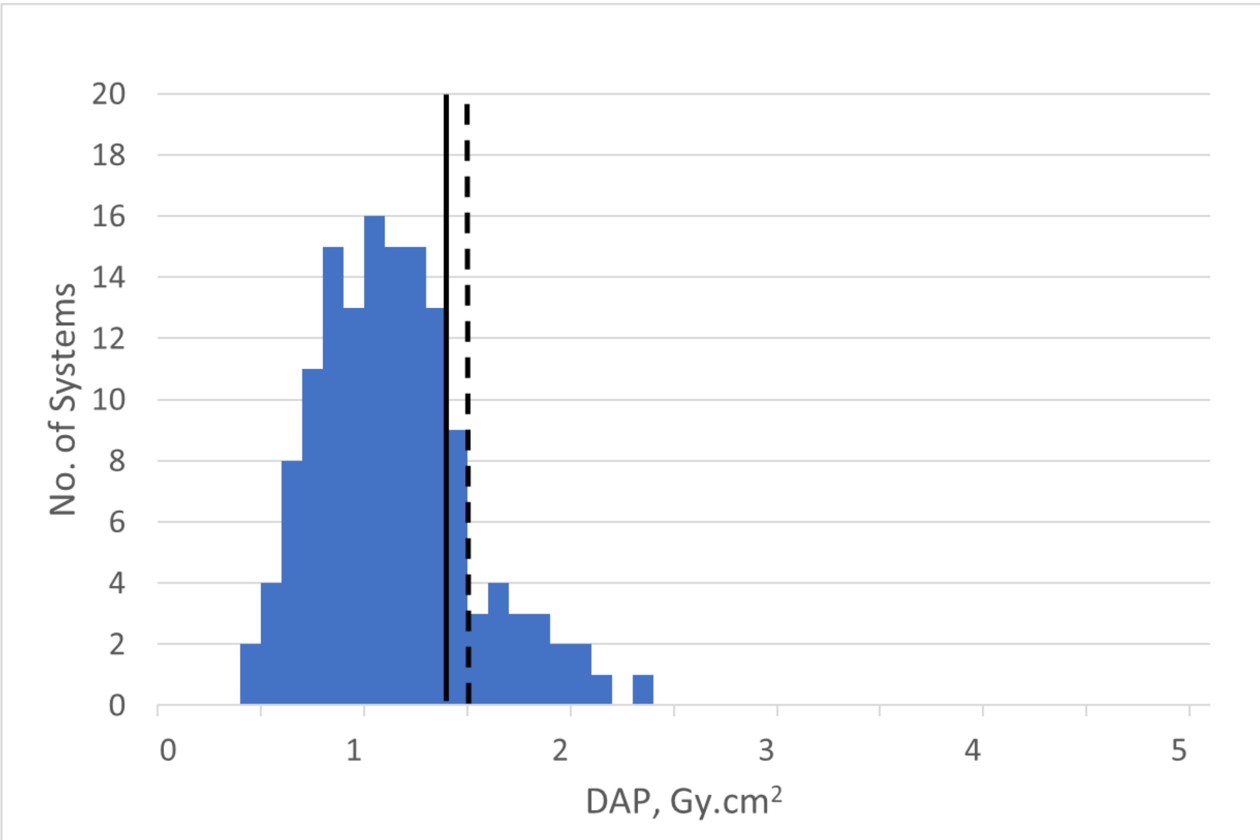
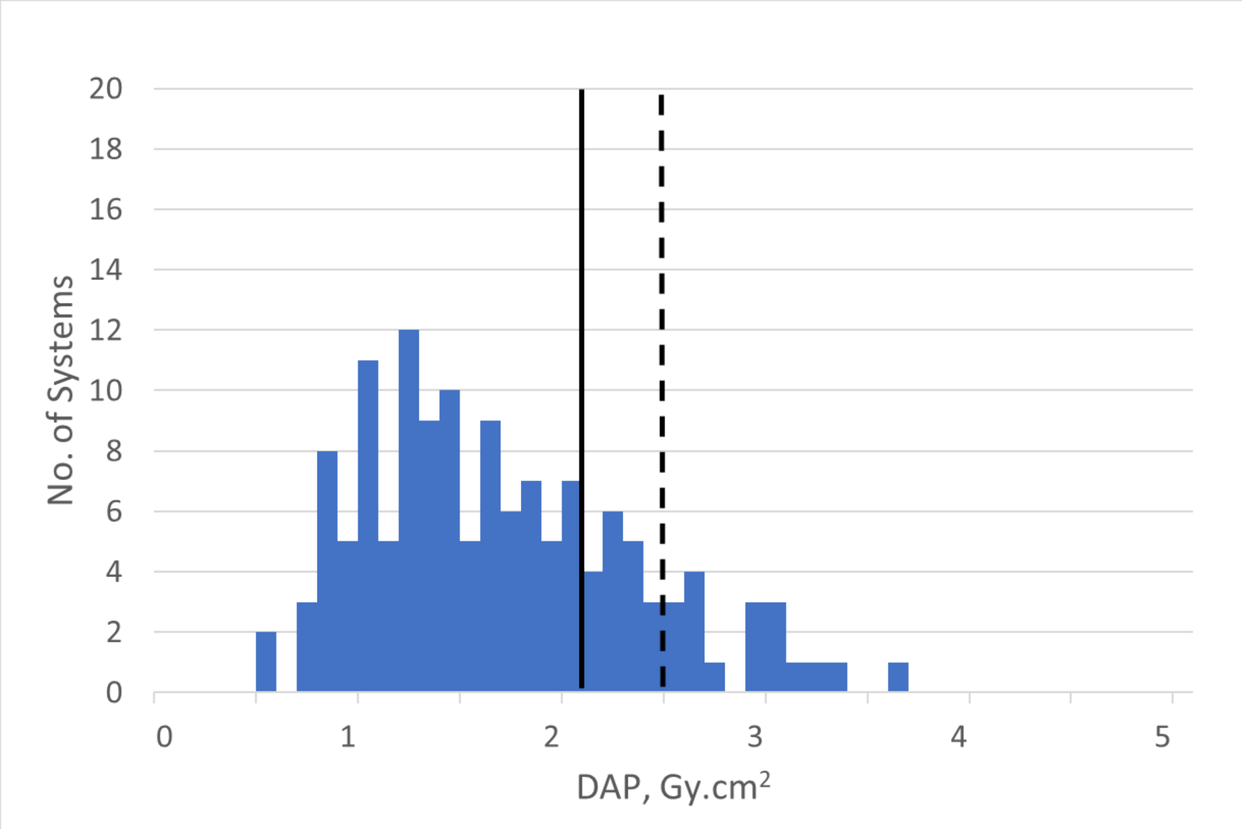


Figure C18. Lumbar spine lateral projection



Plain radiography examinations

Figures are given for all plain radiography examinations for which the survey received data from 10 or more radiography systems representing 30 or more patients (figures C19 to C29).

The 2019 survey third quartile median DAP values are shown as a solid line. The third quartile mean DAP values of the 2010 review (7), generally adopted as the 2010 NDRLs, are given as a dashed line where available. If the value is above the DAP range shown, it is given as a footnote to the figure.

For the foot, the 2019 and 2010 third quartile values almost overlie each other. Facial bones examination data was not received by the 2010 survey (7), so a 2010 third quartile mean DAP value is not given.

Extremity examinations

Figure C19. Foot (single) examination

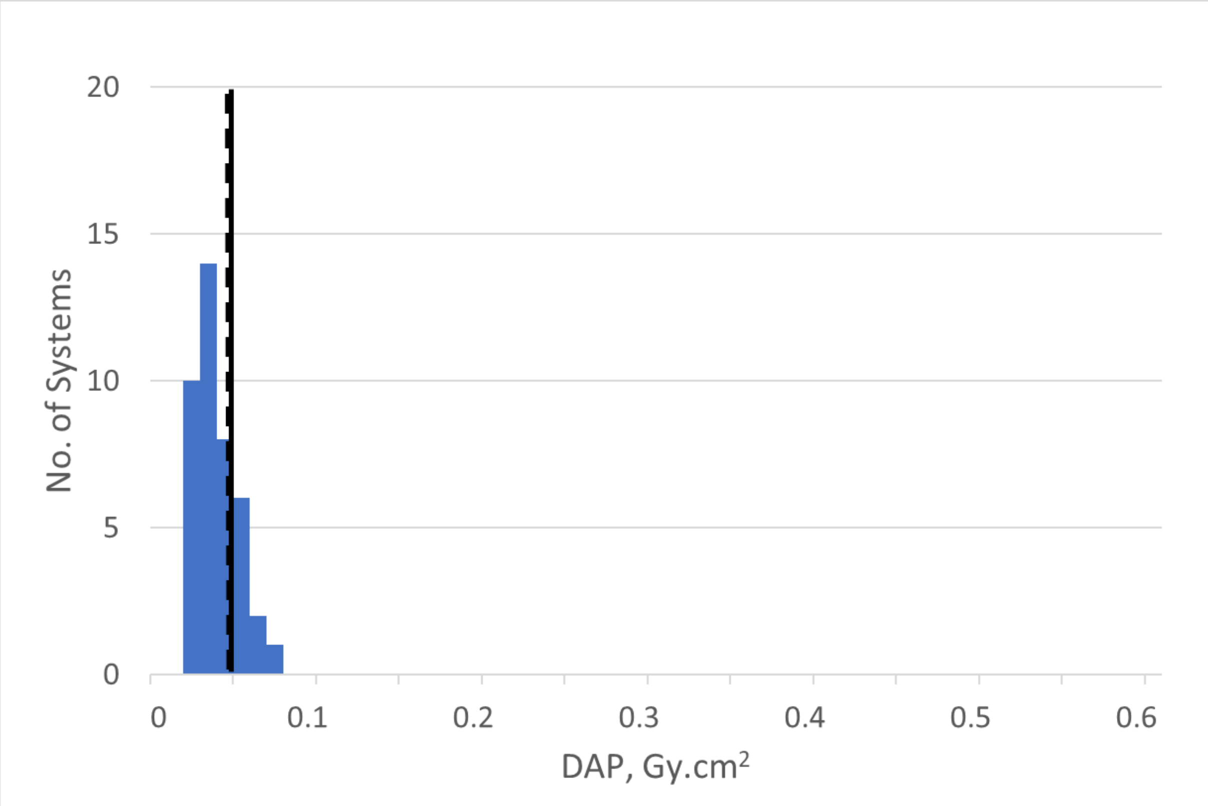
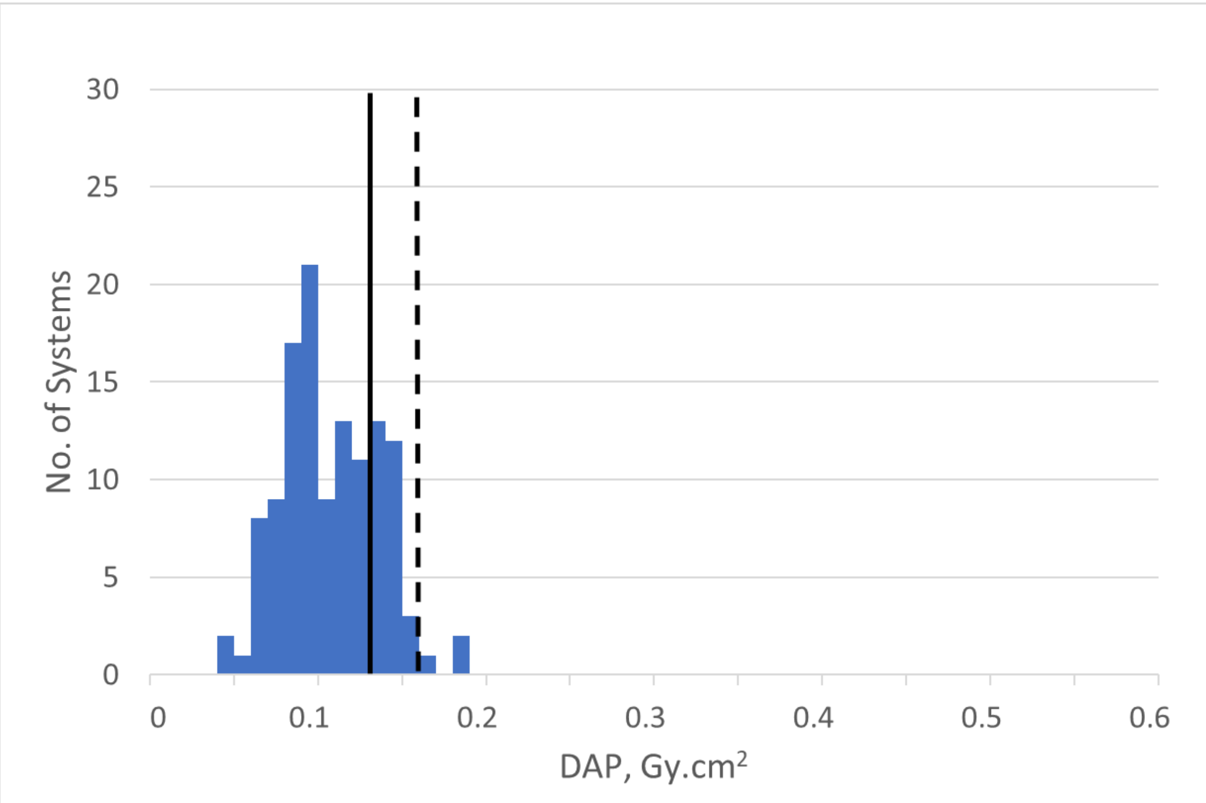
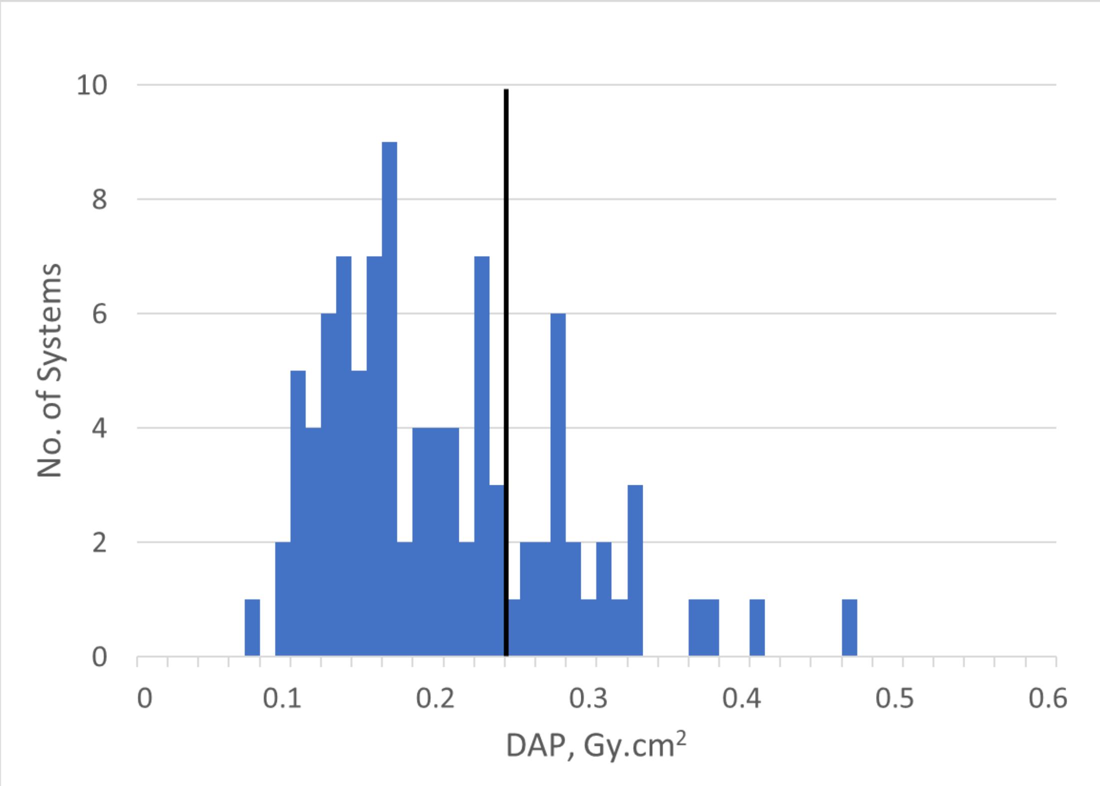


Figure C20. Knee (single) examination



Cervical spine, shoulder, and chest examinations

Figure C21. Cervical spine examination



1. 2010 survey third quartile: 1.5 Gy.cm^2

Figure C22. Shoulder (single) examination

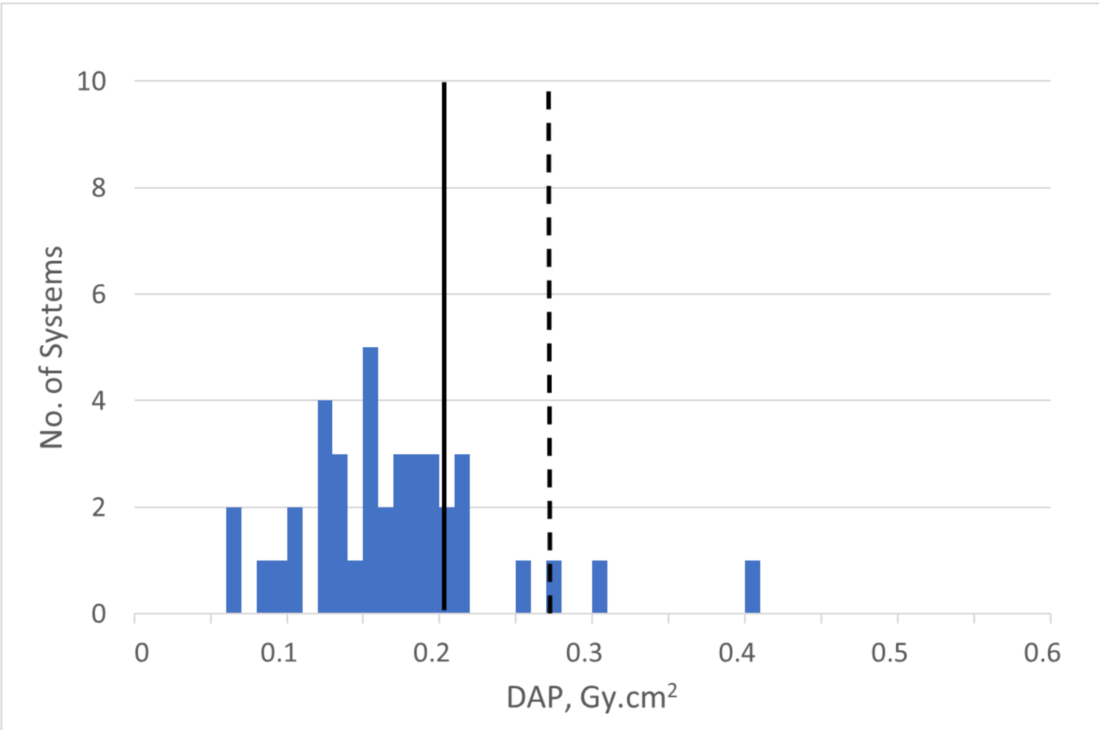
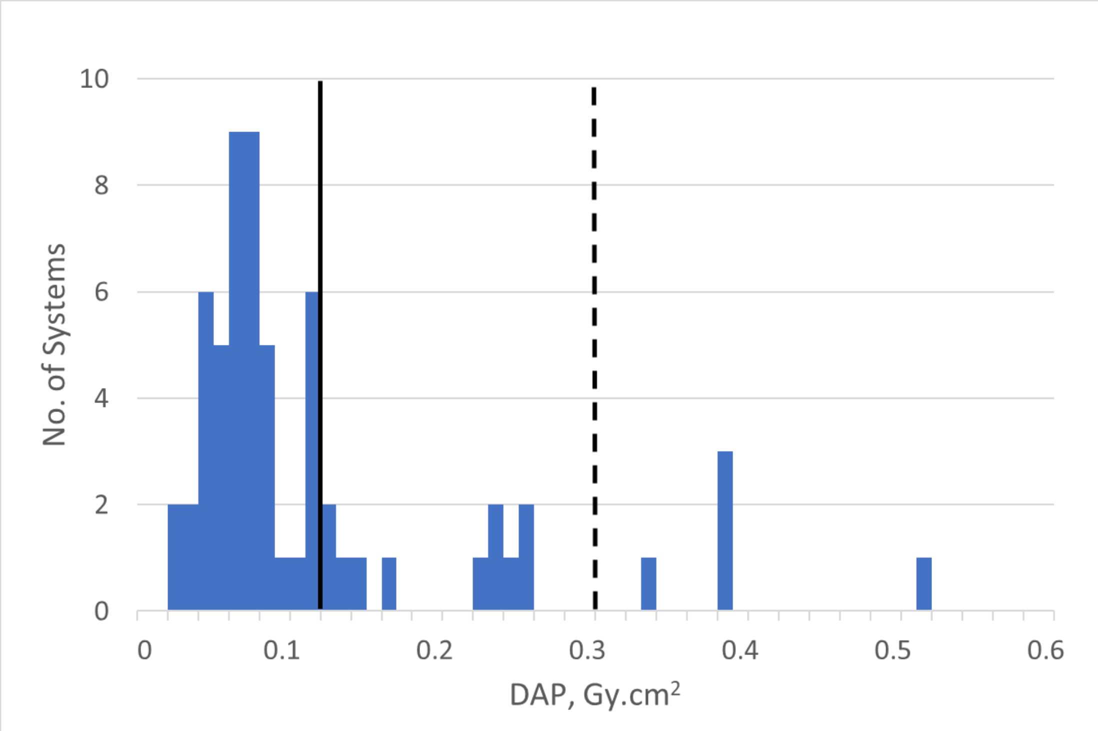
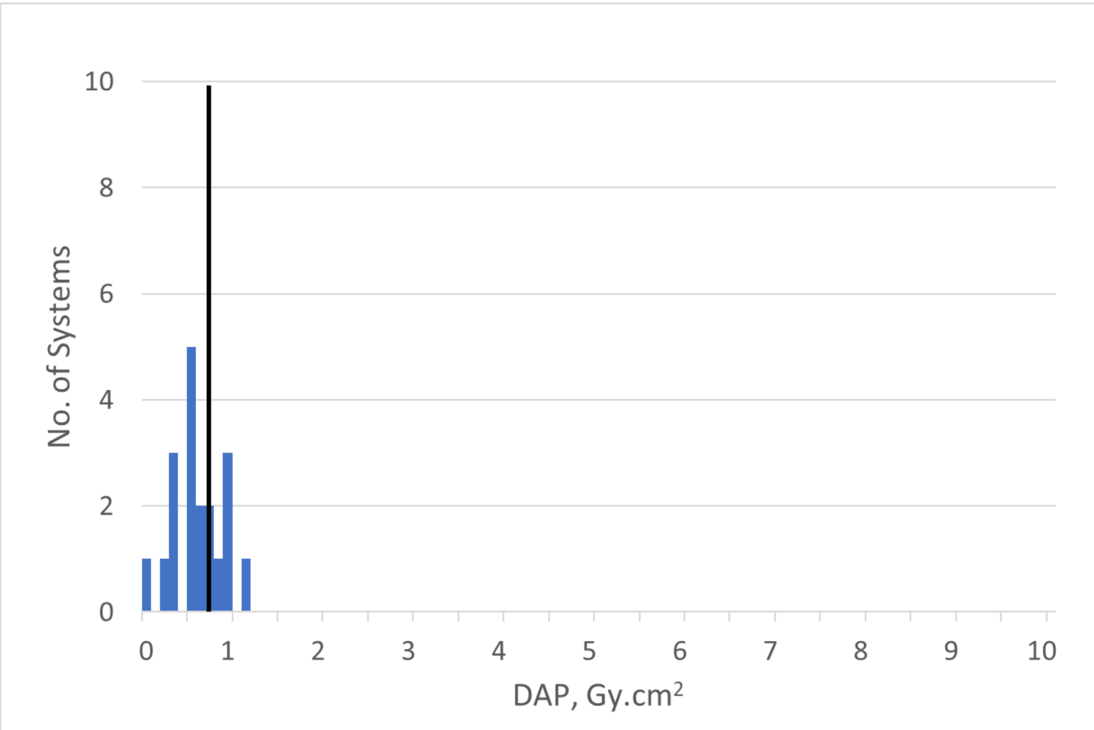


Figure C23. Chest examination



Facial bones, abdomen, pelvis and hip examinations

Figure C24. Facial bones examination



1. No 2010 survey DAP data.

Figure C25. Abdomen examination

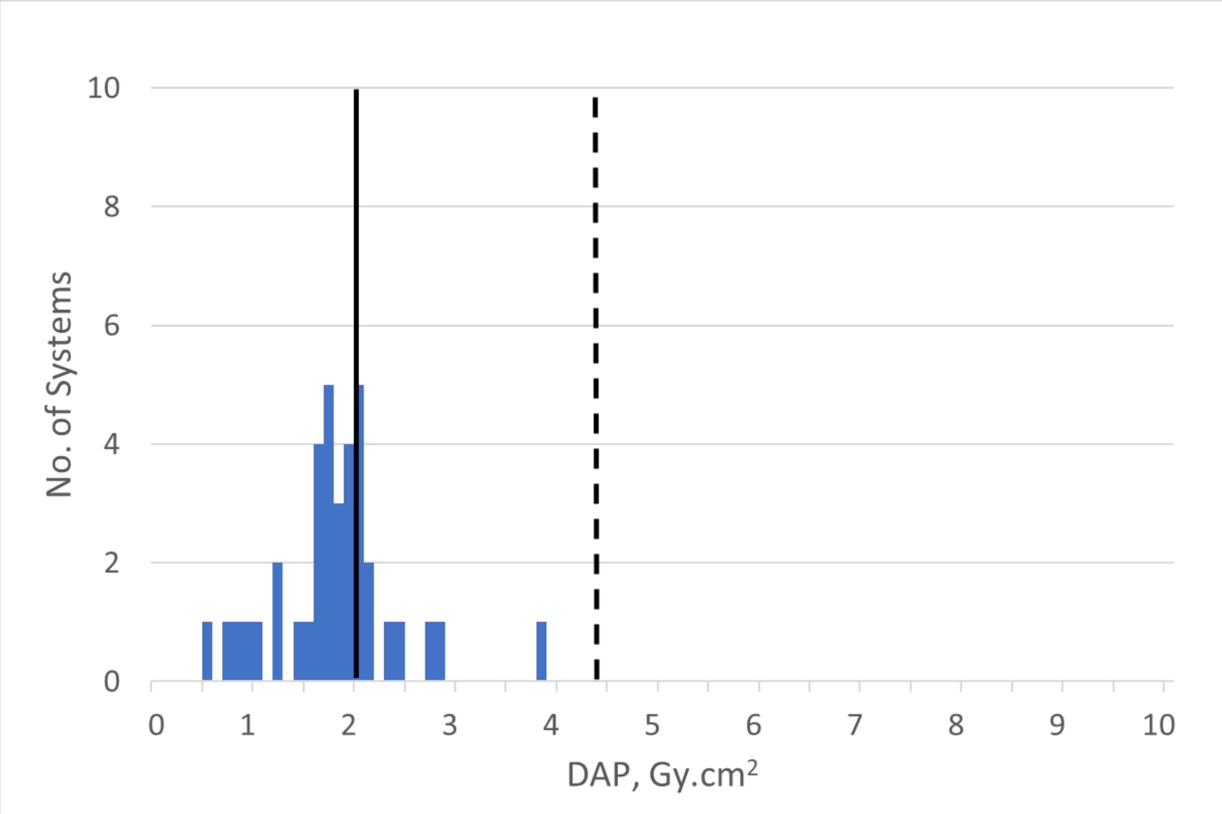


Figure C26. Pelvis examination

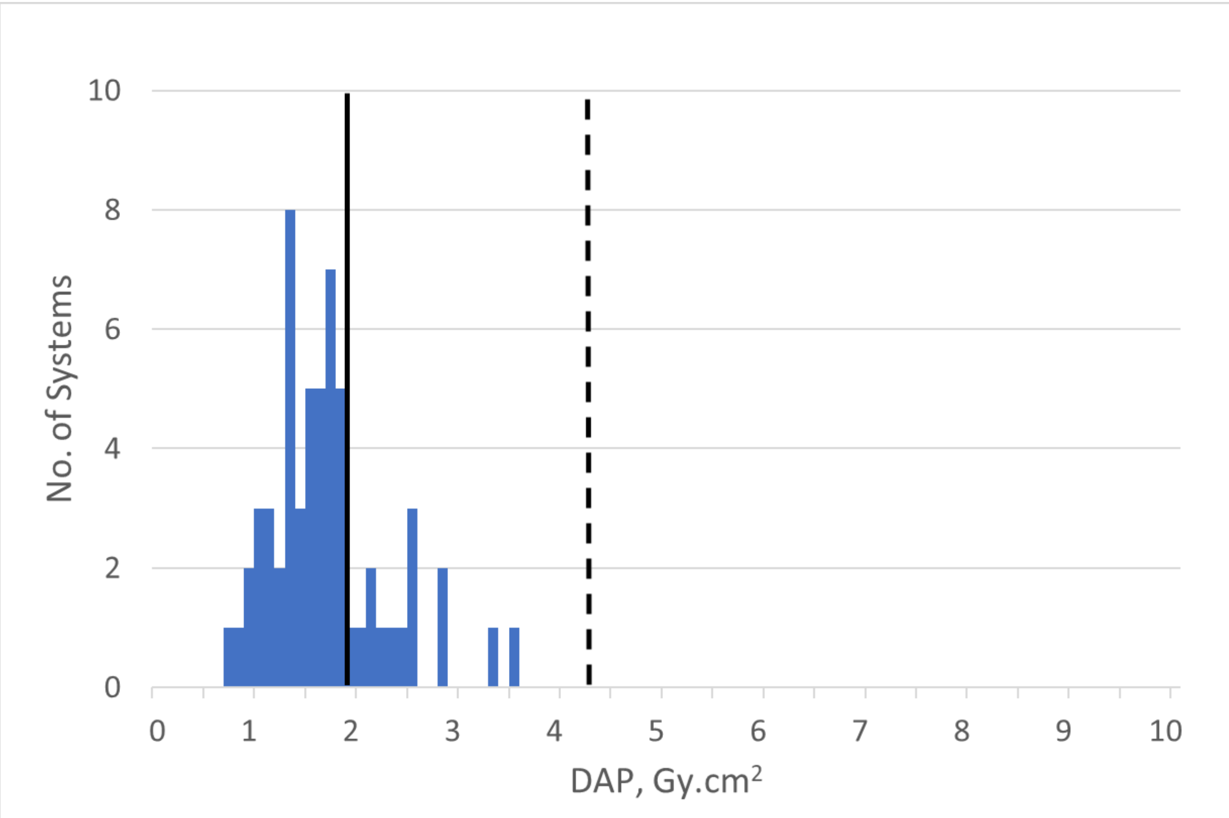
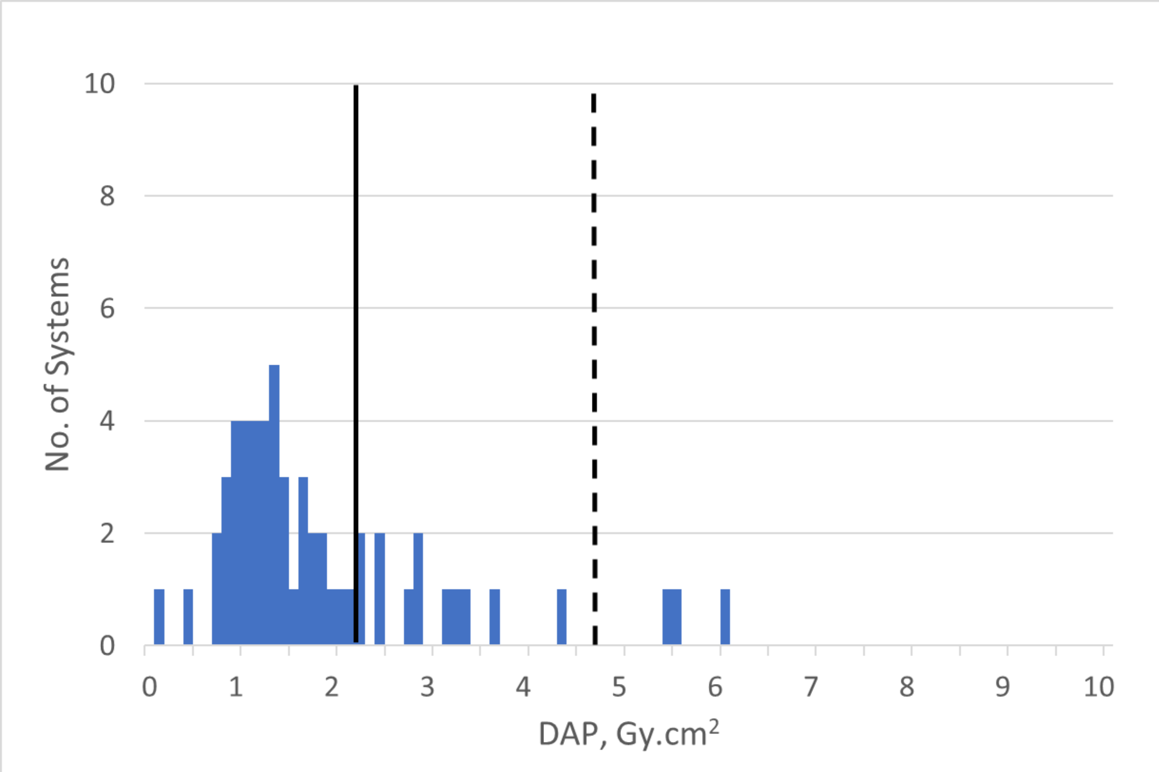


Figure C27. Hip (single) examination



Thoracic and lumbar spine examinations

Figure C28. Thoracic spine examination

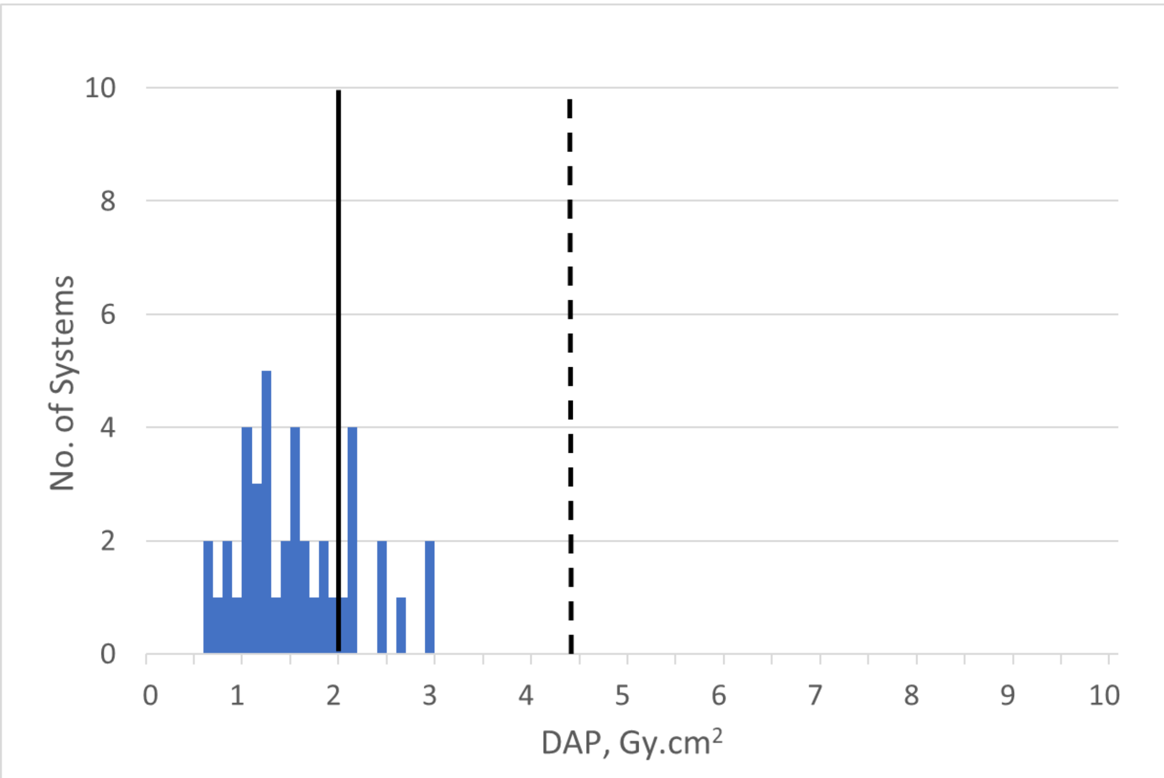
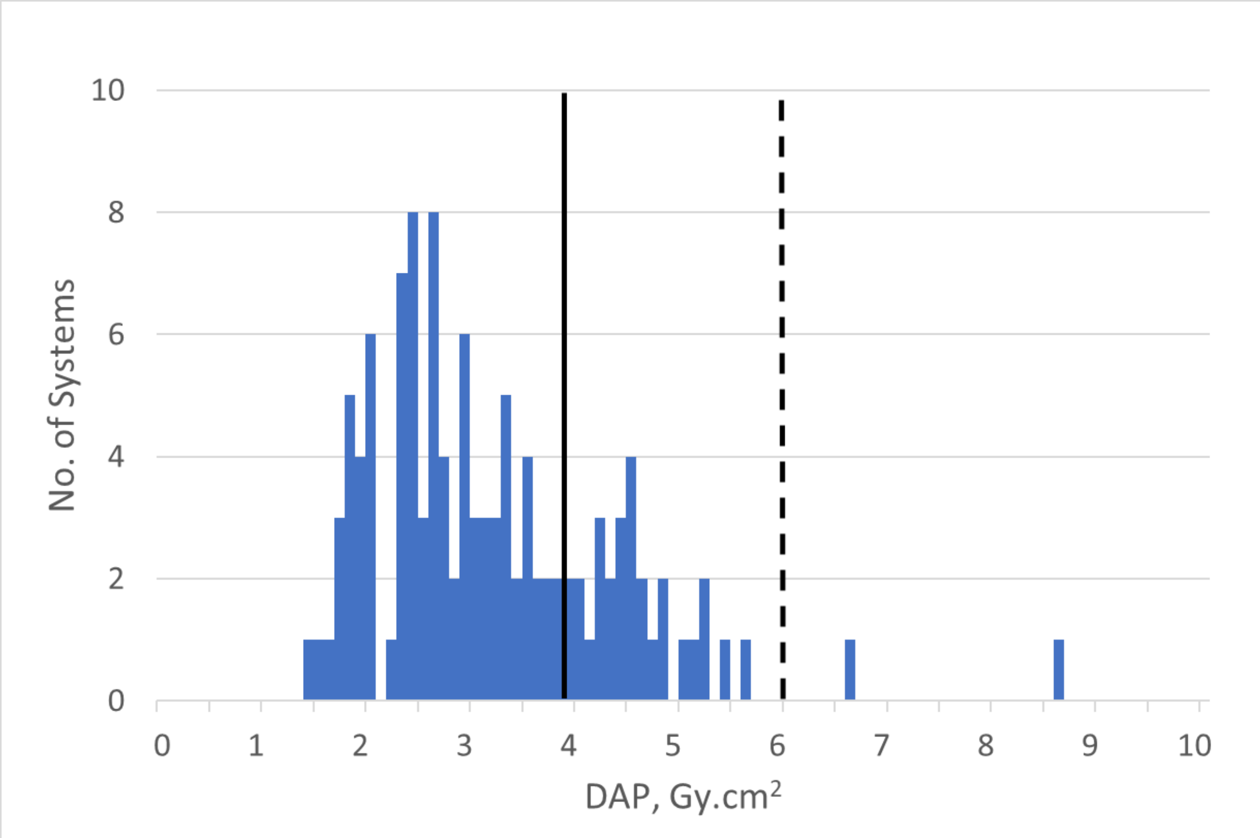


Figure C29. Lumbar spine examination



Fluoroscopy examinations and IR procedures

System median DAP distribution plots have been included for all exams for which 10 or more system samples of 30 or more patient doses were received, plus barium meal and swallow, for comparison with other barium and water soluble contrast (WCS) studies, and radiologically inserted gastronomy tube, to illustrate the fall in DAP values from the 2010 survey.

The plot for video-fluoroscopy barium swallow is shown twice, once with exams for which patients received a similar DAP, and once with the other barium and WSC studies. Distribution plots for generic mobile imaging of the hip, cervical spine and lumbar spine have been included for general information but are not for any specific clinical objective or procedure.

The 2019 survey third quartile median DAP values are shown as a solid line. The third quartile mean DAP values of the 2010 review (7), generally adopted as the 2010 NDRLs, are given as a dashed line where available. If the value is above the DAP range shown, it is given as a footnote to the figure.

Low to medium DAP fluoroscopy examinations and IR procedures

Figure C30. PICC line insertion

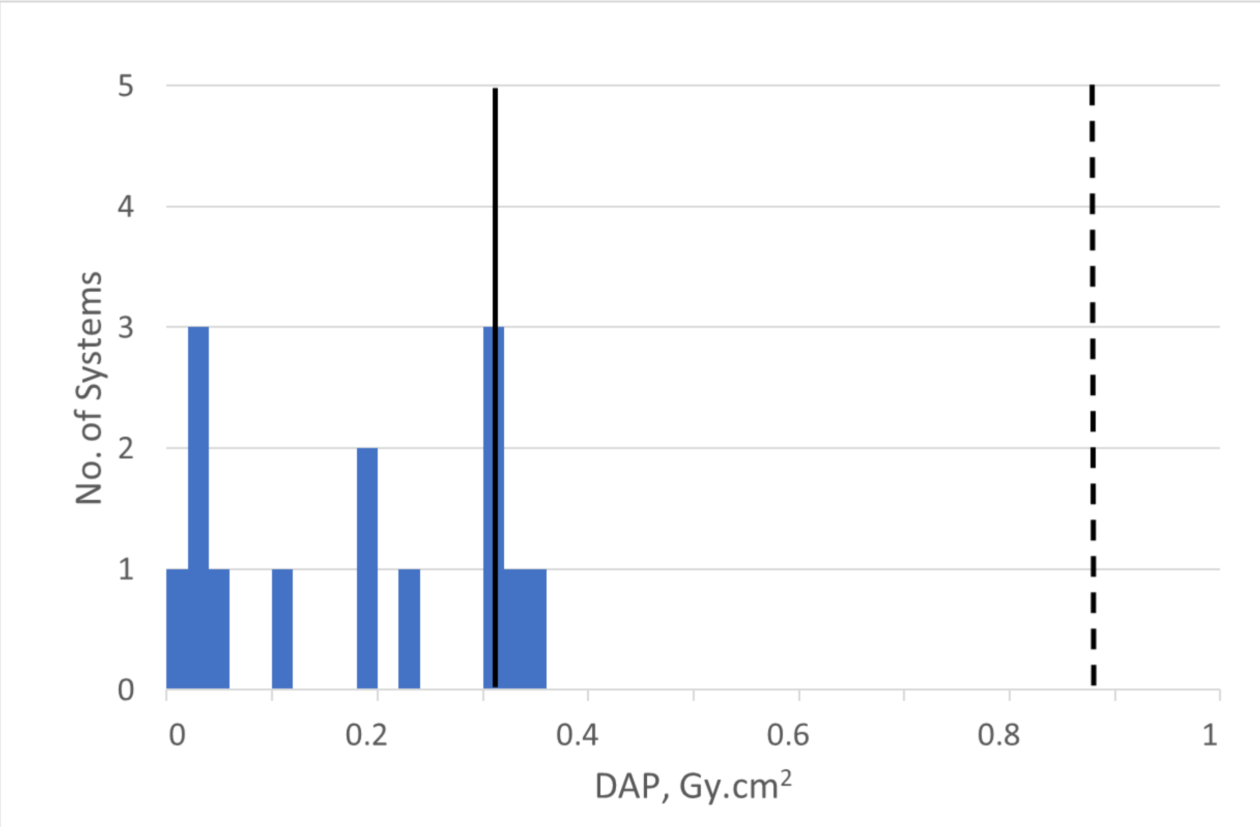


Figure C31. Generic mobile cervical spine imaging

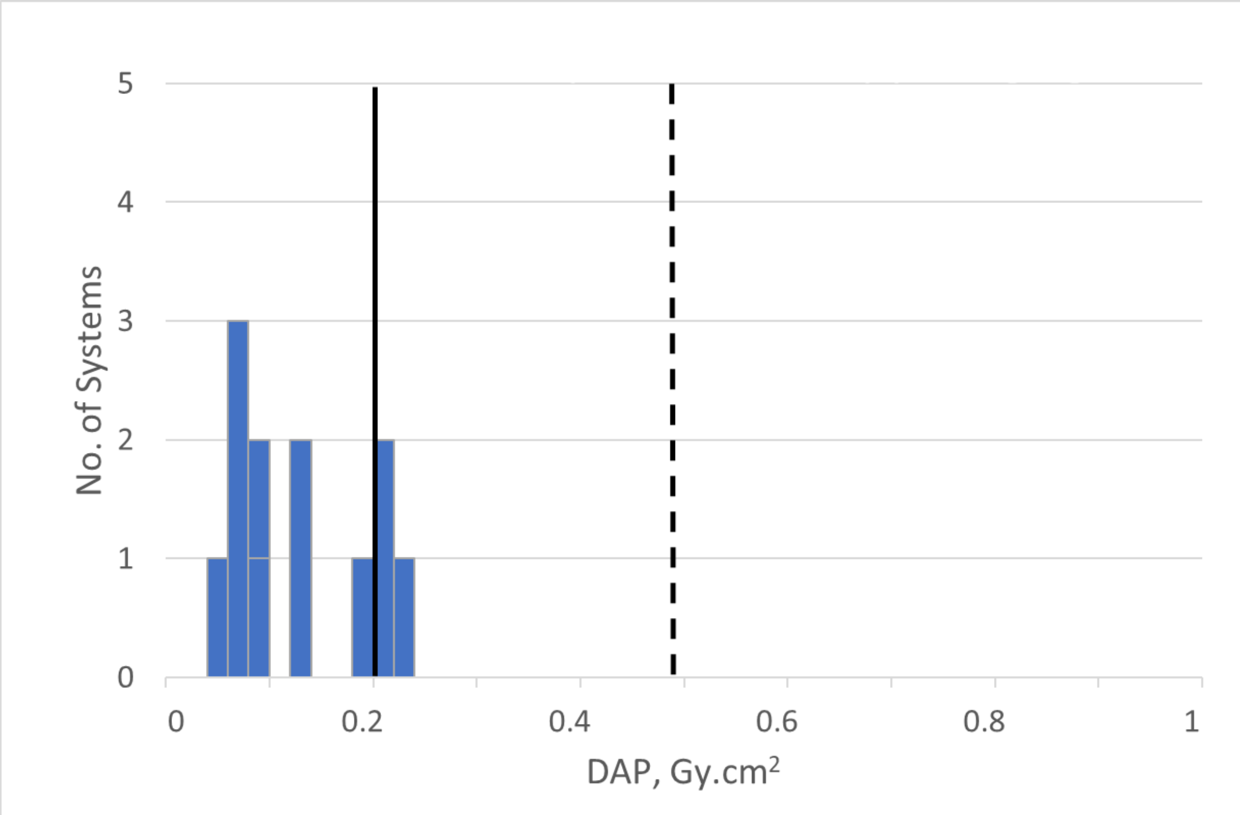


Figure C32. Insertion of TCVC

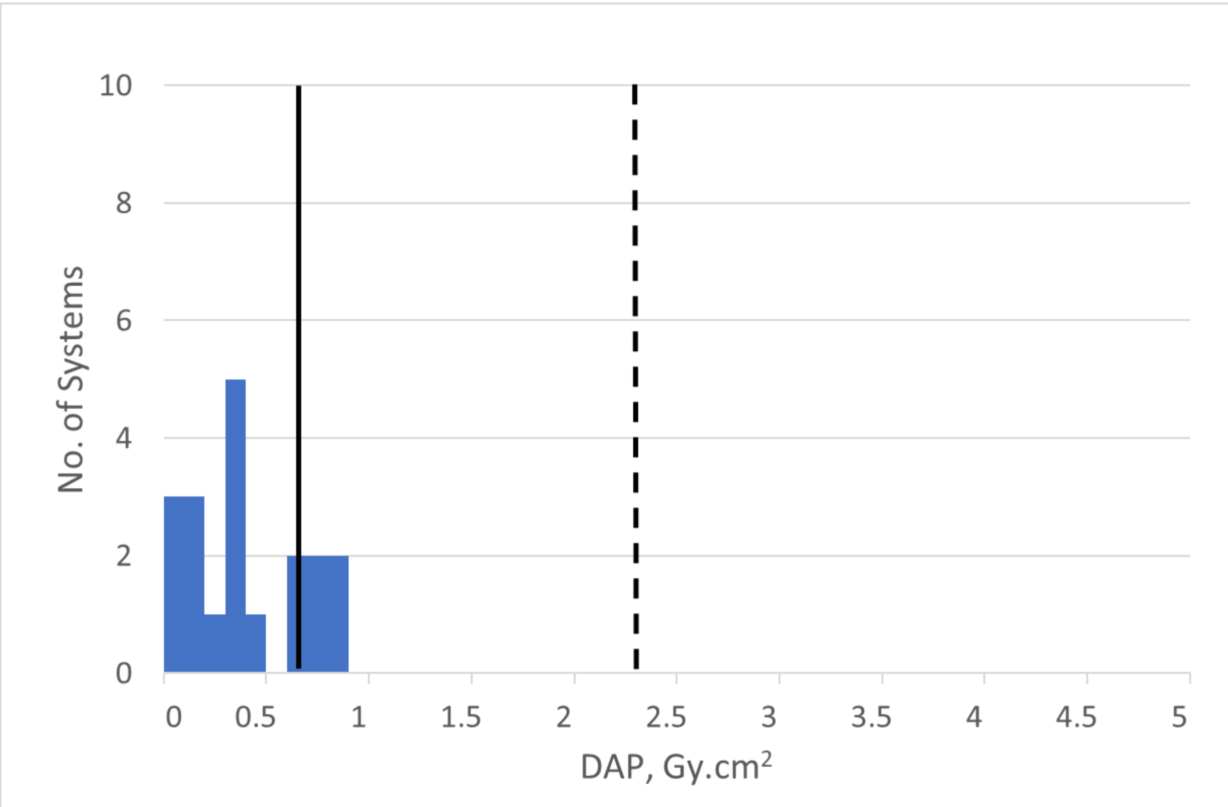
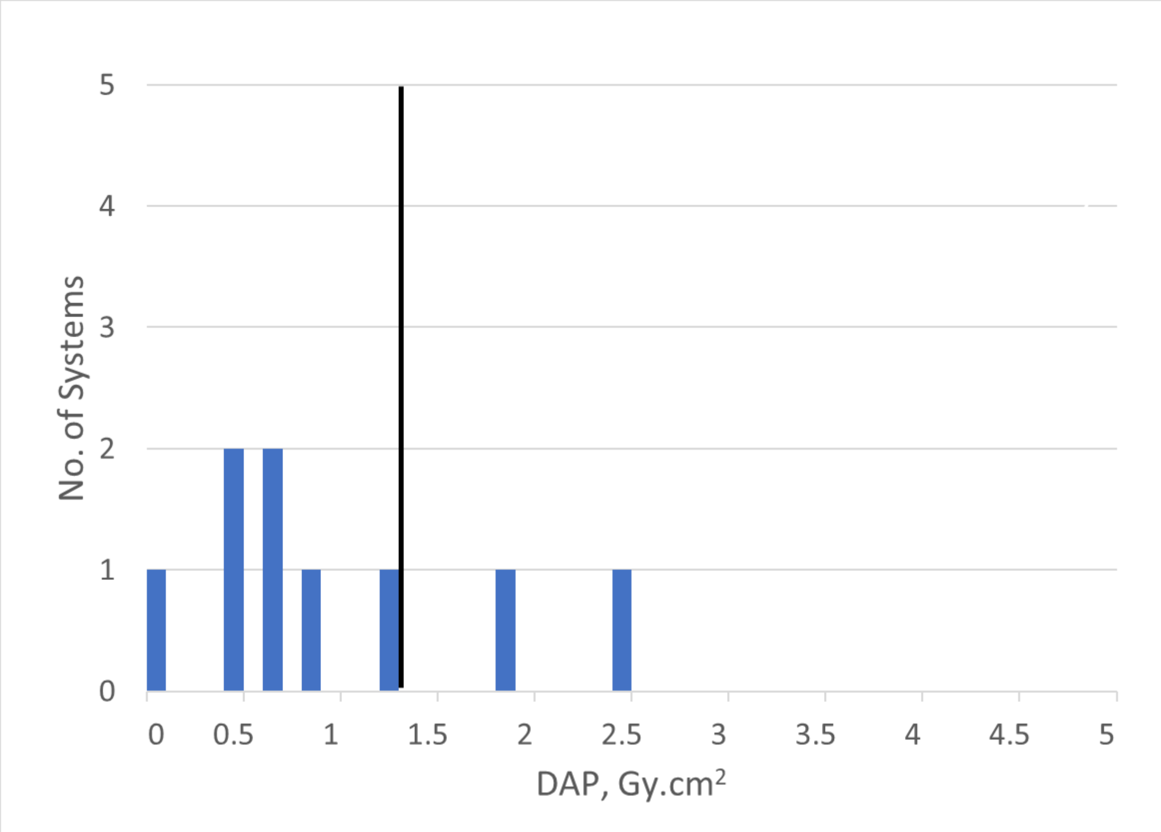


Figure C33. Radiologically inserted gastrostomy tube



1. 2010 survey third quartile: 13 Gy.cm^2

Figure C34 Videofluoroscopy barium swallow

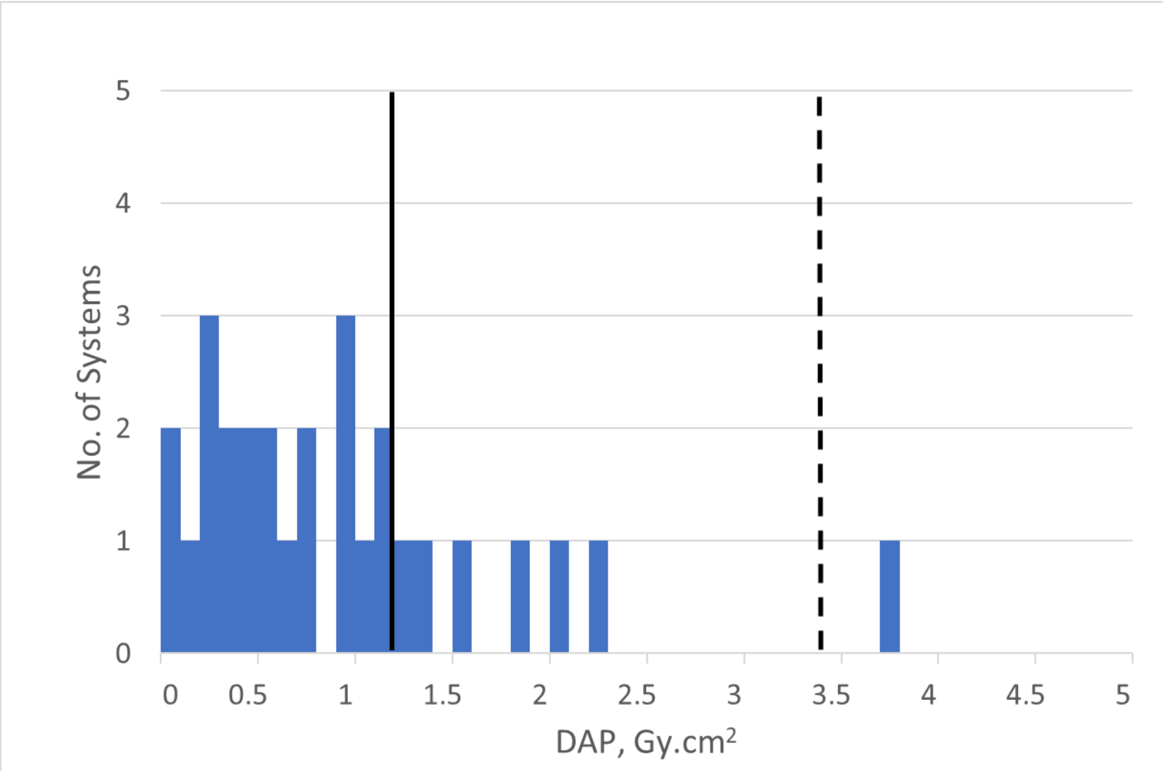


Figure C35. Hysterosalpingography

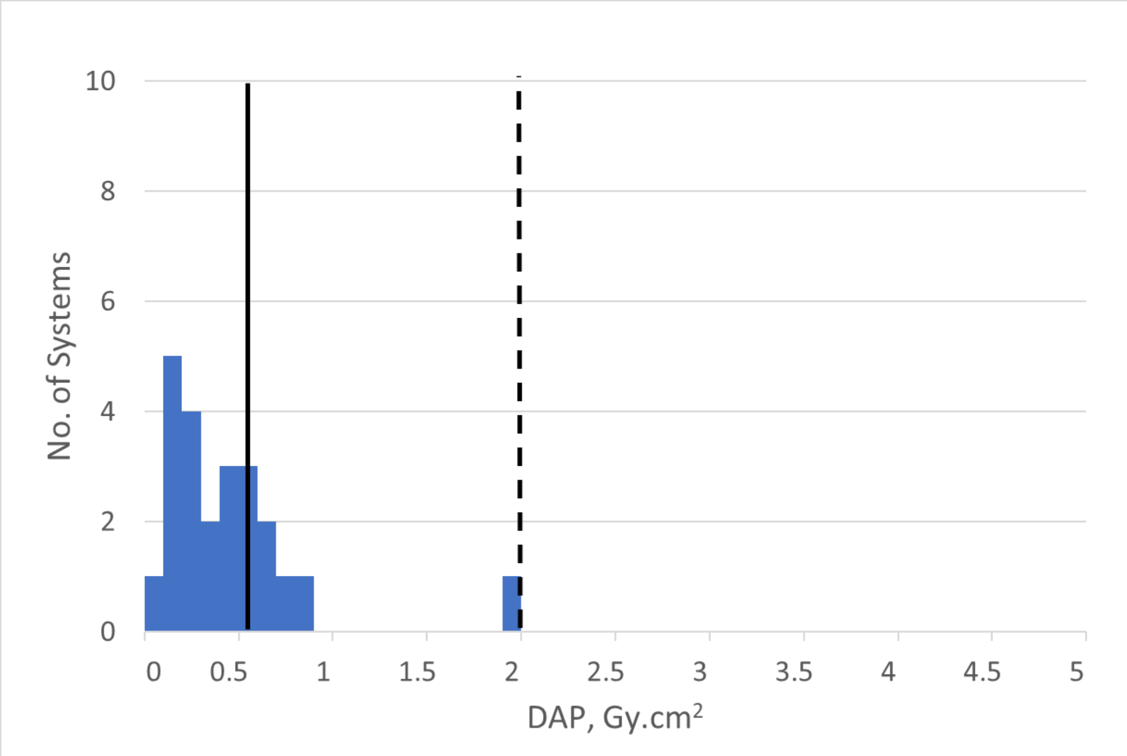
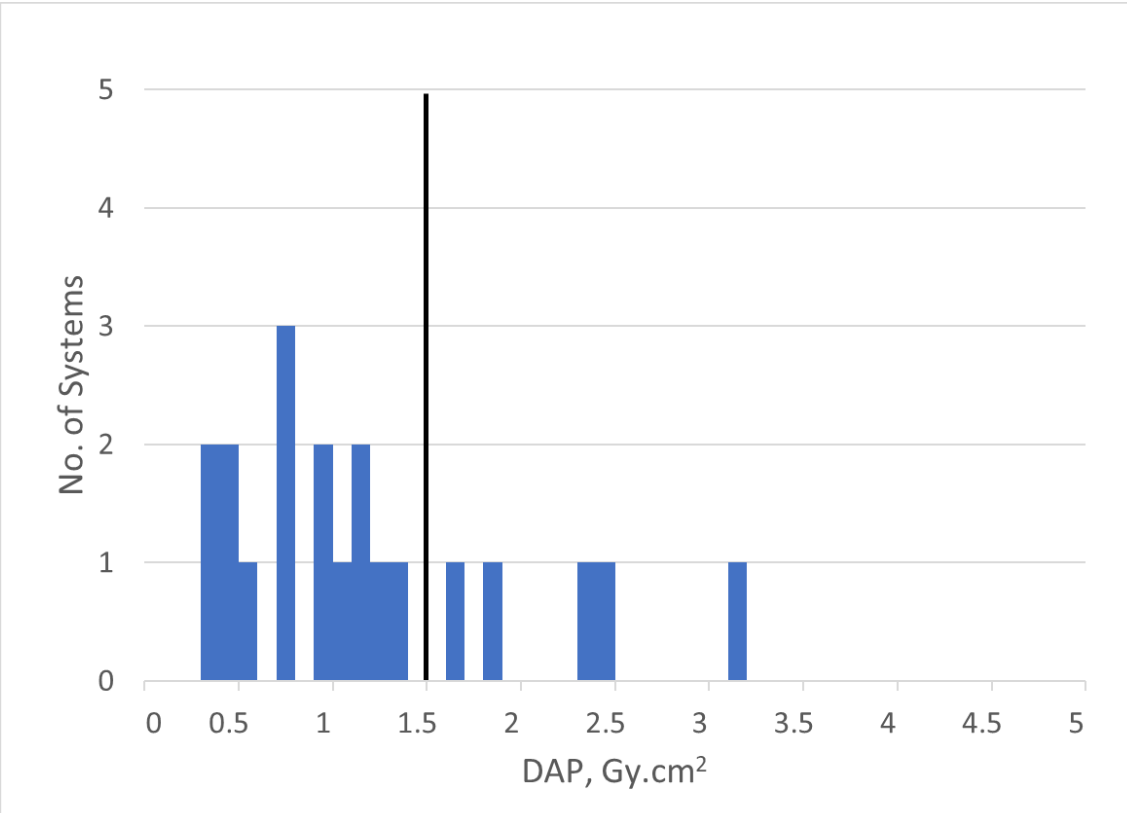
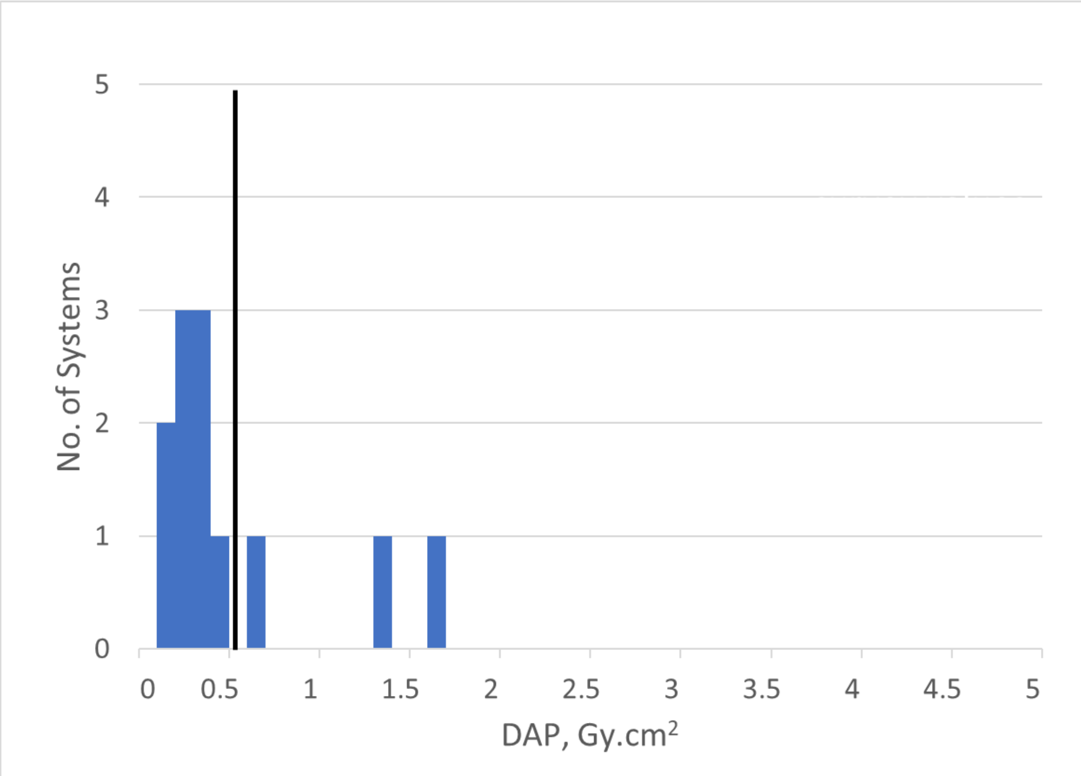


Figure C36. Nephrostomy procedure



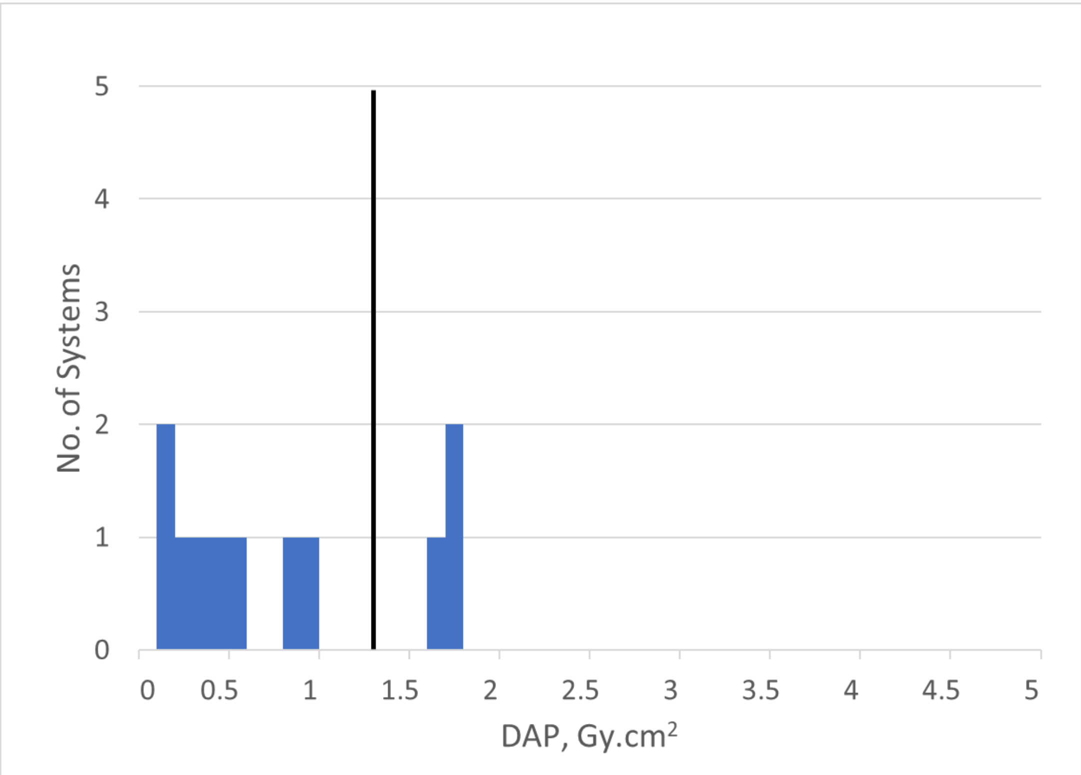
1. 2010 survey third quartile: 13 $Gy.cm^2$

Figure C37. Nephrostomy tube replacement



1. No 2010 survey DAP data

Figure C38. Facet joint injection



1. 2010 survey 3rd quartile: 6.3 Gy.cm2

Figure C39. Mobile: L-spine laminectomy

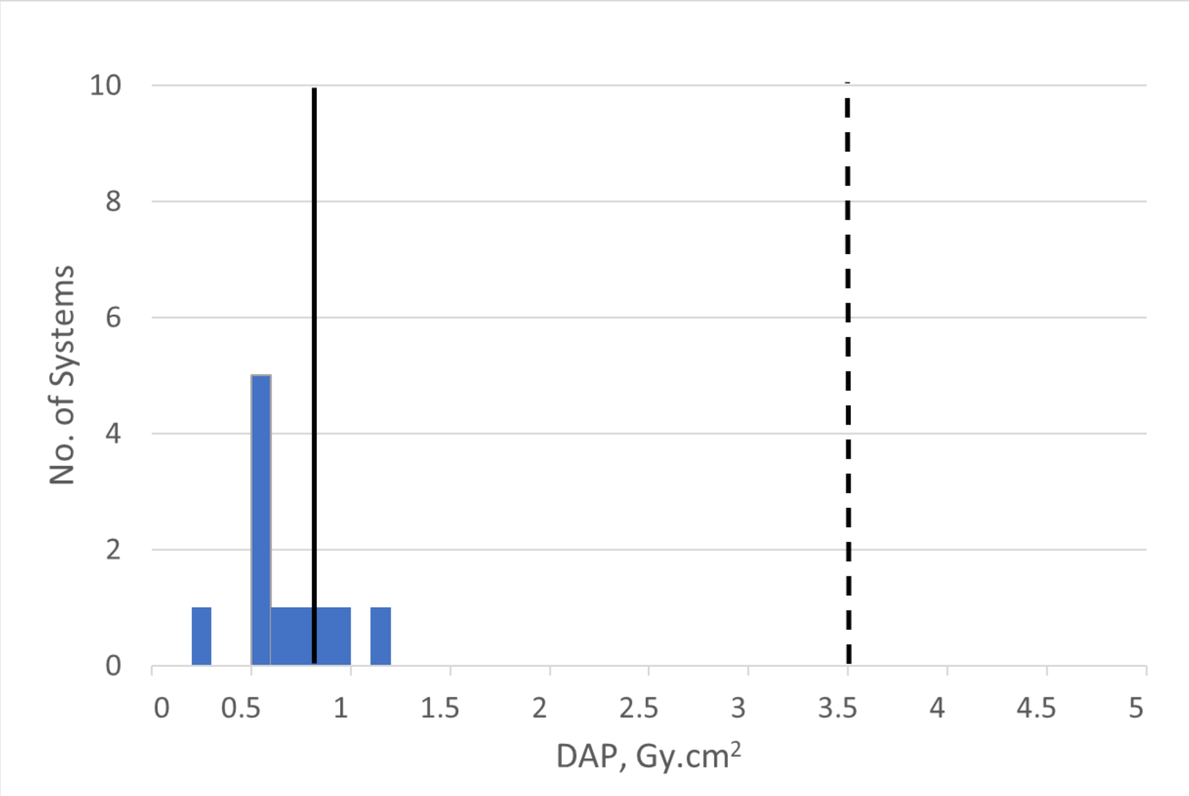


Figure C40. Mobile: orthopaedic hip pinning

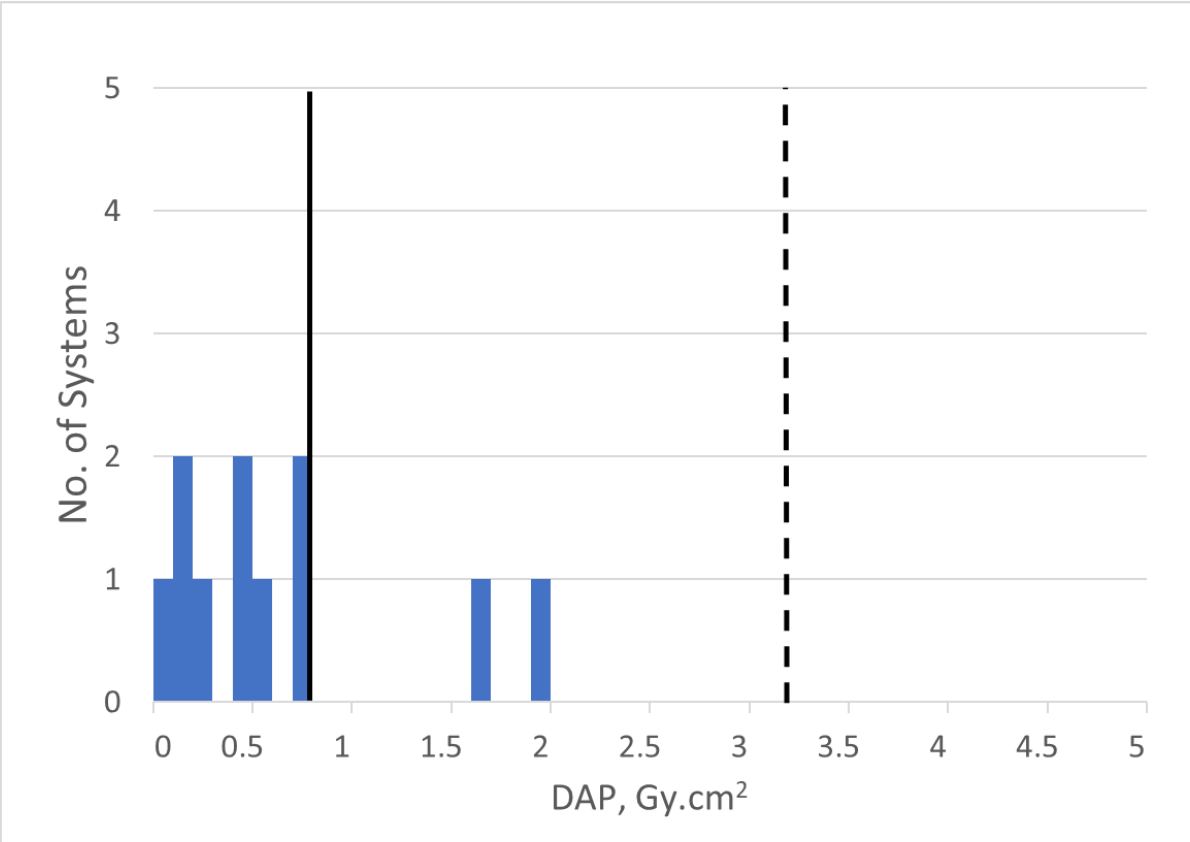


Figure C41. Generic mobile hip imaging

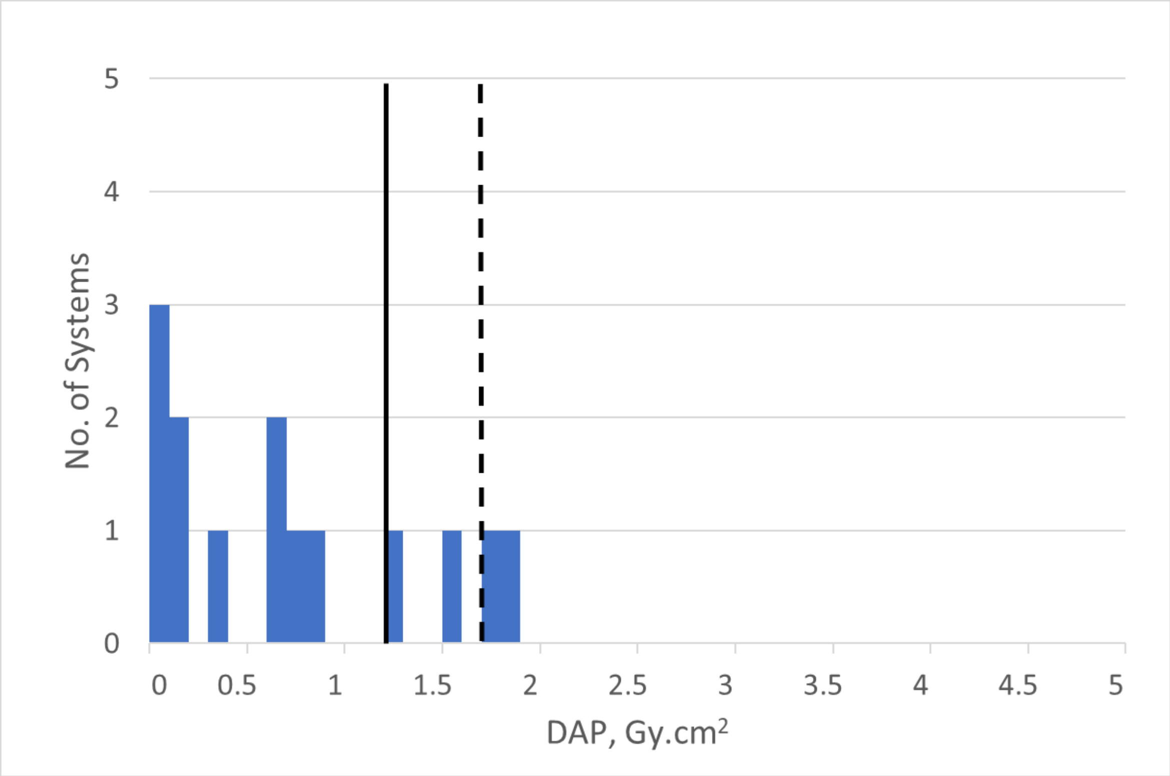


Figure C42. Generic mobile L-spine imaging

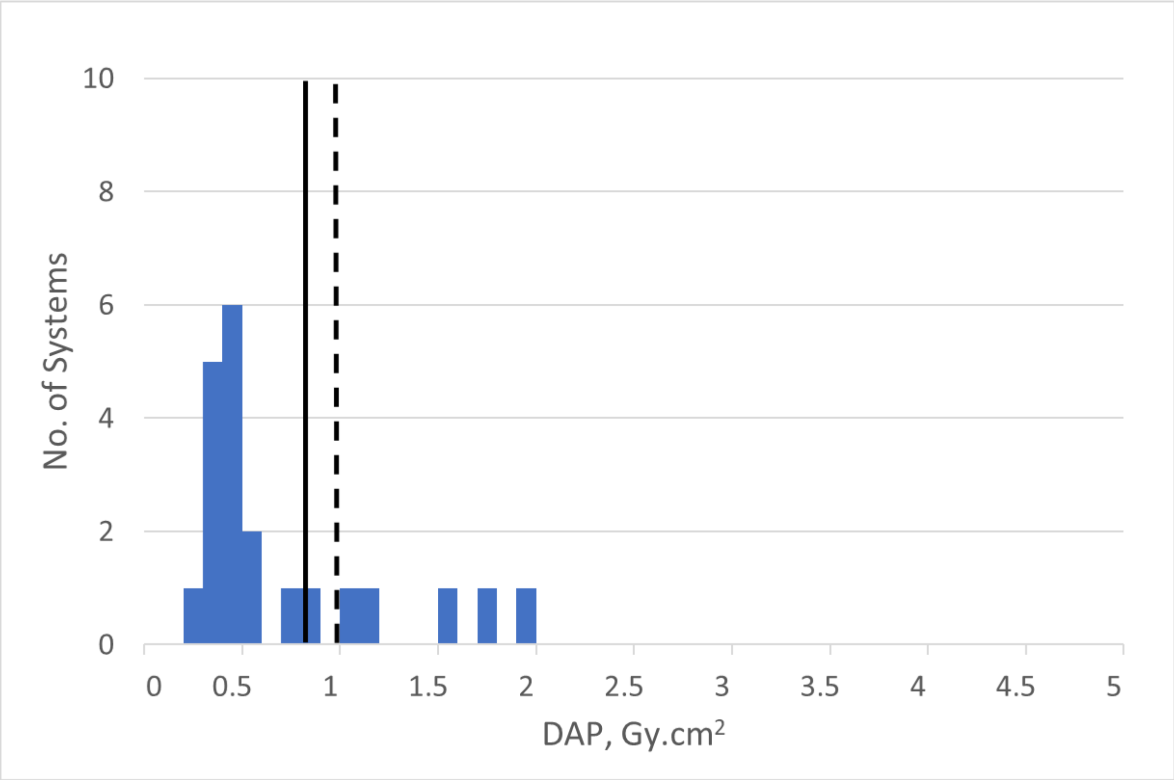


Figure C43. Pacemaker permanent

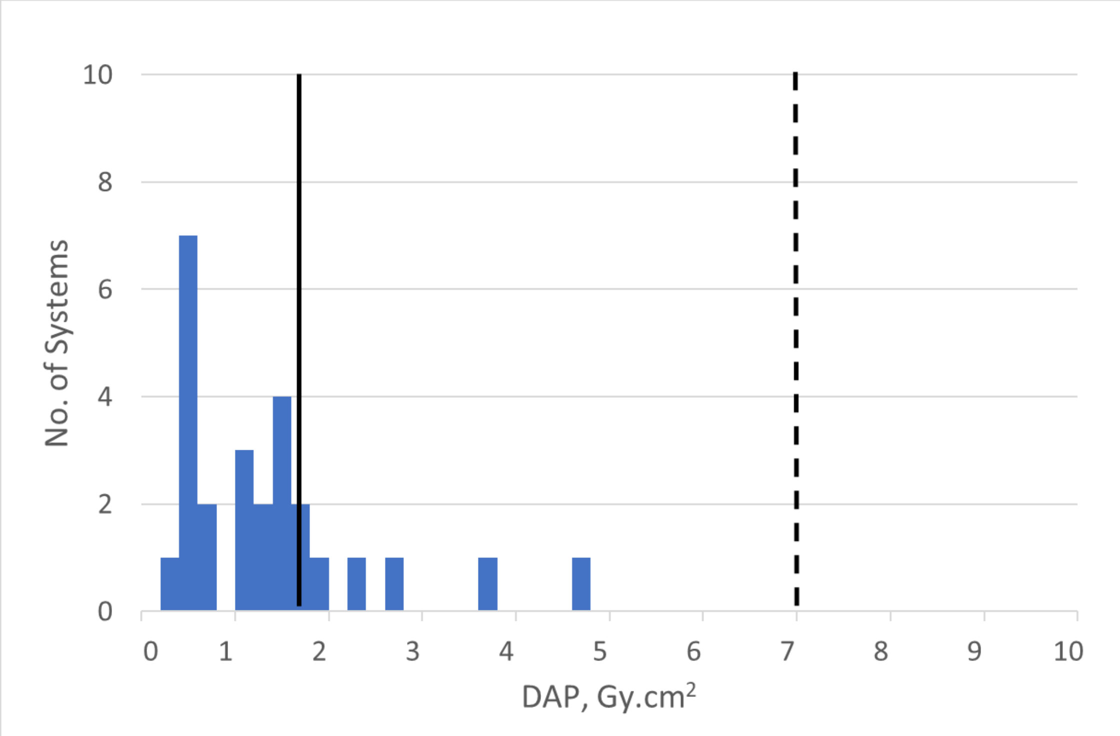
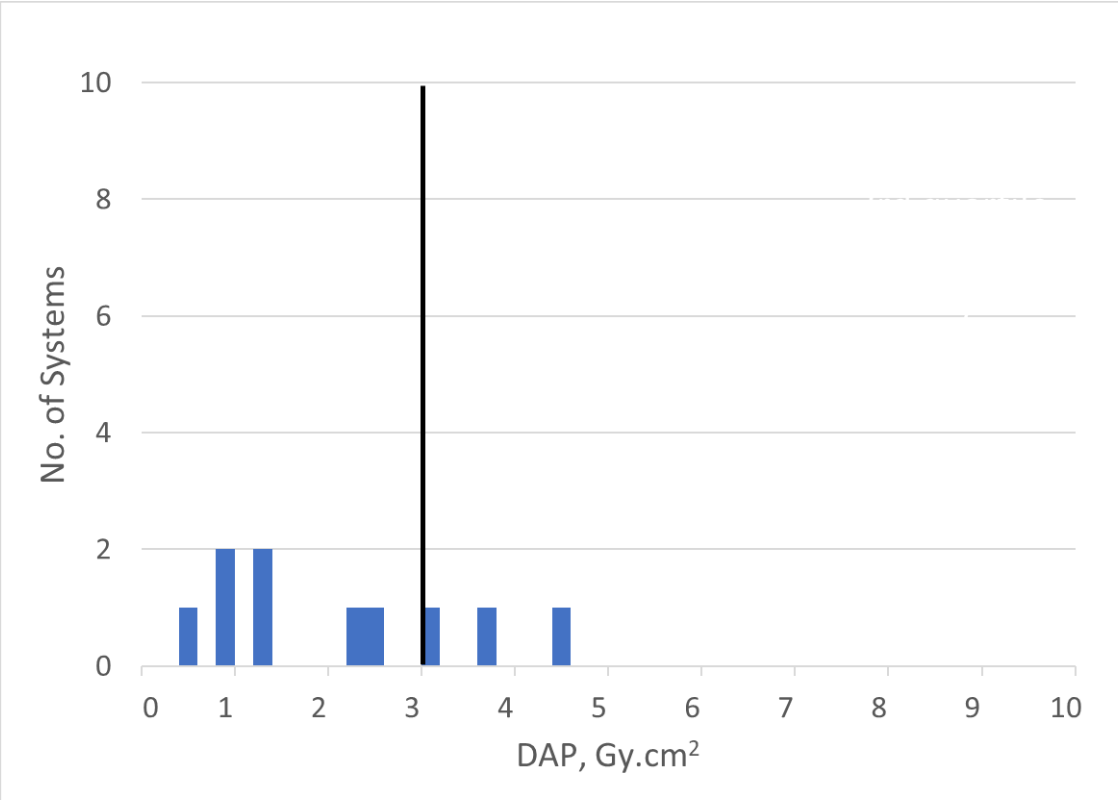


Figure C44. Ureteric stent, antegrade and retrograde



1. 2010 survey third quartile value: 16 Gy.cm^2

Higher dose fluoroscopy examinations and IR procedures

Figure C45. Barium swallow

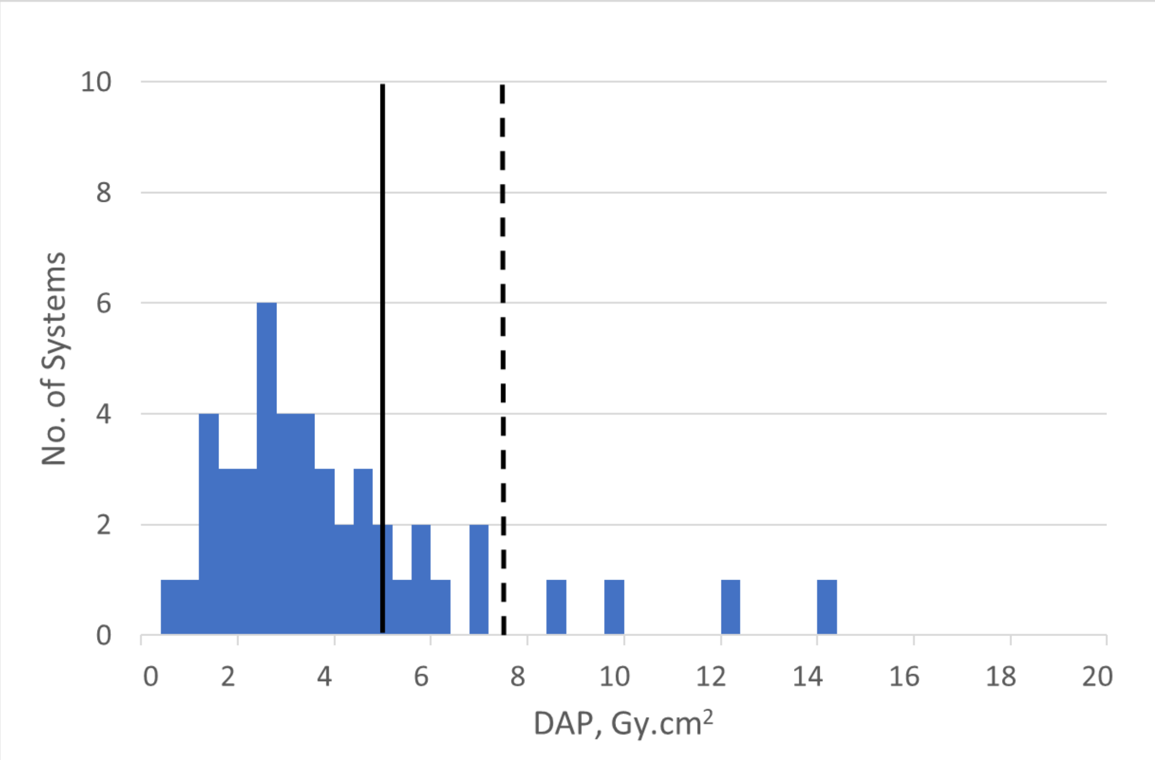


Figure C46. Water soluble contrast swallow

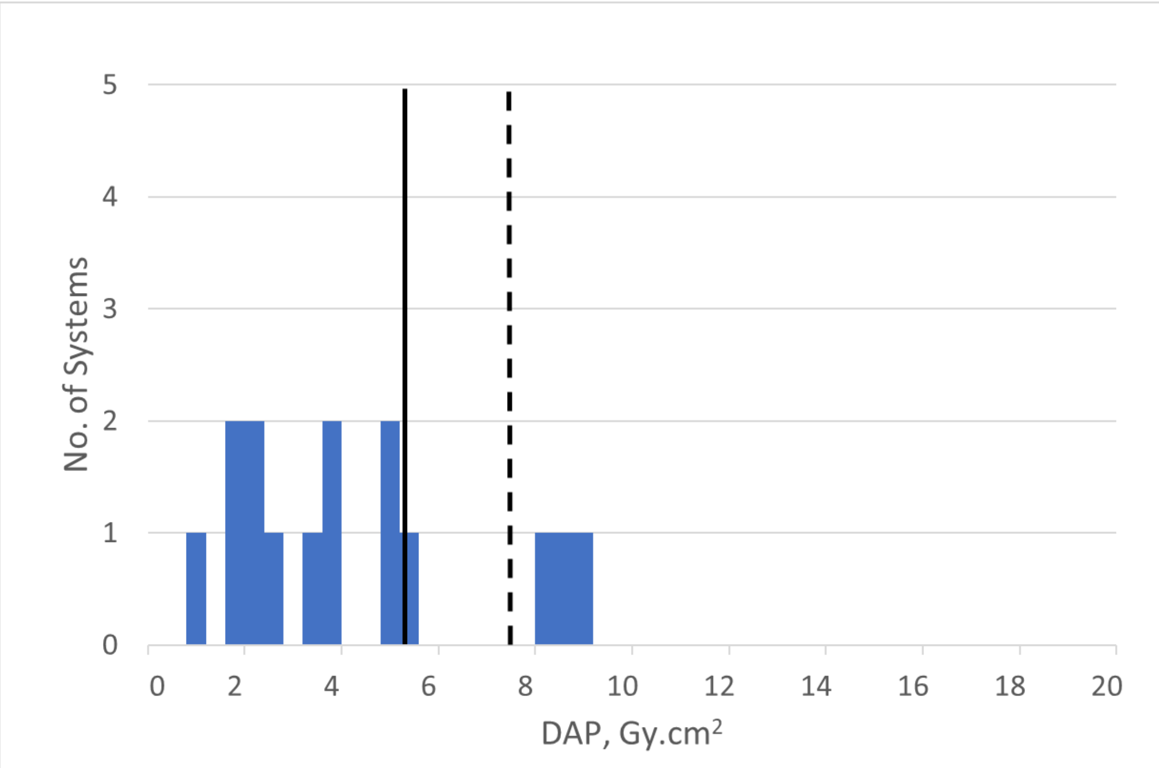


Figure C47. Videofluoroscopy barium swallow (rpt.)

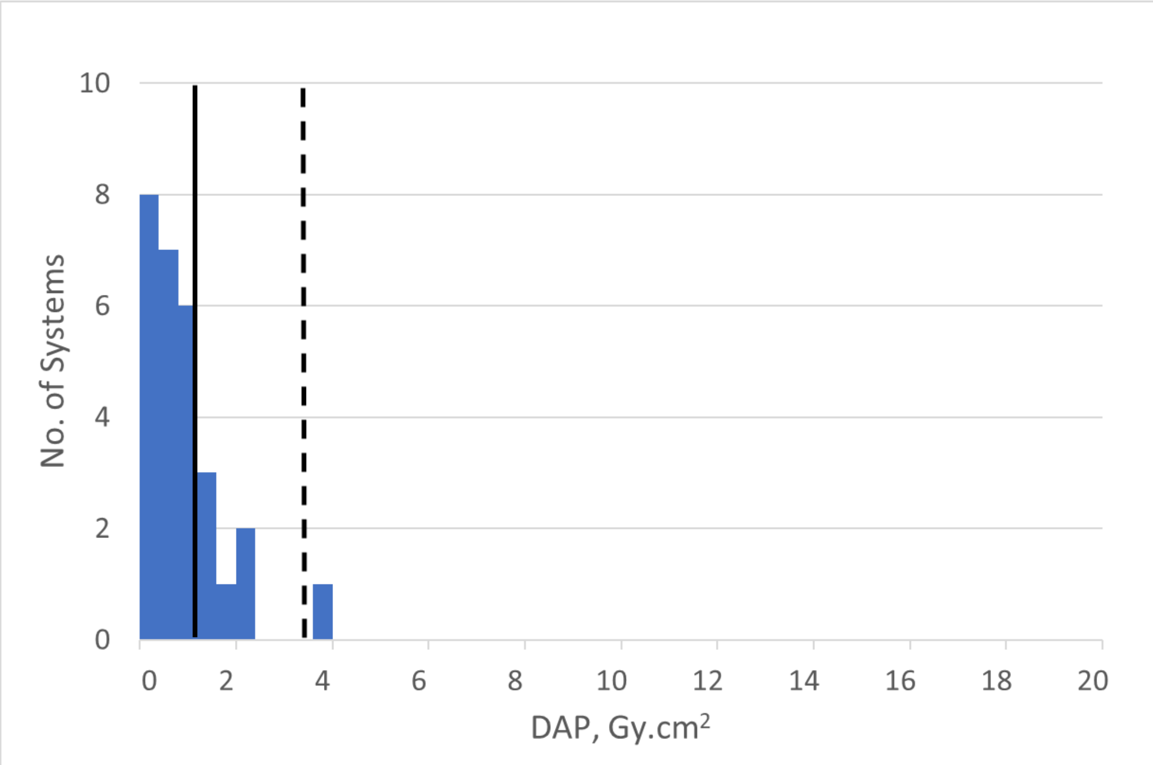
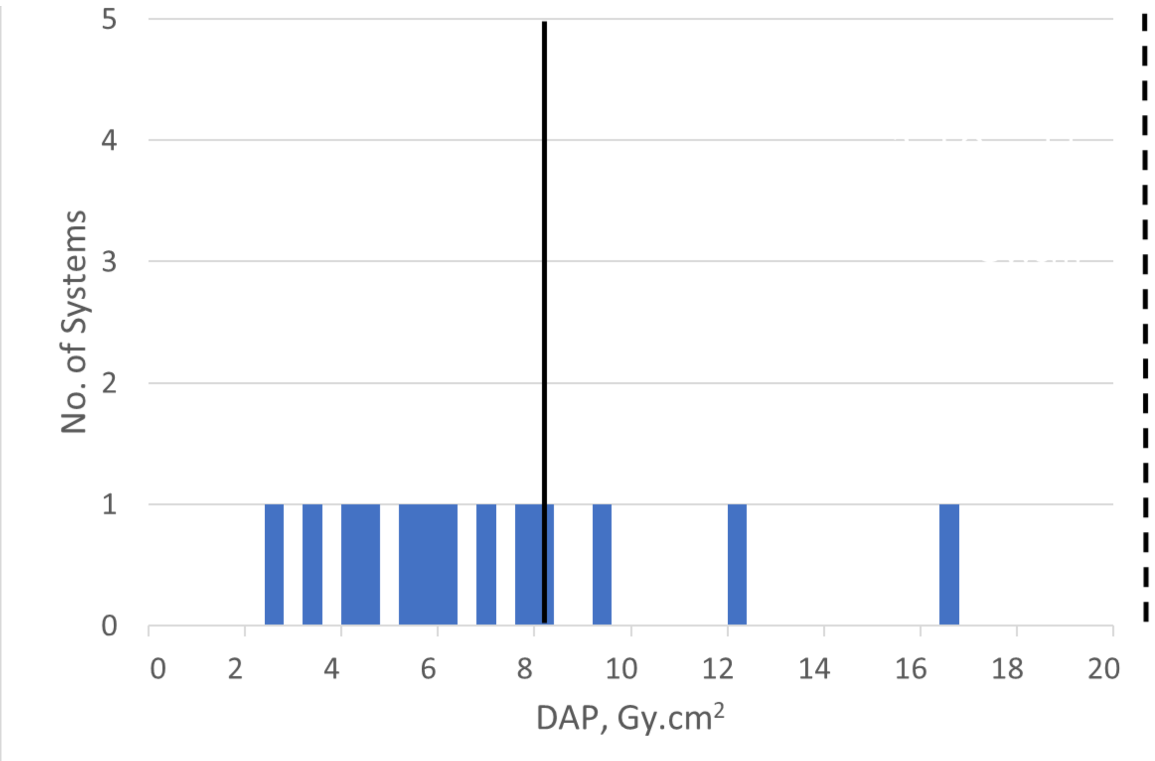


Figure C48. Water soluble contrast enema



1. 2010 Survey third quartile value: 21 $Gy.cm^2$

Figure C49. Barium meal and swallow

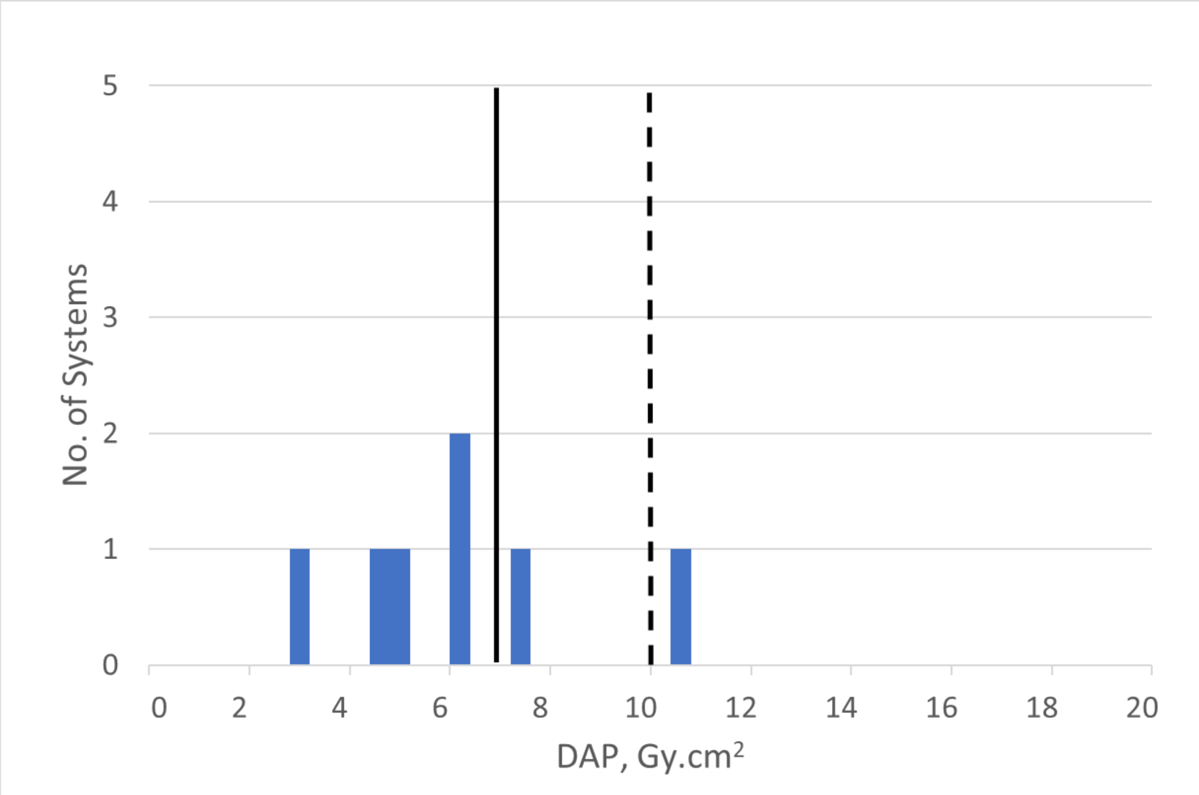


Figure C50. ERCP (diagnostic and interventional)

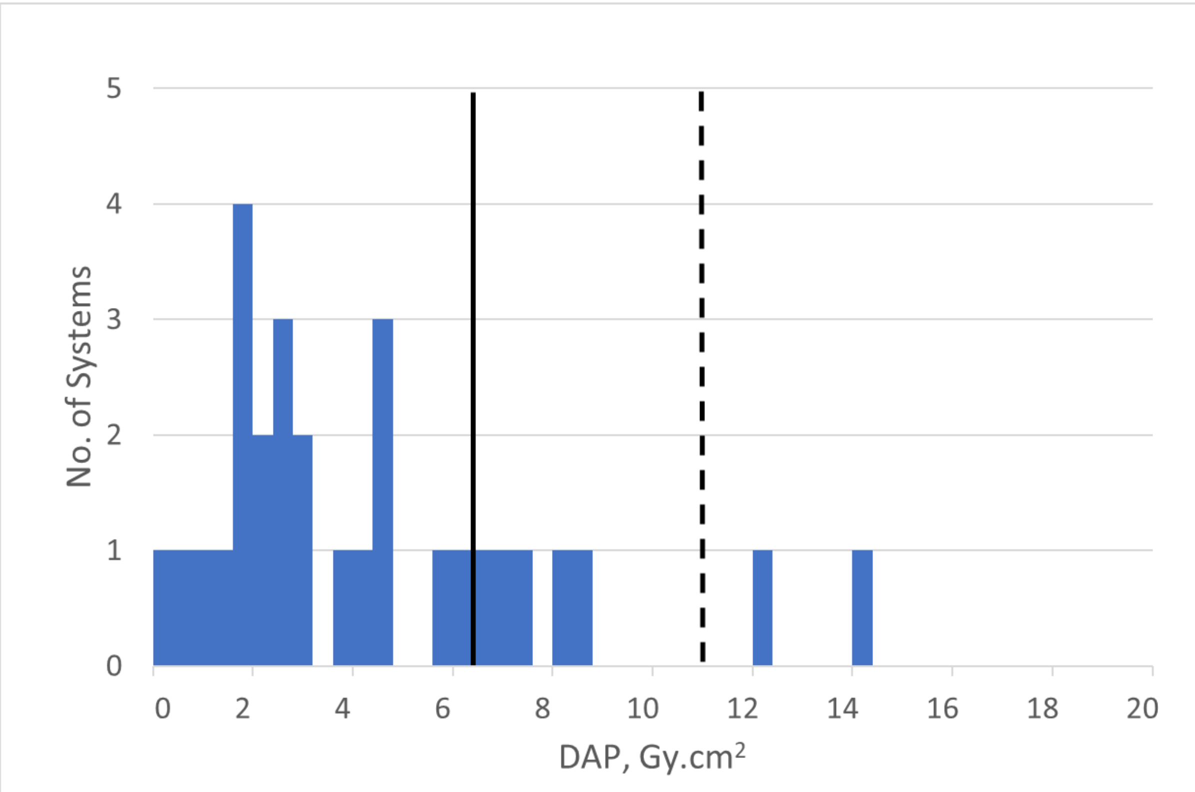
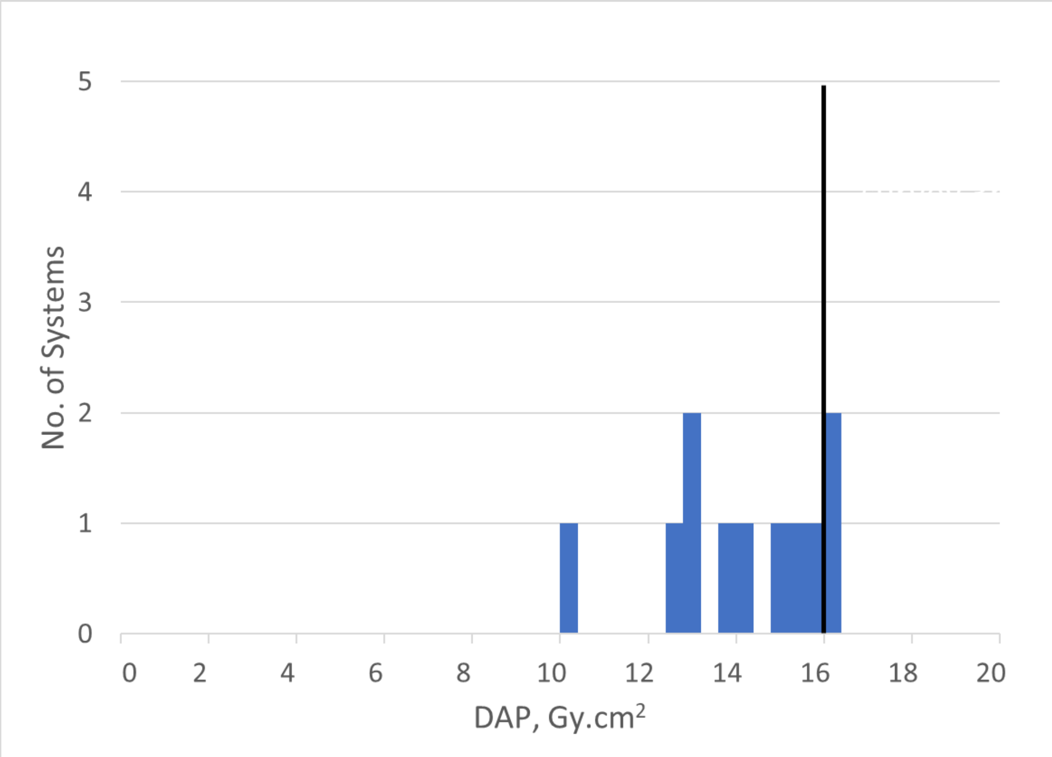
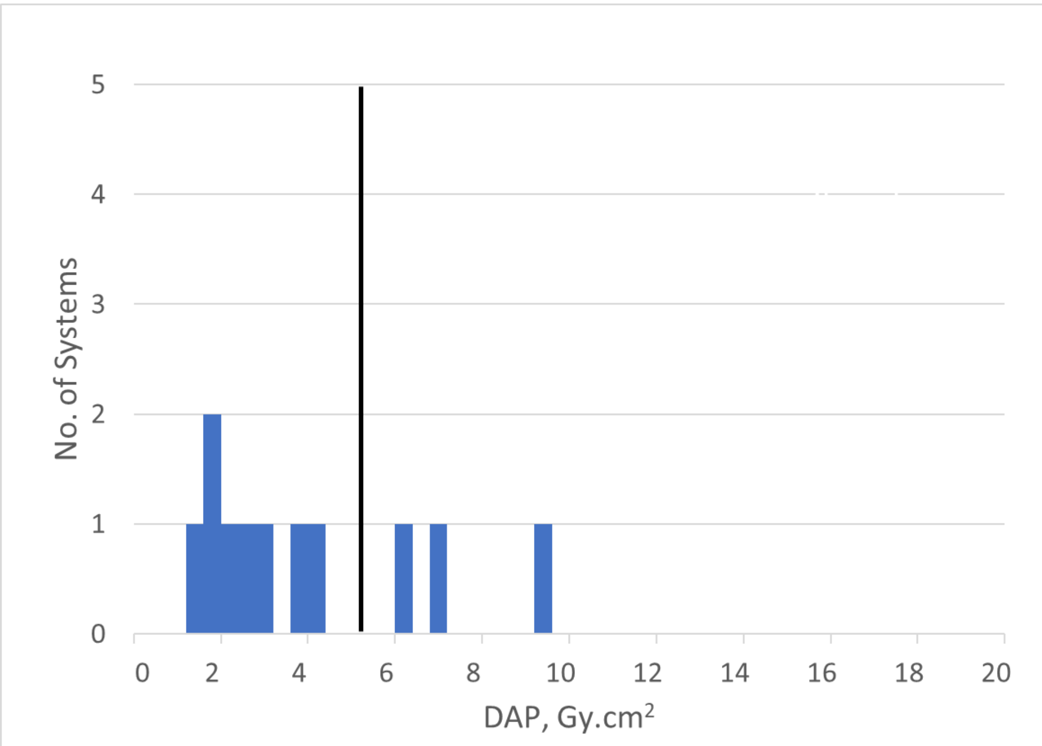


Figure C51. Coronary angiography exam



1. 2010 survey third quartile value: 31 Gy.cm²

Figure C52. Cardiac catheter ablation



1. 2010 survey 3rd quartile value: 27 Gy.cm²

Appendix D: Detector type and use of AEC

DR and CR detector system median DAP histograms

Figures D1 to D29 compare the distribution of system median DAP for system data sets based on 30 or more patient studies for radiography systems using CR and DR detectors.

Plain radiography single projections

The median DAP values for system exam data sets for CR and DR detector systems for the 18 plain radiography single projections listed in Table 18 are compared in figures D1 to D18.

While exams' typical median DAP values for DR detector systems are usually about 20% lower than their typical median DAP values for CR detector systems, figures D1 to D18 show that there is a substantial overlap of the DAP median values for systems using the 2 detector types. Therefore, there is no justification for setting different NDRL values according to detector type.

Chest AP (mobile) (Figure D9) has the largest difference in median DAP values for DR and CR detector systems (Table 18), with half of CR systems having system median DAP values greater than the highest DR system median DAP value. The median and third quartile system median DAP values of CR systems for chest AP (mobile) are approximately 60% higher than those for DR systems (as opposed to about 40% for chest AP).

Figure D11: Chest lateral, for which all projection data sets are for DR detector systems, is included for comparison with other chest projections.

Low dose radiography projections

Figure D1. Cervical spine AP projection

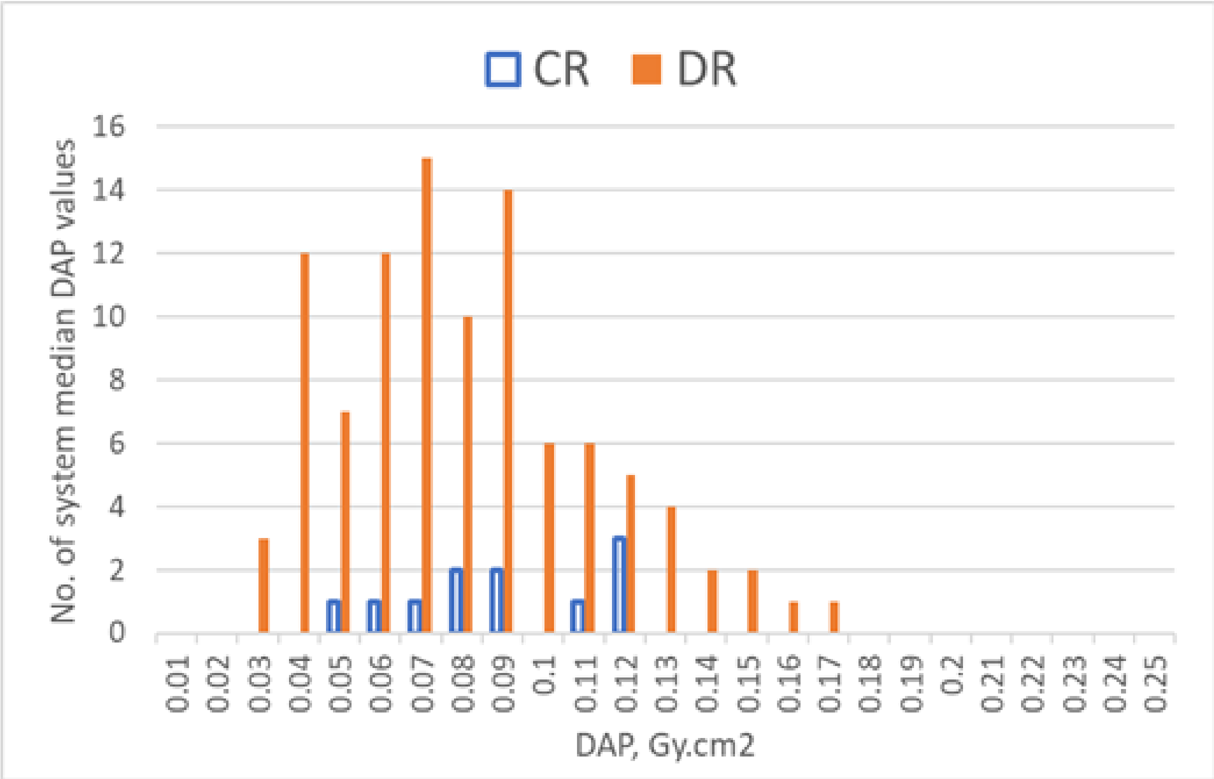


Figure D2. Cervical spine lateral projection

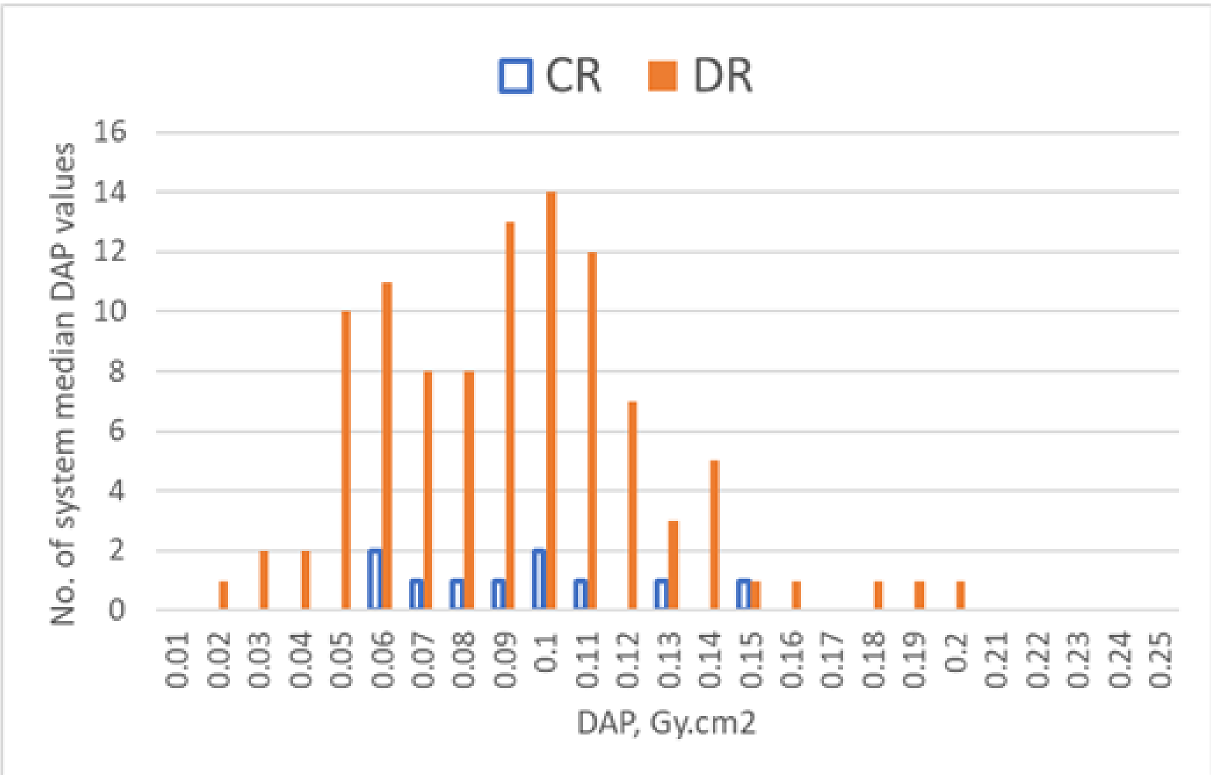


Figure D3. Shoulder (single) AP projection

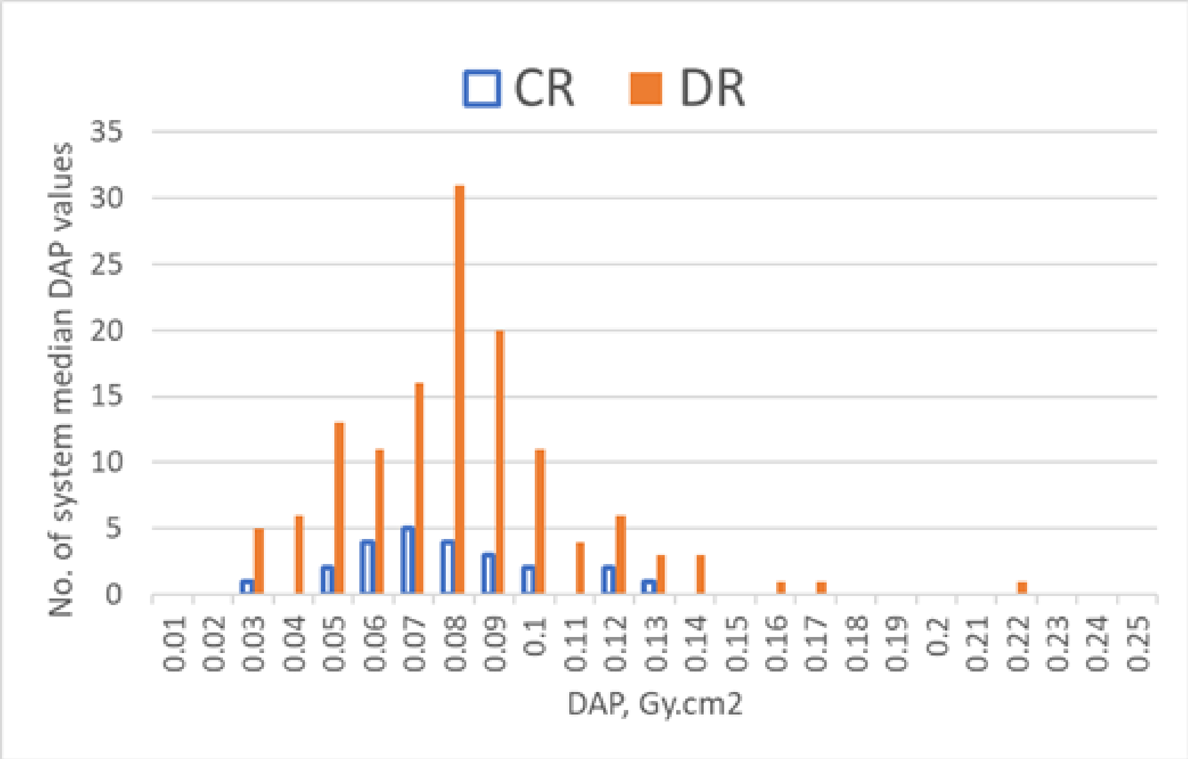


Figure D4. Knee (single) AP projection

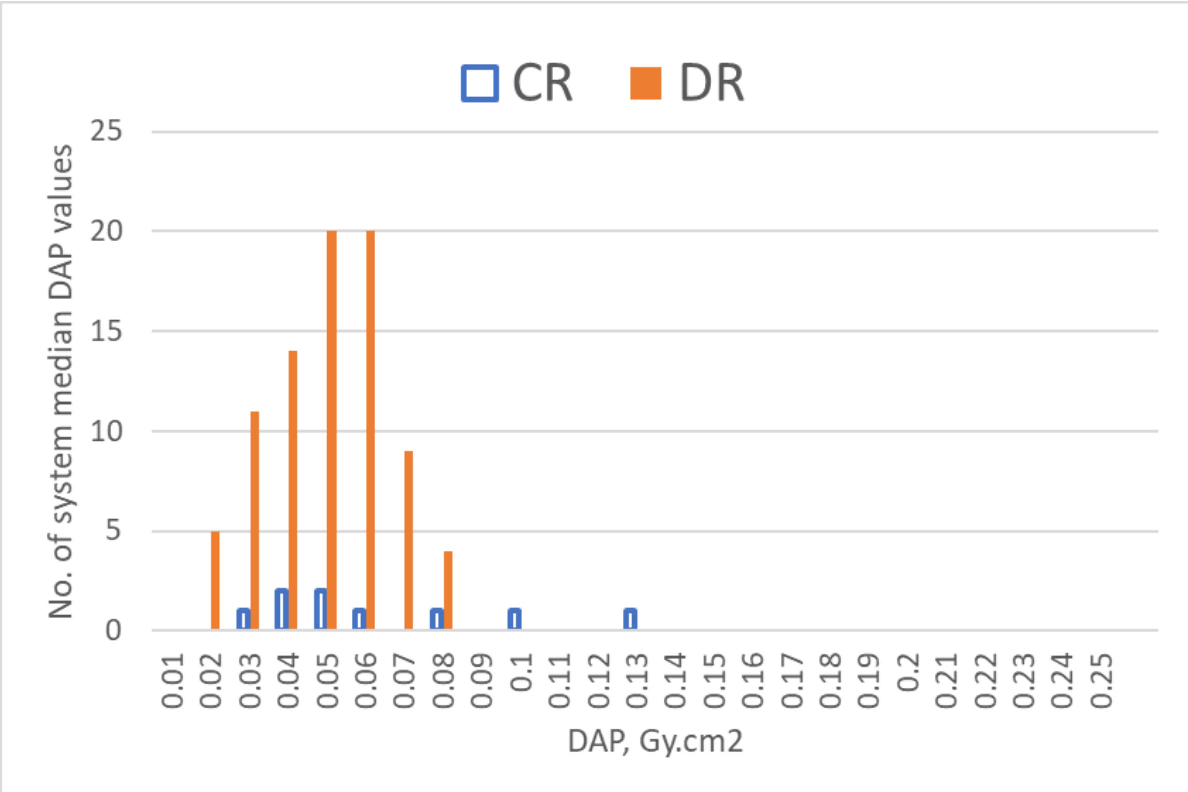


Figure D5. Knee (single) lateral projection

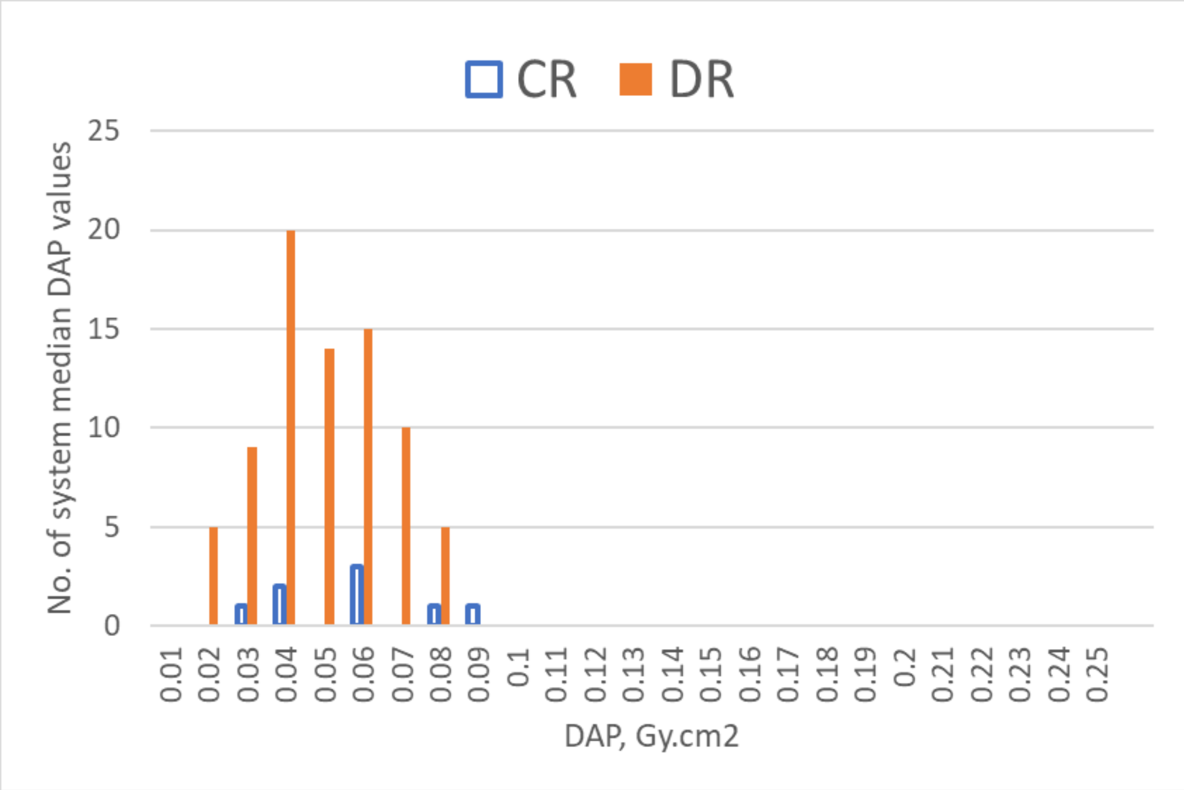


Figure D6. Foot (single) weight bearing DP projection

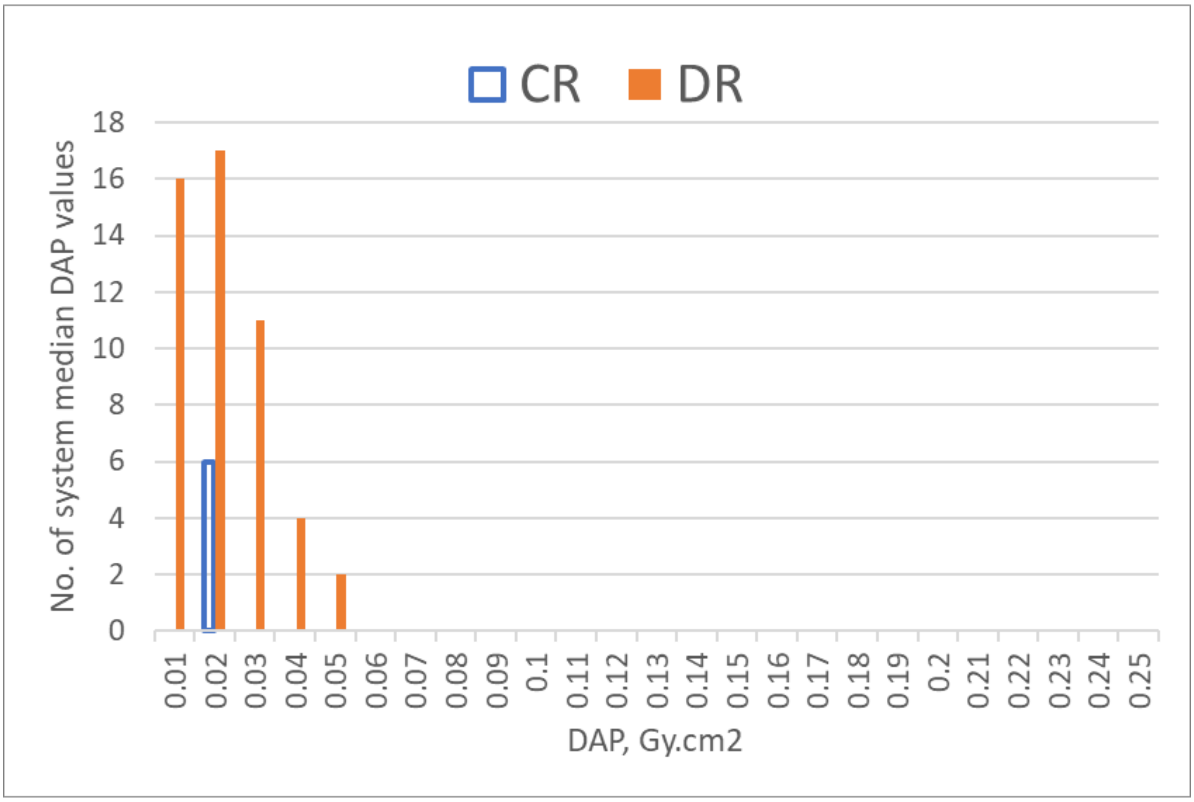
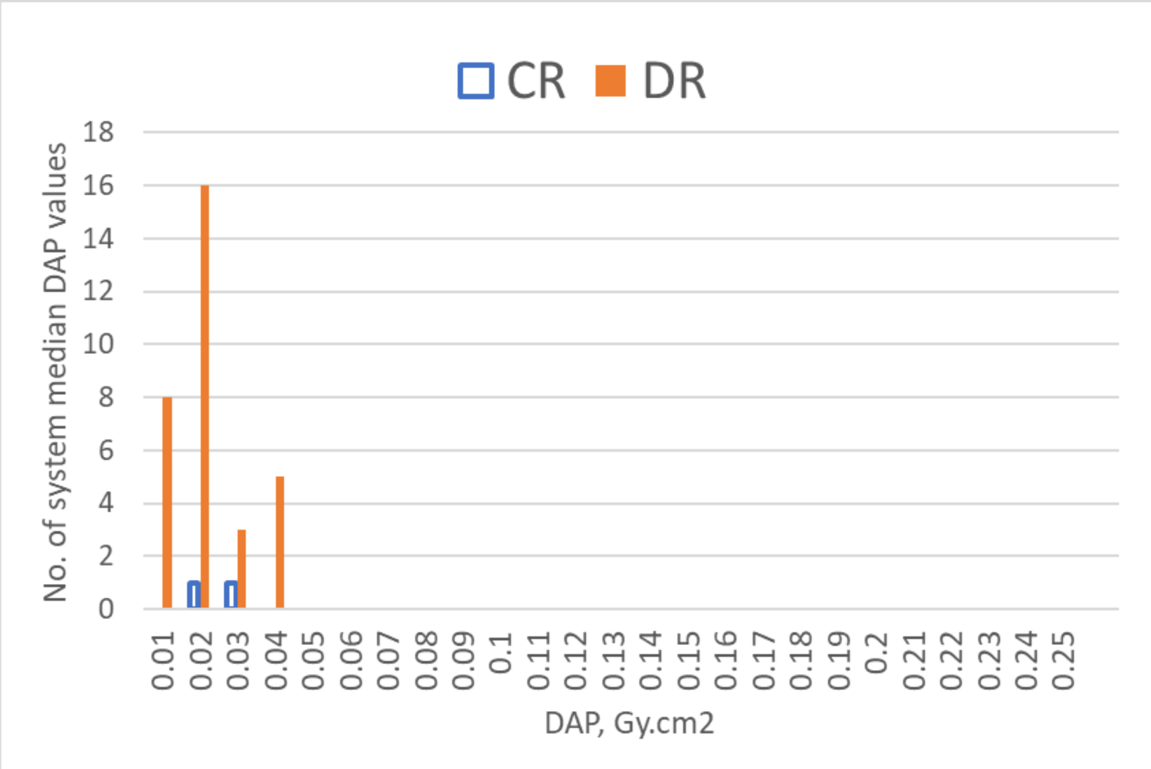


Figure D7. Hand (single) PA projection



Chest projections

Figure D8. Chest AP projection

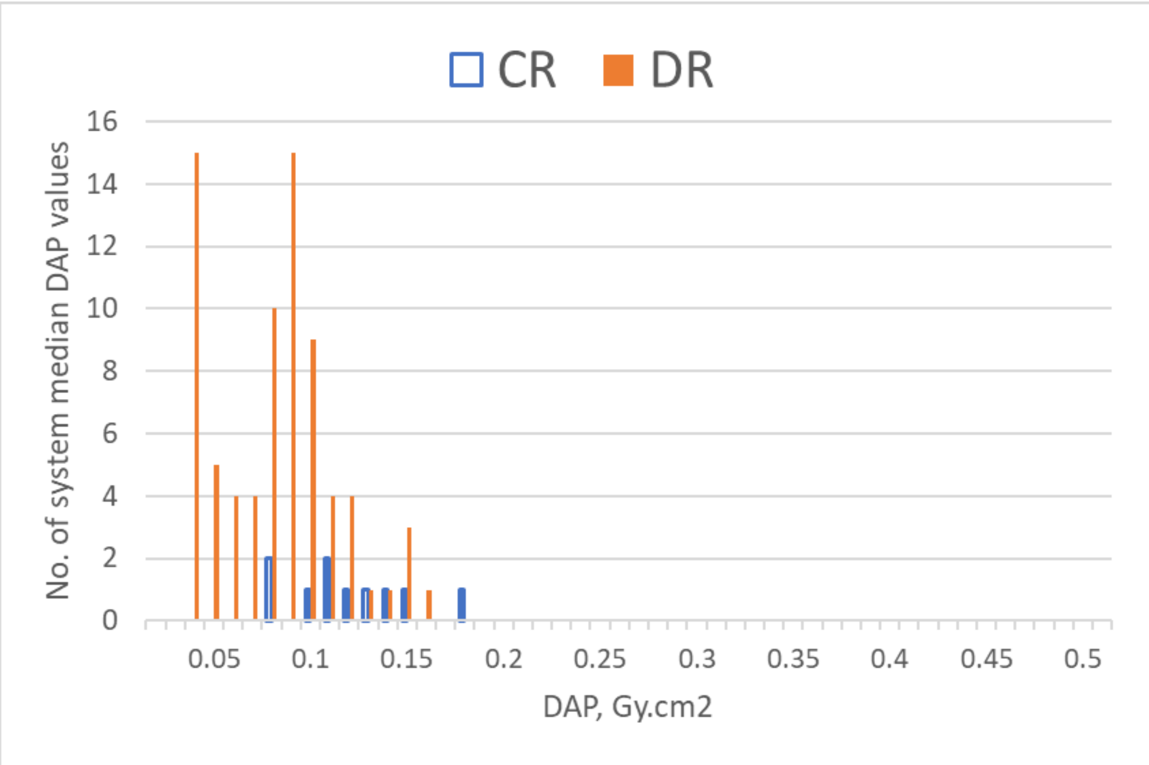


Figure D9. Chest AP projection: mobile system

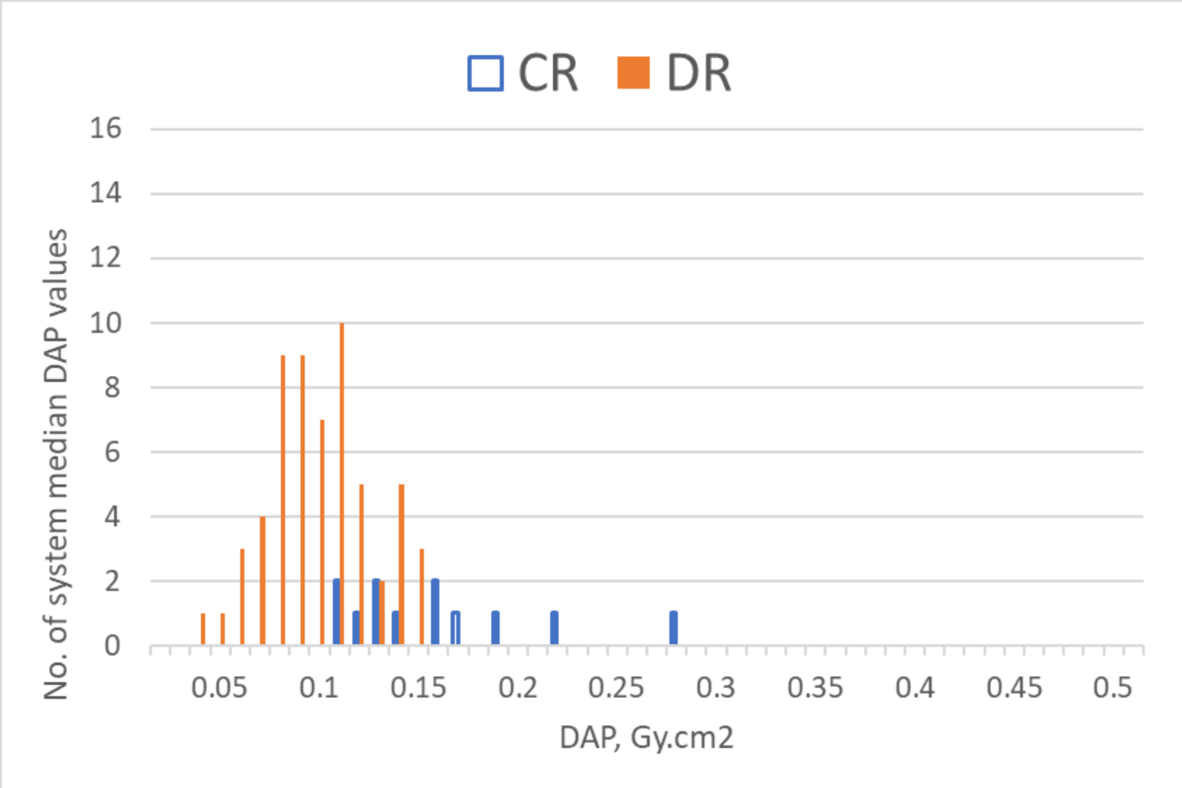


Figure D10. Chest PA projection

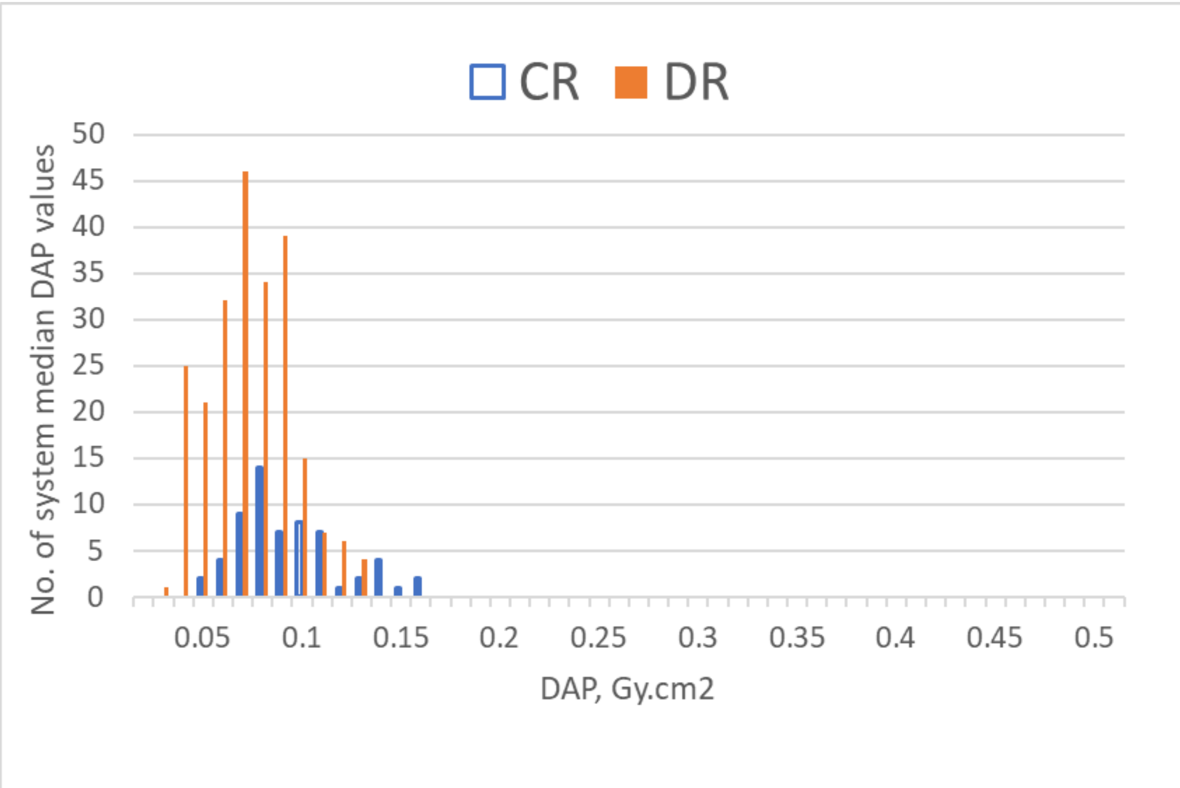
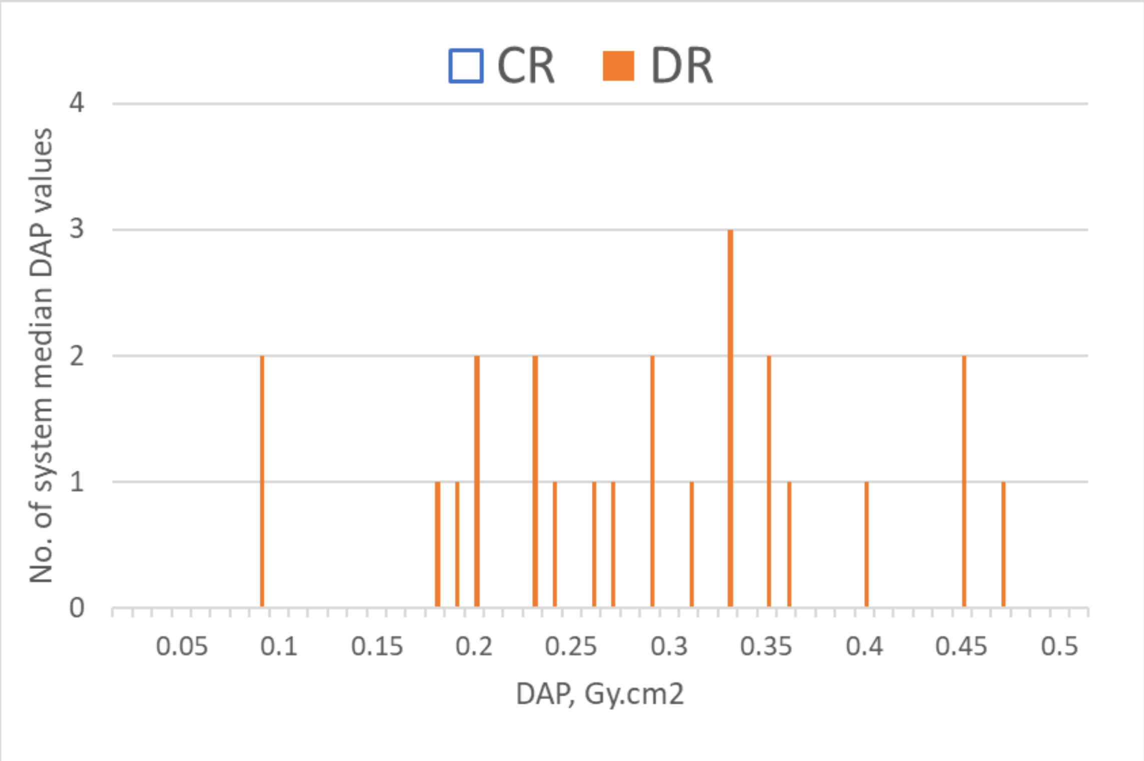


Figure D11. Chest lateral projection



Higher DAP plain radiography projections

Figure D12. Abdomen AP projection

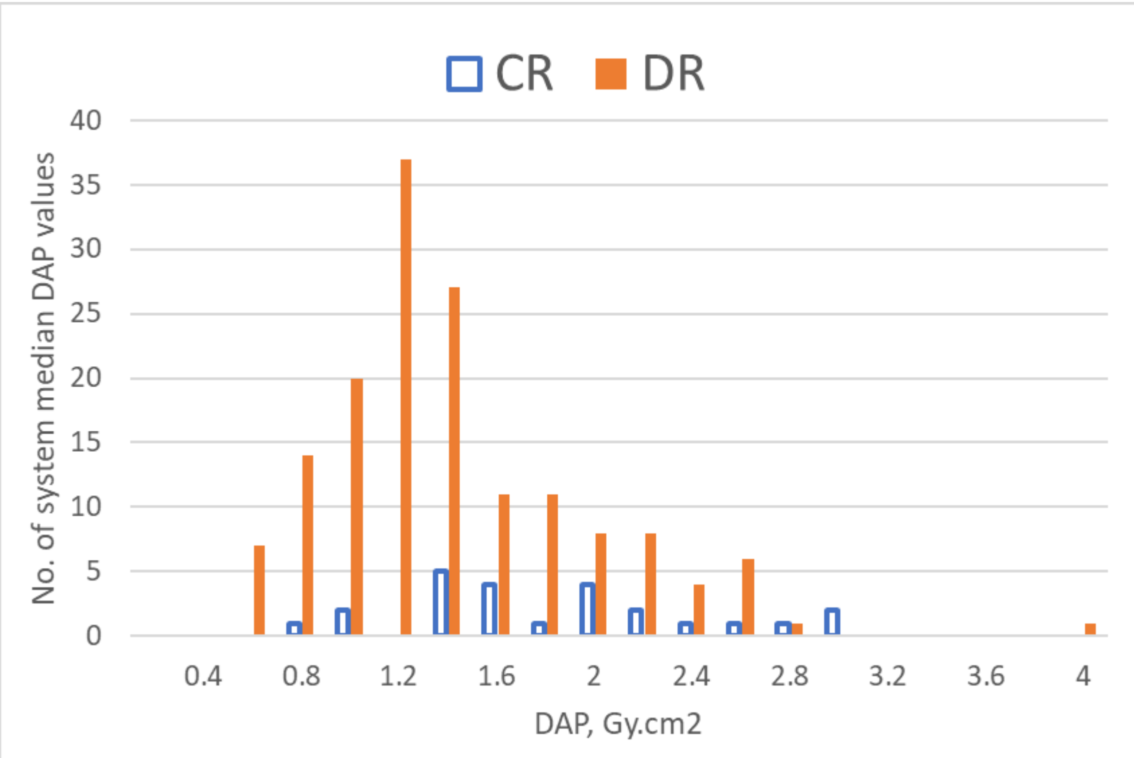


Figure D13. Thoracic spine AP projection

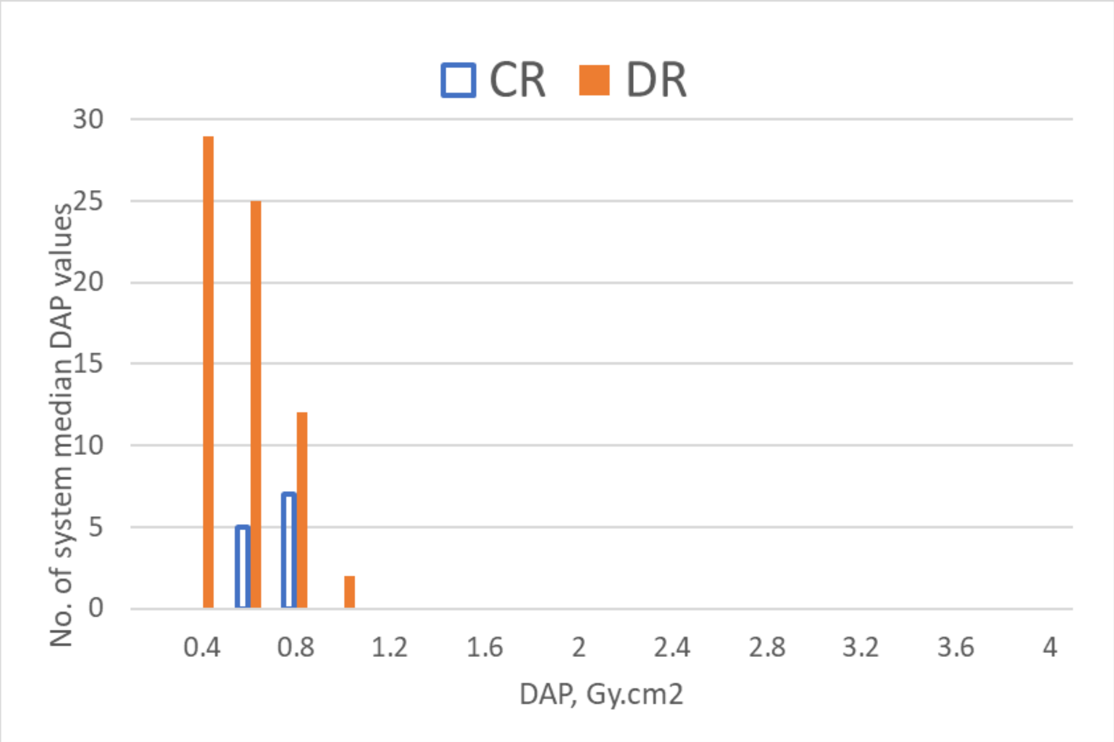


Figure D14. Thoracic spine lateral projection

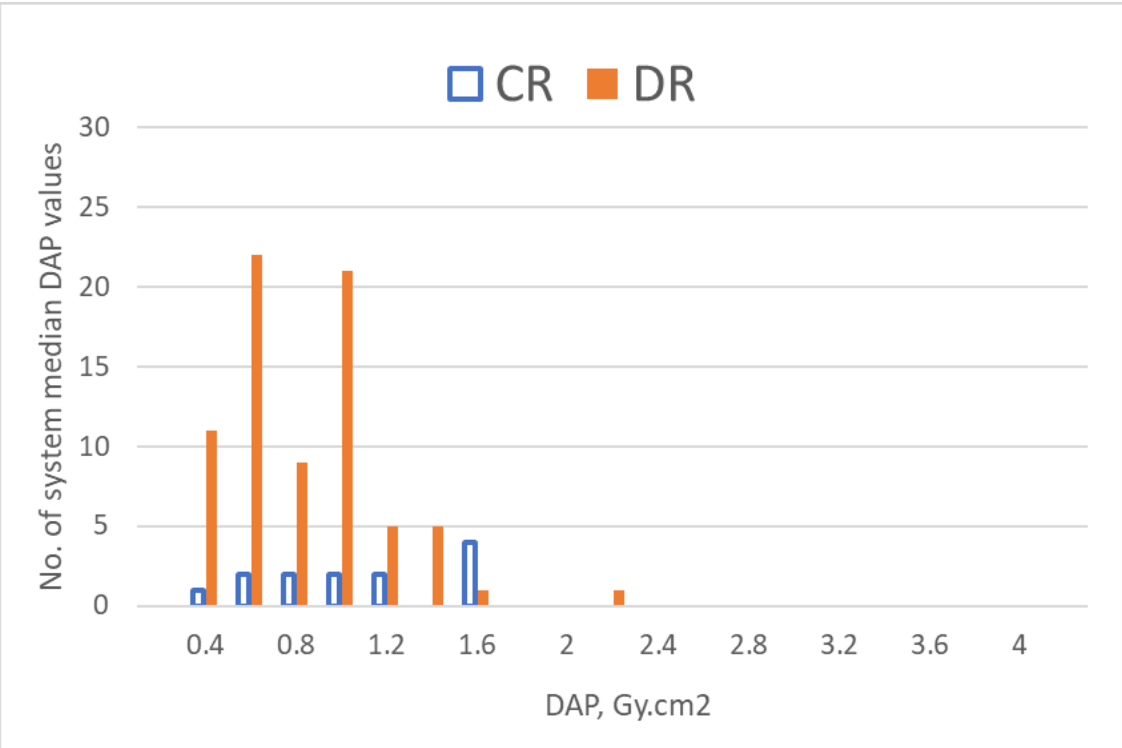


Figure D15. Lumbar spine AP projection

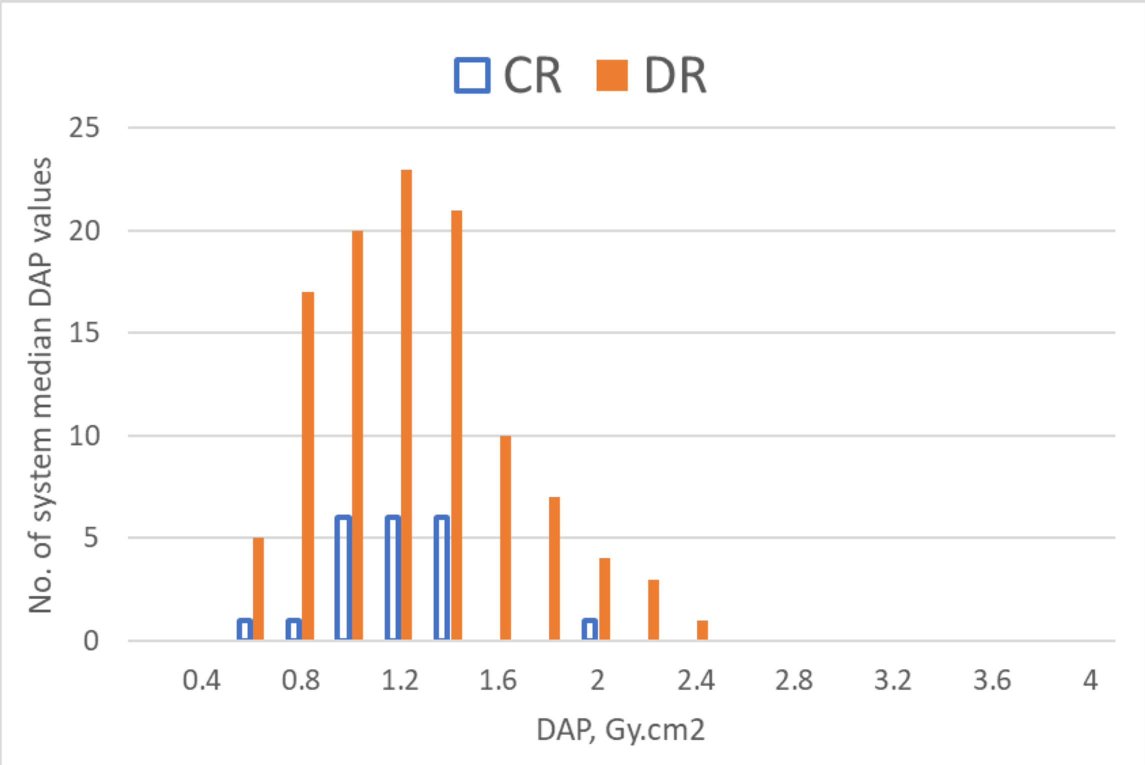


Figure D16. Lumbar spine lateral projection

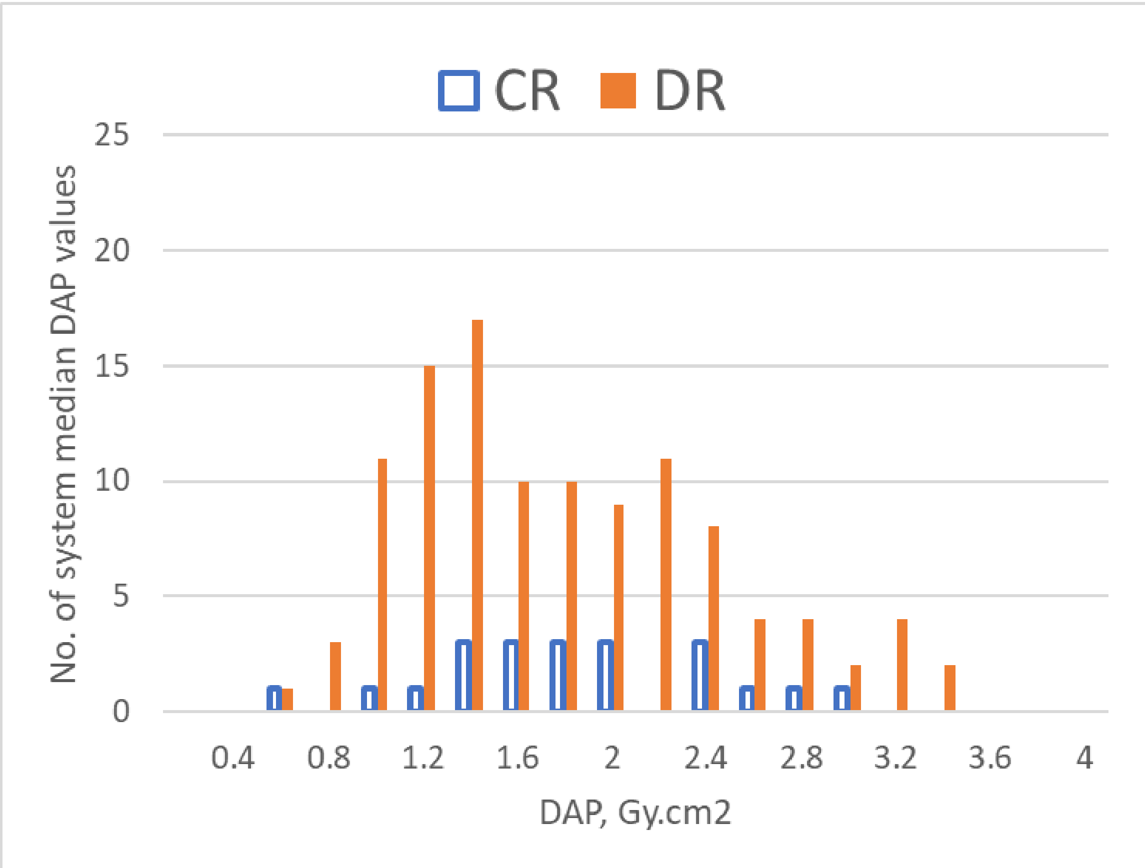


Figure D17. Pelvis AP projection

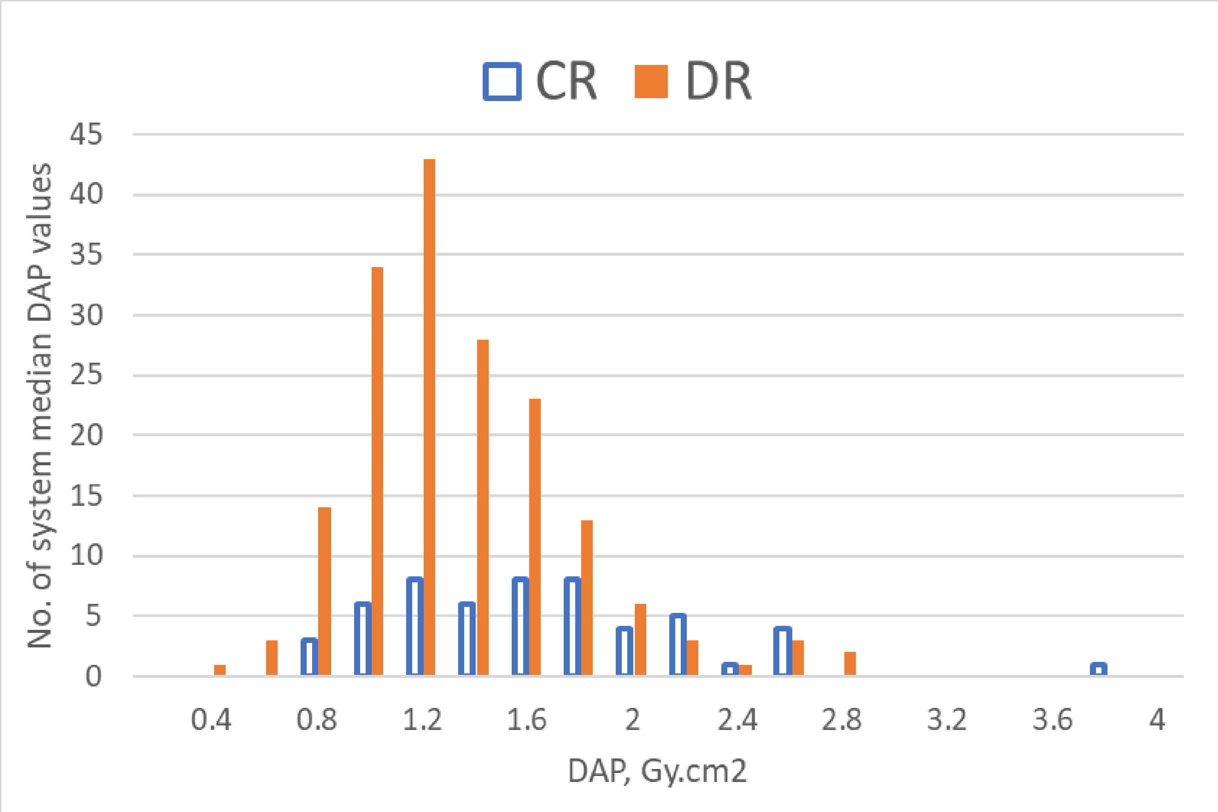
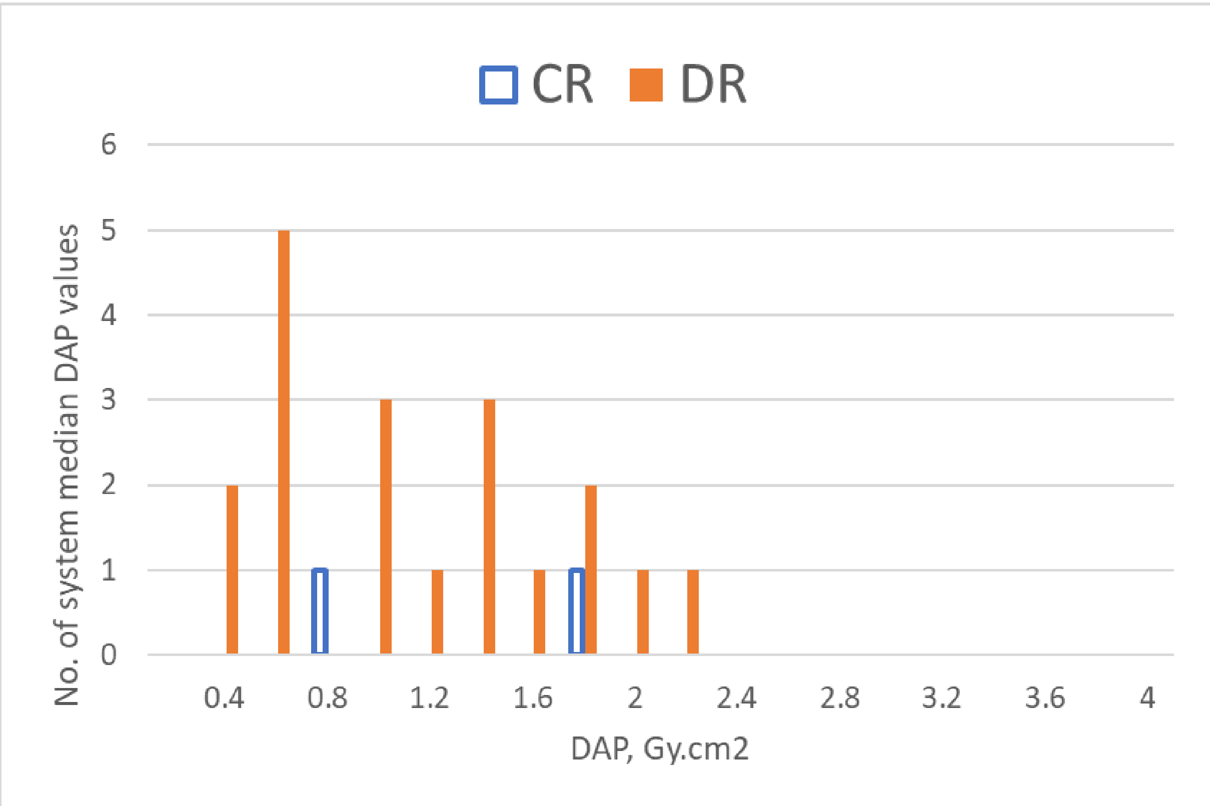


Figure D18. Hip (single) horizontal beam lateral



FPD and II detector system median DAP histograms

Fluoroscopy examinations and IR procedures

Figures D19 to D29 compare the distribution of the system median DAP values for systems with FPD and II detectors for 10 exams from Table 19. Three IR procedures are not included as they have less than 3 II detector results. Nephrostomy tube replacement (Figure 22) is included for comparison with Nephrostomy (Figure 21). The system median DAP distribution for video-fluoroscopy barium swallow is shown twice, as Figure D19, for comparison with other low to medium DAP exams (0 to 5 Gy.cm^2 horizontal scale) and as Figure D27 for comparison with other barium and water soluble contrast (WSC) exams (0 to 20 Gy.cm^2).

The significant overlap of system median values seen for the 2 types of detector show that there is no justification for setting separate NDRLs based on detector type.

Low to medium DAP fluoroscopy examinations and IR procedures

Figure D19. Videofluoroscopy barium swallow

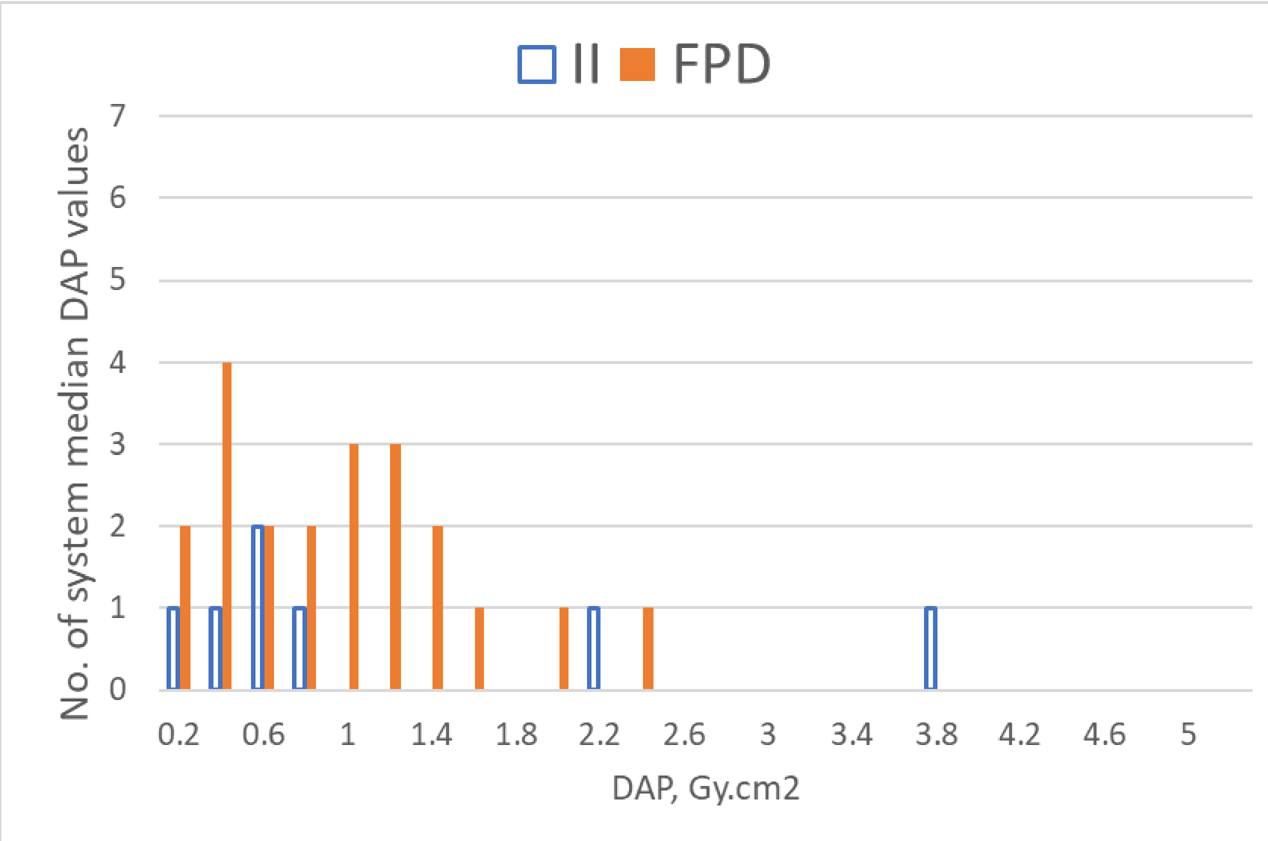


Figure D20. Hysterosalpingography

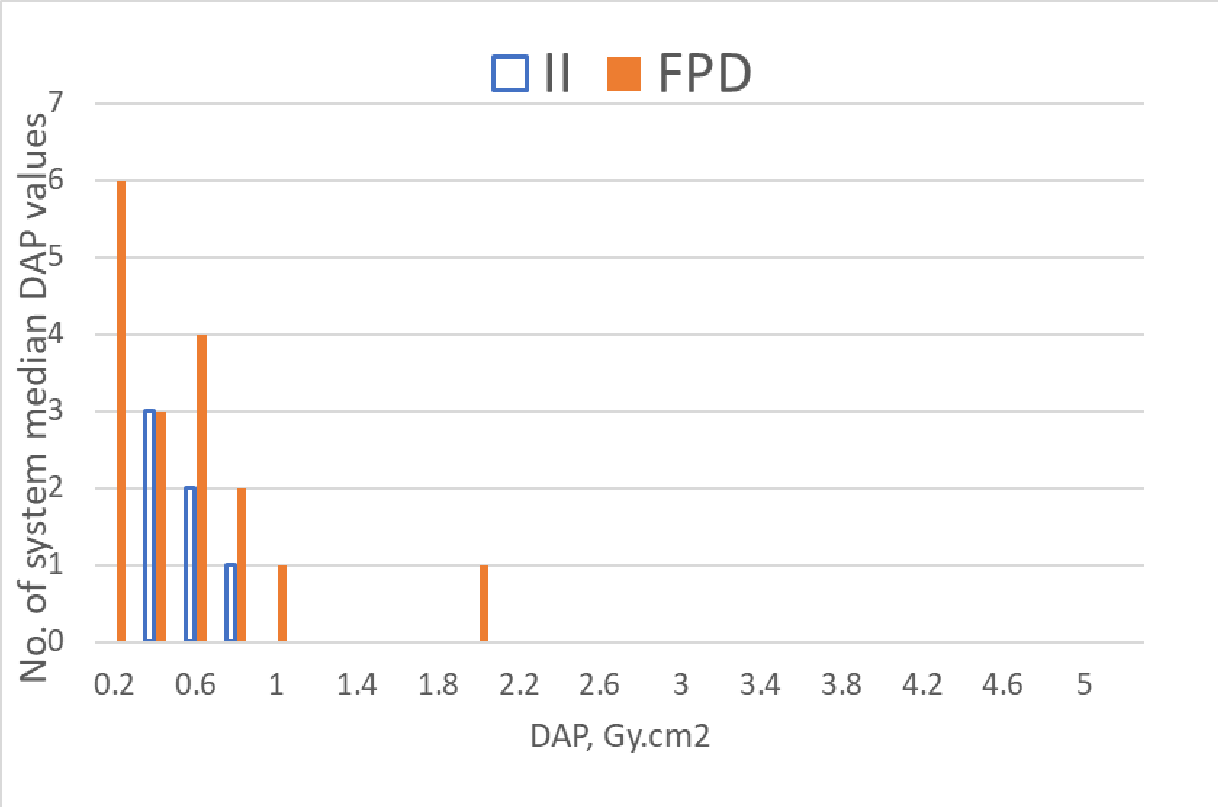


Figure D21. Nephrostomy IR procedure

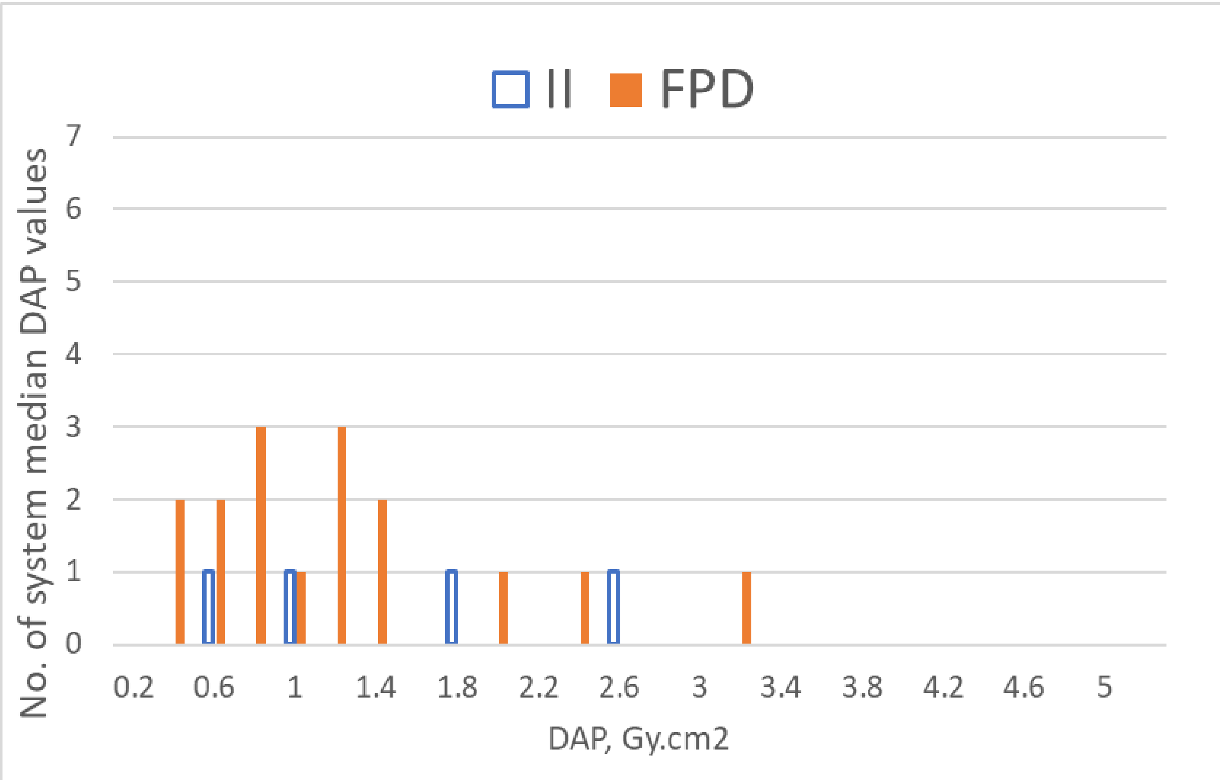


Figure D22. Nephrostomy tube replacement

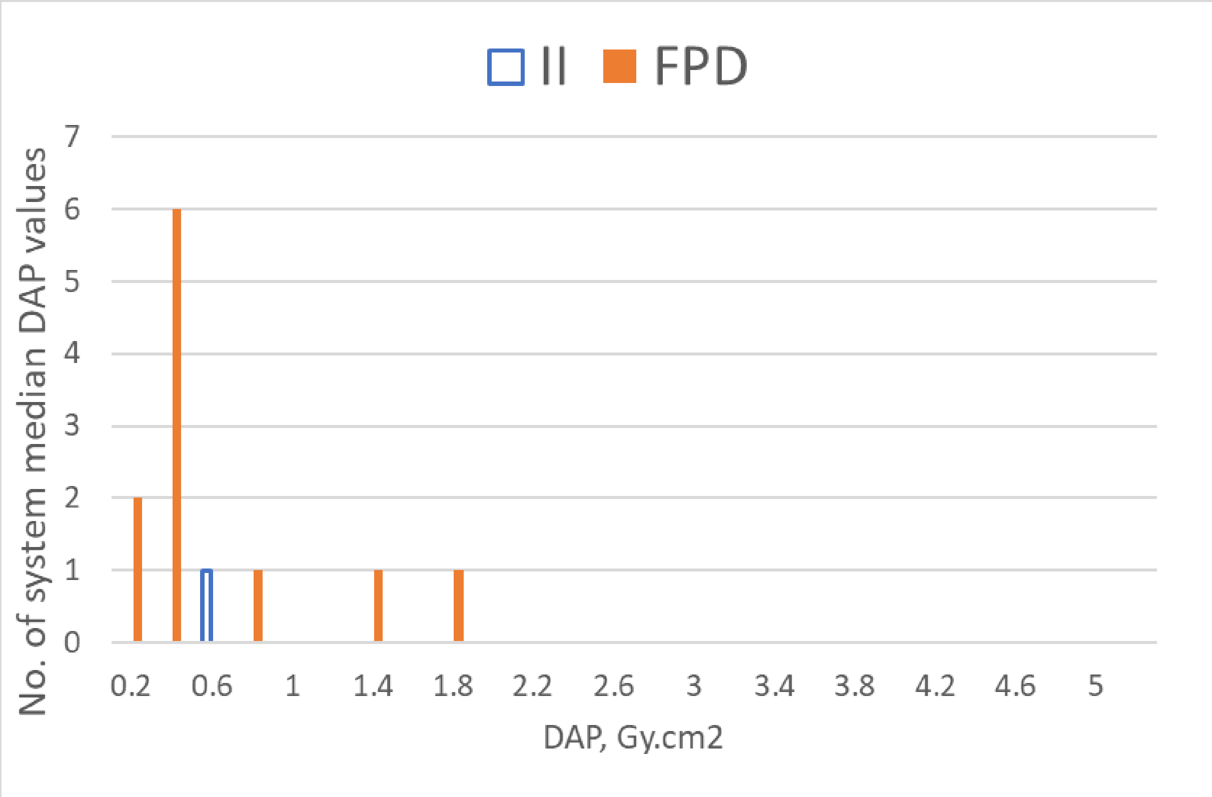


Figure D23. Pacemaker implant: single or dual chamber

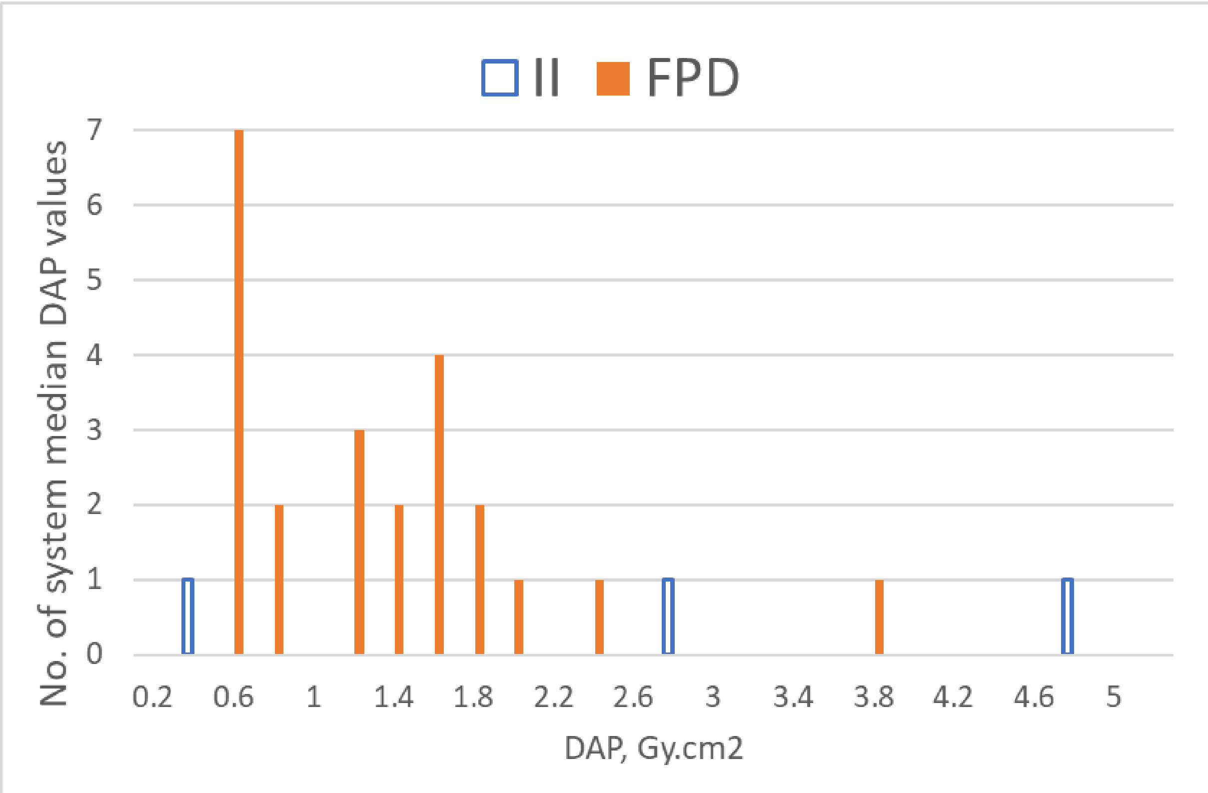
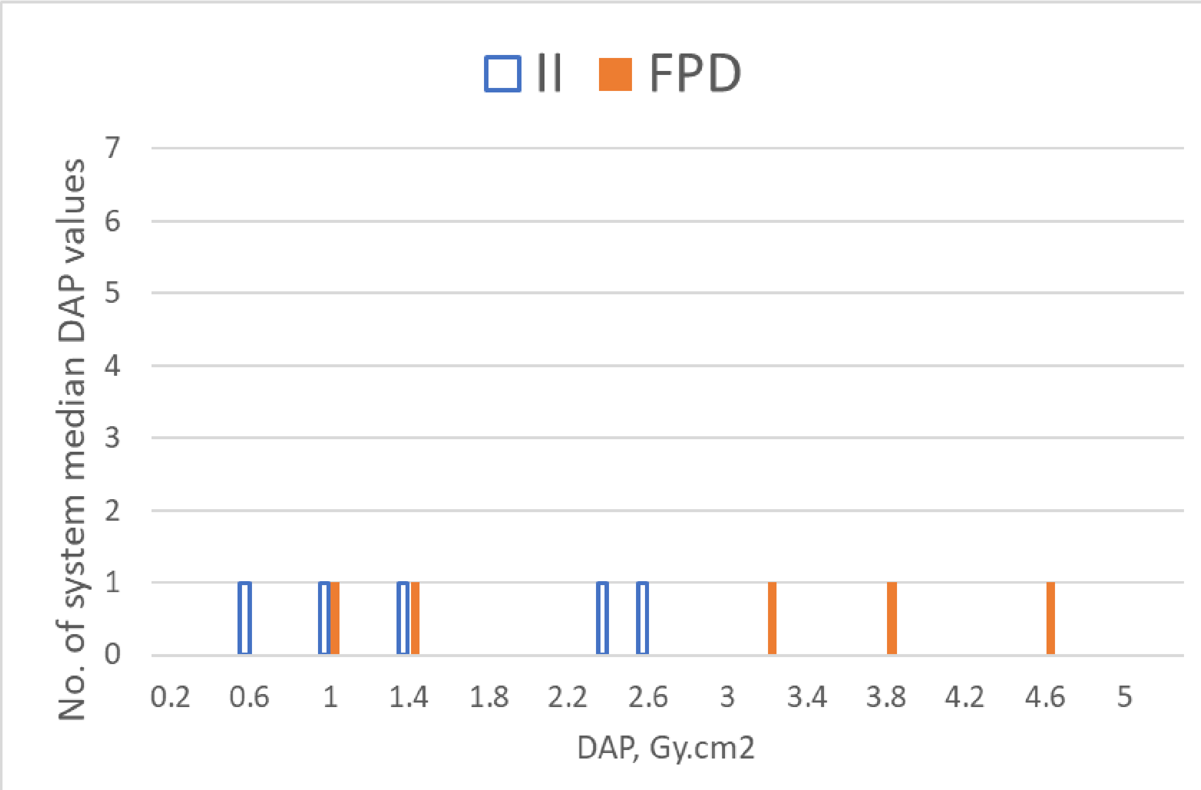


Figure D24. Ureteric stent, antegrade and retrograde



Higher dose fluoroscopy examinations and IR procedures

Figure D25. Barium swallow

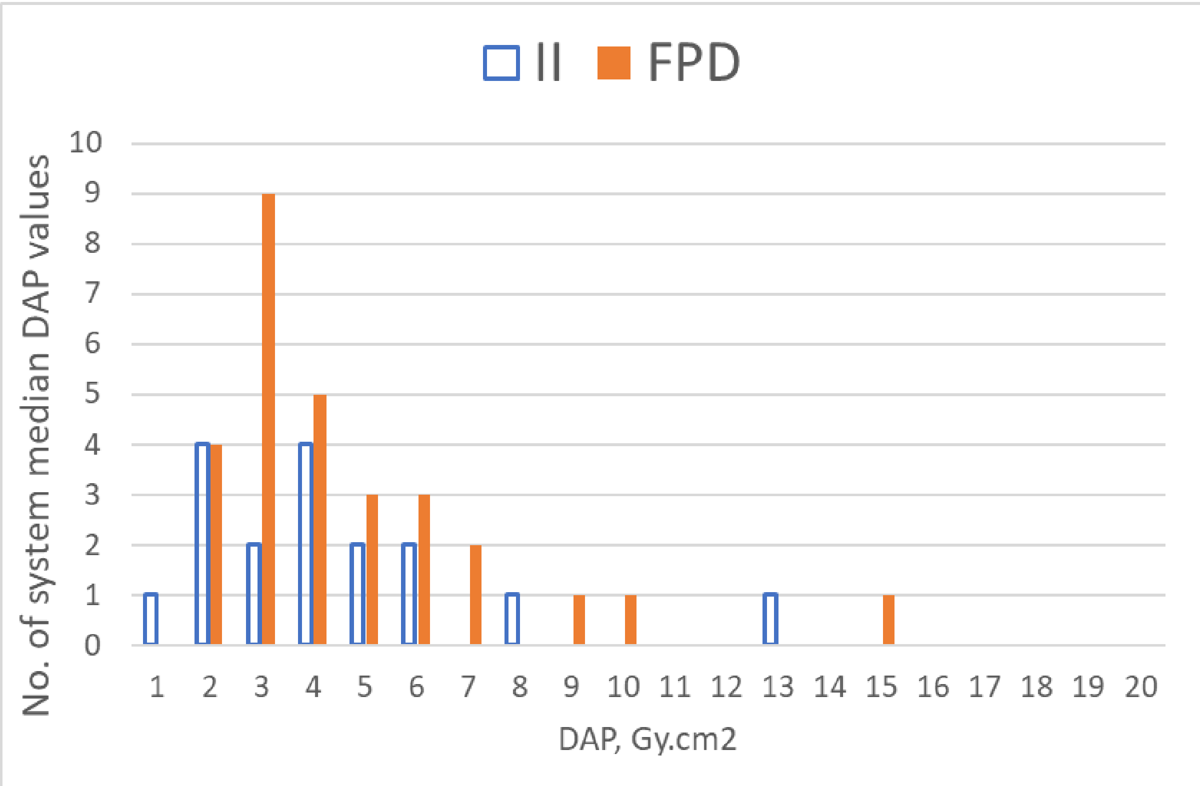


Figure D26. Water soluble contrast swallow

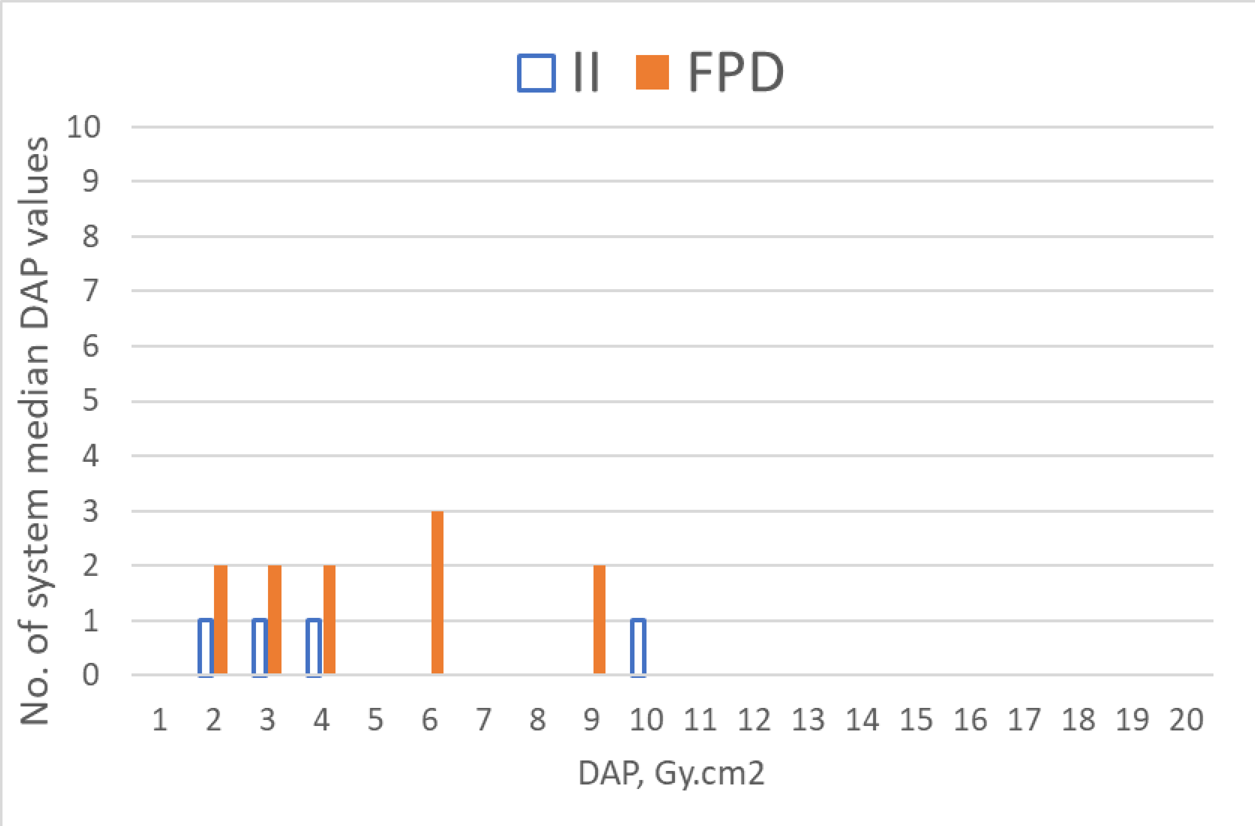


Figure D27. Videofluoroscopy barium swallow (rept.)

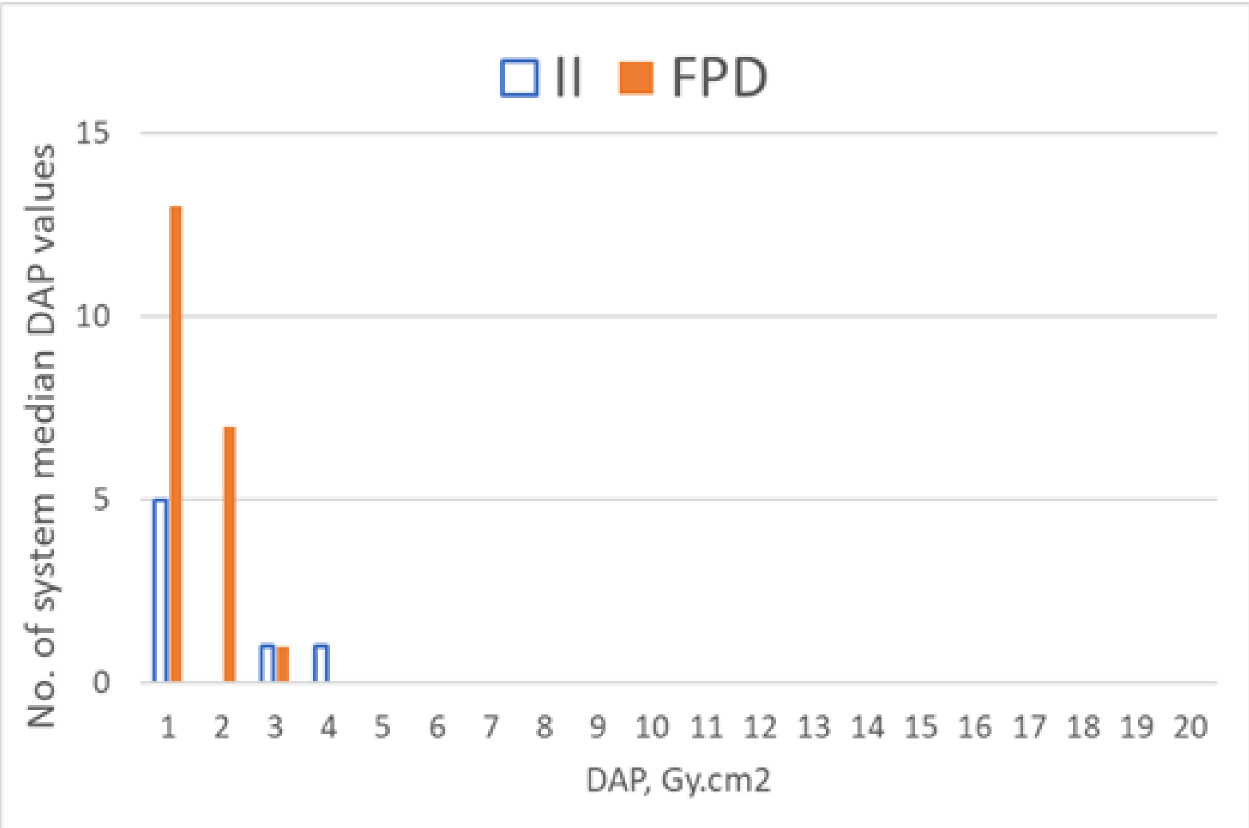


Figure D28. Water soluble contrast enema

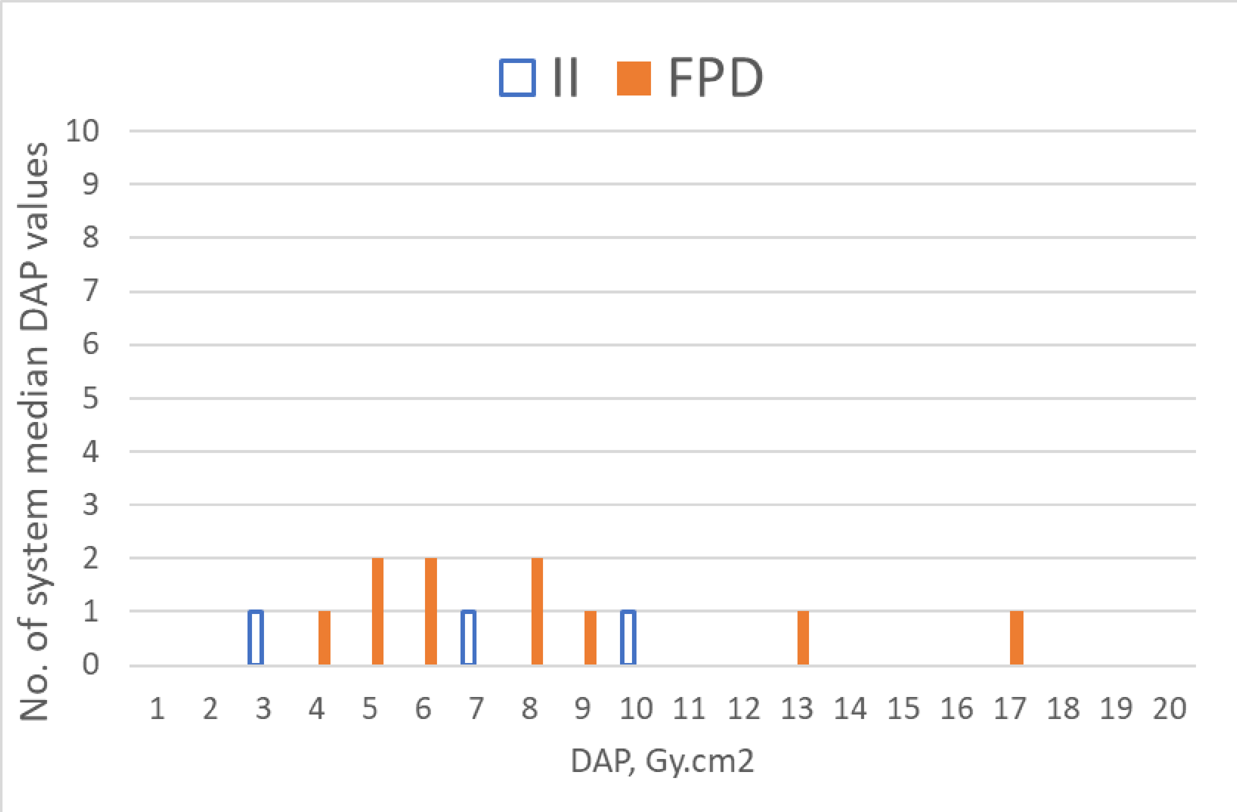
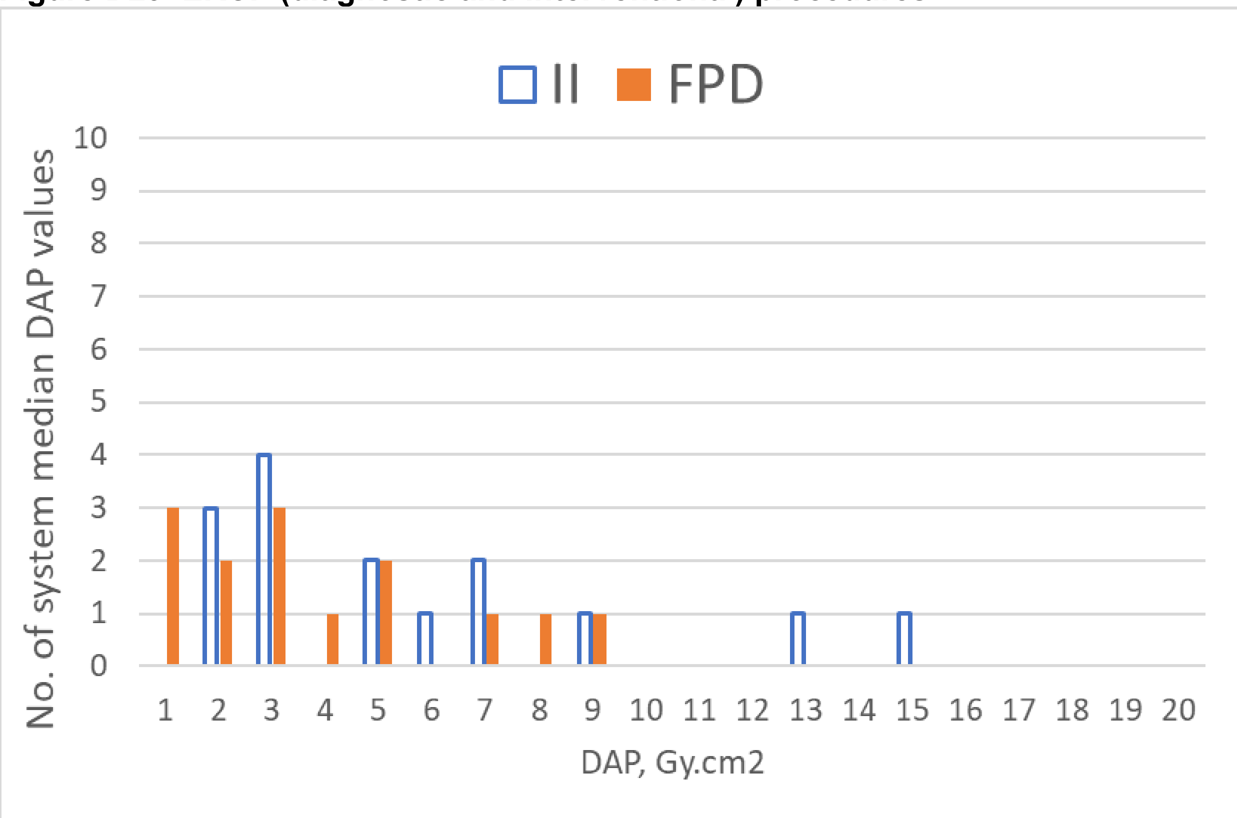


Figure D29. ERCP (diagnostic and interventional) procedures



Influence of automatic exposure control

Figures D30 to D33 compares the distributions of system median DAP values for systems which did and did not use AEC for chest PA, chest AP, cervical spine AP and cervical spine lateral projections. These are the 4 plain radiography single projections for which there were substantial fractions of systems both using and not using AEC. In all 4 cases, the mean values of the system median DAP values for AEC using systems and non-AEC using systems differed from each other by less than the sum of their standard errors of the mean. Again, there are no grounds for proposing separate NDRL values.

For all other projections considered by the survey there was a very strong bias to either using or not using AEC.

Figure D30. Chest PA – comparison of system median DAP values (Gy.cm²) when AEC used or not used

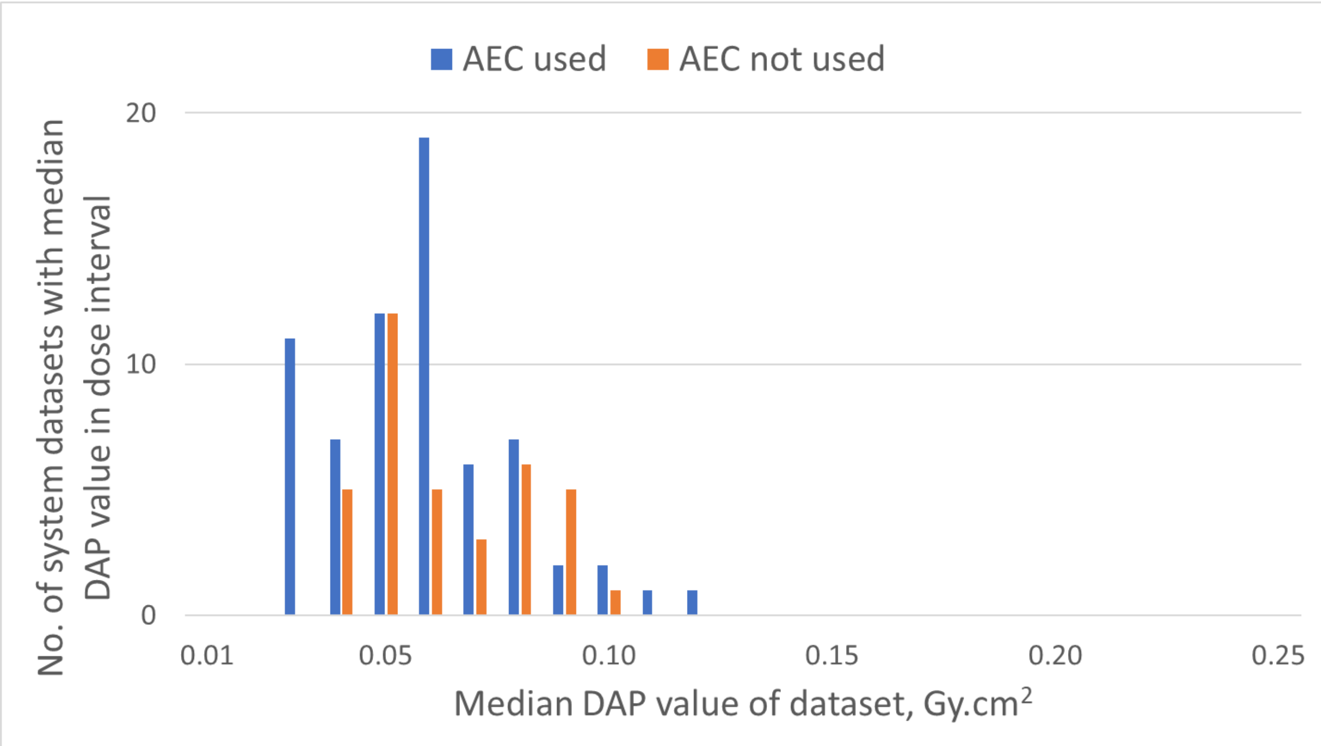


Figure D31. Chest AP – comparison of system median DAP values (Gy.cm²) when AEC used or not used

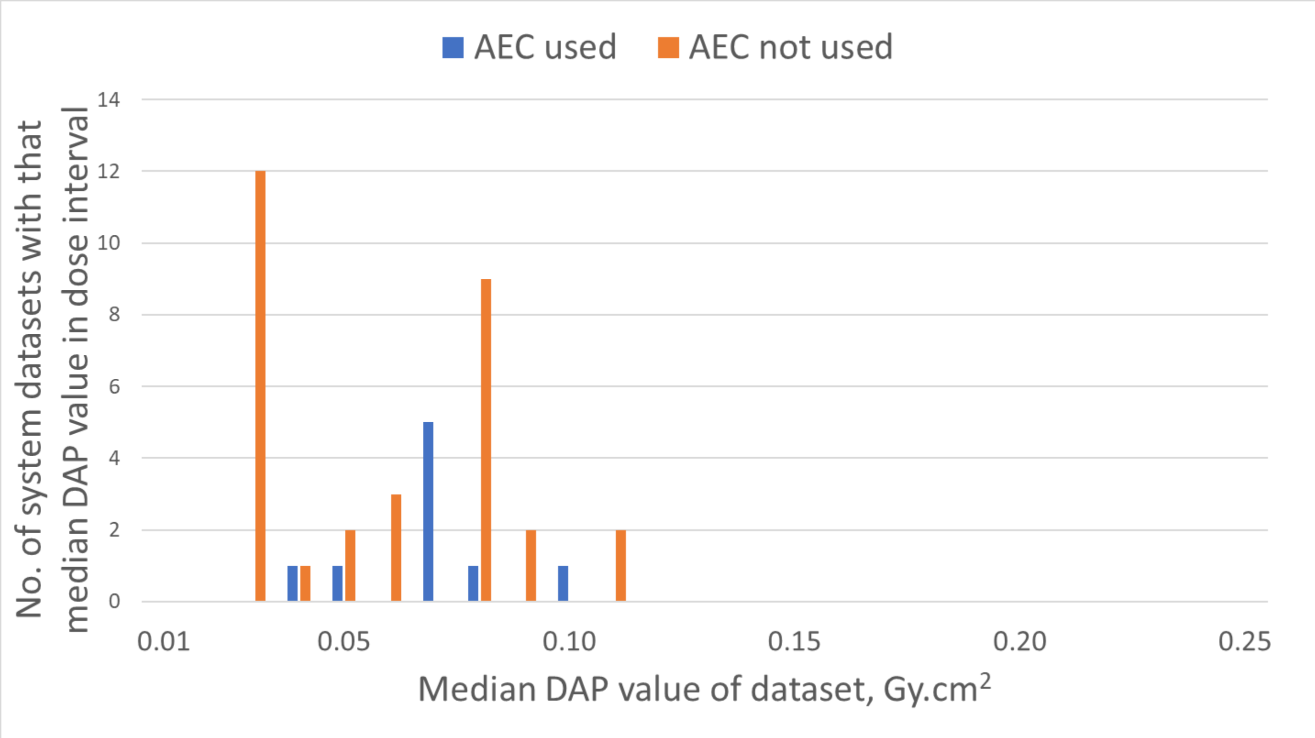


Figure D32. Cervical spine AP – comparison of system median DAP values (Gy.cm²) when AEC used or not used

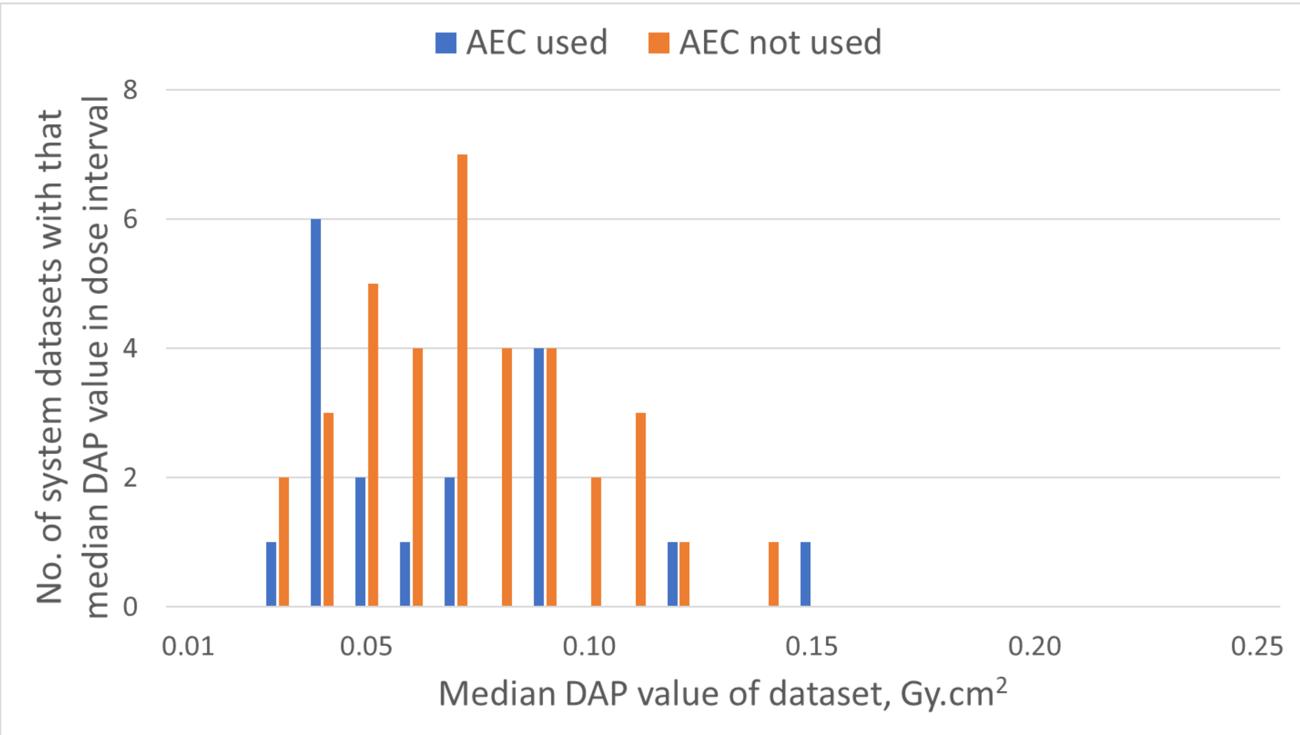
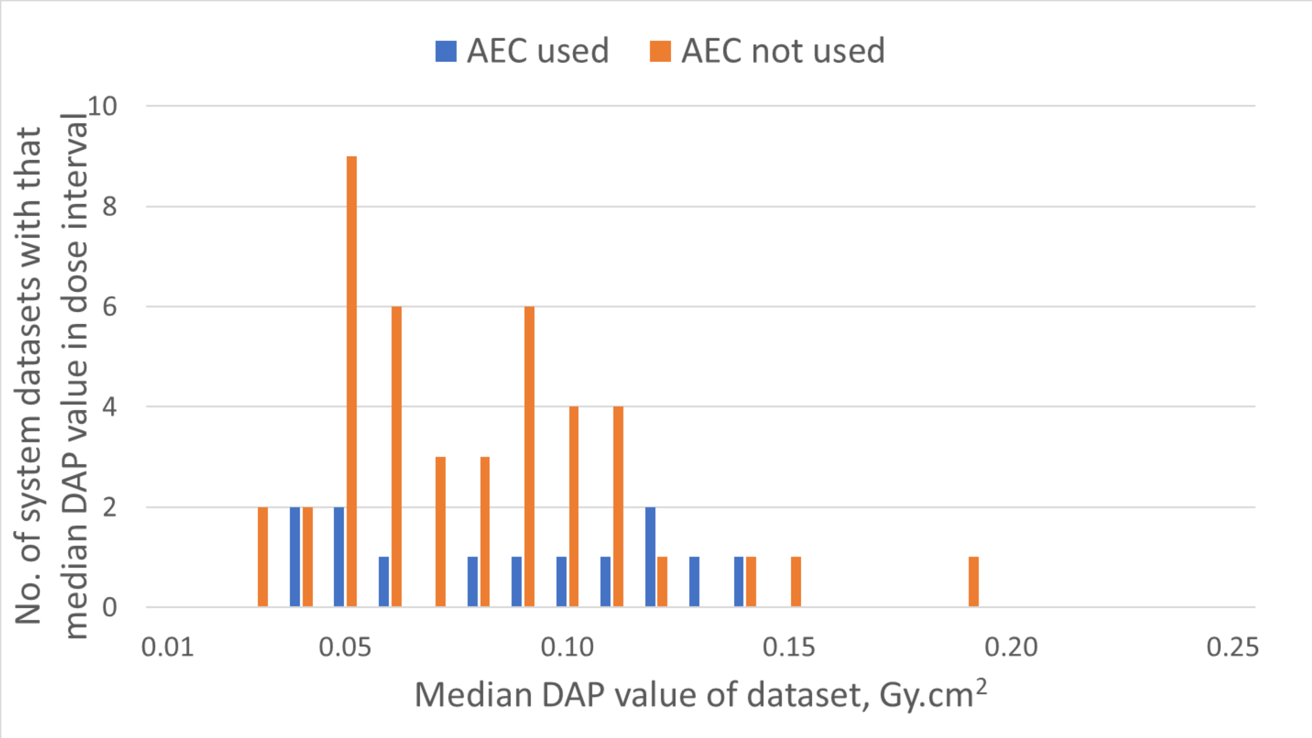


Figure D33. Cervical spine lateral – comparison of median system DAP values (Gy.cm²) when AEC used or not used



Appendix E: Fluoroscopy time data

As discussed in the main text, the survey received limited fluoroscopy time data for fluoroscopy examinations and IR procedures that was insufficient for recommending NDRL or typical values. However, it was felt it would be useful to include a summary of the data received and, where appropriate, to compare it with the 2010 survey (7) findings.

To make optimum use of the limited information received by the 2019 survey, the analysis of the fluoroscopy time data is based on system exam data sets of 10 or more patients. Fluoroscopy time data for fluoroscopy examinations is given in tables E1 to E3 and for IR procedures in tables E4 to E6. Tables E1 and E4 show the diversity of fluoroscopy time system data sets received for fluoroscopy examinations and IR procedures respectively. Tables E2 and E3 respectively give information on the median and mean fluoroscopy time distributions of the fluoroscopy examinations. Tables E5 and E6 give the equivalent information for IR procedures. As in previous survey reports (5,6,7), fluoroscopy times are reported in units of minutes and decimal fractions of minutes (for example, 2 minutes and 30 seconds is recorded as 2.5 minutes).

A comparison of fluoroscopy time values with the DAP values for the same exams (for example, tables E2 and E5 versus tables 15 and 17), shows there is no link between different exams' typical fluoroscopy times and their DAP values. A good illustration of this is a comparison of the typical median fluoroscopy times and DAP values for barium swallow and videofluoroscopy barium swallow. Patients will generally receive a significantly higher DAP from barium swallow exam than a videofluoroscopy barium swallow exam, as a larger region of the body is imaged. However, videofluoroscopy barium swallow exams generally require longer imaging times as they assess the mechanics of the throat in use, as opposed to shorter times required to image the morphology of the digestive passage from the mouth to the stomach.

Table E1. Simple fluoroscopy examinations (adult): survey contributions of fluoroscopy time data sets of 10 or more patients

Fluoroscopy examinations	Survey participants	Hospital regions	NHS boards, trusts etc.	Hospitals	All systems	Systems with image intensifier detectors	Systems with flat panel detectors	Patients
Angiography – coronary [notes 1,2,3]	2 (3) [note 4]	1 (2)	2 (3)	3 (4)	5 (7)	0	5 (7)	2,518 (2,633)
Barium meal and swallow [notes 1,2]	3	4	4	4	4	0	4	107
Water soluble contrast enema [notes 1,2]	4	3	4	4	4	0	4	180
Barium swallow [notes 1,2]	11	6	12	14	14 (16)	3	11 (13)	2,705 (2,849)
Water soluble contrast swallow [notes 1,2]	4	3	4	5	5	1	4	274
Videofluoroscopy barium swallow [note 1]	7	6	8	11	11	2	9	811
Hysterosalpingography [notes 1,2]	5	4	6	7	7	0	7	684

1. 2010 Review (7): National Reference Dose (NRD) fluoroscopy time value recommended (same NRD used for equivalent barium and water soluble contrast exam)
2. 2005 Review (6): NRD fluoroscopy time value recommended (same NRD used for equivalent barium and water soluble contrast exam)
3. Exam not on survey request list
4. Values in brackets are for system mean value data sets where their data set size differs from that of the equivalent system median data set

Table E2. Simple fluoroscopy examinations (adult): summary of system median fluoroscopy time values for data sets of 10 or more patients (minutes and decimal fractions of minutes)

Fluoroscopy examinations	Number of systems	Percentile, minutes					InterQuartile range 75th to 25th %ile	IQ range % median
		5th	25th	50th (median)	75th	95th		
Angiography – coronary [notes 1,2,3]	5	3.1	3.2	3.3	3.4	3.8	0.12	3.6%
Barium meal and swallow [note 1,2]	4	1.2	1.3	1.4	1.5	1.6	0.19	14%
Water soluble contrast enema [notes 1,2]	4	0.57	0.63	0.95	1.3	1.5	0.70	73%
Barium swallow [note 1,2]	14	0.45	0.83	1.1	1.3	1.7	0.43	40%
Water soluble contrast swallow [note 1,2]	5	0.44	0.60	0.90	1.0	1.2	0.40	44%
Videofluoroscopy barium swallow [note 1]	11	2.1	2.3	2.6	2.8	3.1	0.55	21%
Hysterosalpingography [notes 1,2]	7	0.12	0.18	0.23	0.27	0.55	0.087	37%

1. 2010 Review (7): NRD Fluoroscopy time value recommended (same NRD used for equivalent barium and water soluble contrast exams)
2. 2005 Review (6): NRD Fluoroscopy time value recommended (same NRD used for equivalent barium and water soluble contrast exams)
3. Exam not on survey request list

Table E3. Simple fluoroscopy examinations (adult): summary of system mean fluoroscopy time values for data sets of 10 or more patients (minutes and decimal fractions of minutes)

Fluoroscopy examinations	Number of systems	Mean, minutes	Standard error of mean	Mean as percentile	Percentiles, minutes				
					5th	25th	50th	75th	95th
Angiography – coronary [notes 1,2,3]	7	4.4	±0.16	30th	3.8	4.4	4.5	4.7	4.8
Barium meal and swallow [notes 1,2]	4	1.8	±0.14	58th	1.5	1.7	1.8	1.9	2.1
Water soluble contrast enema [notes 1,2]	4	1.1	±0.22	49th	0.70	0.76	1.1	1.5	1.5
Barium swallow [notes 1,2]	16	1.2	±0.11	47th	0.60	1.0	1.3	1.6	1.8
Water soluble contrast swallow [note 1,2]	5	1.1	±0.14	39th	0.65	0.86	1.2	1.2	1.4
Videofluoroscopy barium swallow [note 1]	11	2.6	±0.13	45th	2.0	2.4	2.8	3.0	3.1
Hysterosalpingography [notes 1,2]	7	0.36	±0.092	72nd	0.19	0.22	0.24	0.42	0.75

1. 2010 Review (7): NRD Fluoroscopy time value recommended (same NRD used for equivalent barium and water soluble contrast exams)
2. 2005 Review (6): NRD Fluoroscopy time value recommended (same NRD used for equivalent barium and water soluble contrast exams)
3. Exam not on survey request list

Table E4. Simple IR procedures (adult): survey contributions of fluoroscopy time data sets of 10 or more patients

IR procedures	Survey participants	NHS regions	NHS boards, trusts etc.	Hospitals	All systems	Systems with image intensifier detectors	Systems with flat panel detectors	Patients
Cardiac catheter ablation (RF)	2	2	2	2	3	0	3	453
ERCP (diagnostic and interventional) [notes 3]	5	5	6	6	6	2	4	1275
Pacemaker (single or dual chamber: permanent) [notes 1,2]	3	2	3	3	6	0	6	471
Facet joint injection [notes 1,2]	1	1	1	1	3	3	0	123
Insertion of tunnelled central venous catheter [notes 1,2,4]	4	2	4	4	4	0	4	296
PICC line insertion	6	4	6	7	9	1	8	1,677
Radiologically inserted gastrostomy tube	3	3	3	3	3	0	3	281
Nephrostomy [notes 1,2]	4	3	4	4	4	0	4	266

IR procedures	Survey participants	NHS regions	NHS boards, trusts etc.	Hospitals	All systems	Systems with image intensifier detectors	Systems with flat panel detectors	Patients
Stent (ureteric) [note 3]	5	3	5	5	7	4	3	476
Stent (ureteric antegrade)	3	2	3	3	3	0	3	155
Stent (ureteric retrograde)	2	2	2	2	4	4	0	312
Mobile imaging of orthopaedic hip pinning	3	2	3	3	3	3	0	112

1. 2010 Review (7): National Reference Dose Fluoroscopy time value recommended
2. 2005 Review (6): National Reference Dose Fluoroscopy time value recommended
3. Exam not on survey request list
4. A broadened procedure definition, which includes the previously reported Hickman Line procedure

Table E5. Simple IR procedures (adult): system median fluoroscopy time values for data sets of 10 or more patients (minutes and decimal fraction of minutes)

IR procedures	Number of systems	Percentile, minutes					InterQuartile range 75th to 25th %ile	IQ range % median
		5th	25th	50th (median)	75th	95th		
Cardiac catheter ablation (RF)	3	10	11	11	11	12	0.78	7.1%
ERCP (diagnostic and interventional) [note 3]	6	0.40	1.5	1.9	2.5	2.9	0.99	52%
Pacemaker (permanent) single or dual chamber [notes 1,2]	6	3.1	3.2	3.4	3.5	3.8	0.31	9.2%
Facet joint injection [notes 1,2,3]	3	0.17	0.30	0.45	0.47	0.48	0.17	38%
Insertion of tunnelled central venous catheter [notes 1,2,4]	4	0.37	0.46	0.55	0.65	0.78	0.19	34%
PICC line insertion	9	0.023	0.13	0.40	0.45	0.61	0.33	81%
Radiologically inserted gastrostomy tube	3	1.0	1.3	1.6	1.8	1.9	0.51	32%
Nephrostomy [notes 1,2]	4	0.75	1.0	1.3	1.6	2.0	0.63	48%
Stent (ureteric) [note 3]	7	0.068	0.22	0.71	4.7	7.0	4.5	640%
Stent (ureteric antegrade)	3	3.2	4.7	6.7	6.9	7.0	2.2	32%
Stent (ureteric retrograde)	4	0.051	0.12	0.21	0.38	0.64	0.26	120%
Mobile imaging of orthopaedic hip pinning	3	0.55	0.75	1.0	1.05	1.1	0.30	30%

1. 2010 Review (7): National Reference Dose (NRD) Fluoroscopy time value recommended
2. 2005 Review (6): NRD Fluoroscopy time value recommended
3. Exam not on survey request list
4. A broadened procedure definition, which includes the previously reported Hickman Line procedure

Table E6. Simple IR procedures (adult): system mean fluoroscopy time values for data sets of 10 or more patients (minutes and decimal fractions of minutes)

IR procedures	Number of systems	Mean, minutes	Standard error of mean	Mean as a percentile	Percentile, minutes				
					5th	25th	50th	75th	95th
Cardiac catheter ablation (RF)	3	13	±0.41	60th	13	13	13	14	14
ERCP (diagnostic and interventional) [note 3]	6	2.4	±0.57	38th	0.52	1.9	2.5	3.1	4.0
Pacemaker (permanent) single or dual chamber installation [notes 1,2]	6	4.3	±0.24	67th	3.7	3.9	4.1	4.5	5.1
Facet joint injection [notes 1,2]	3	0.37	±0.087	36th	0.22	0.32	0.44	0.46	0.47
Insertion of tunnelled central venous catheter [notes 1,2,4]	4	0.86	±0.18	56th	0.53	0.65	0.82	1.0	1.3
PICC line insertion	9	0.60	±0.12	52nd	0.083	0.43	0.56	0.83	1.0
Radiologically inserted gastrostomy tube	3	1.9	±0.39	44th	1.3	1.6	2.0	2.3	2.5
Nephrostomy [notes 1,2]	4	2.4	±0.58	50th	1.3	1.5	2.4	3.3	3.5
Stent (ureteric) [note 3]	7	3.4	±1.5	63rd	0.23	0.66	0.96	5.8	9.3
Stent (ureteric antegrade)	3	7.2	±1.8	46th	4.4	5.8	7.5	8.8	9.8
Stent (ureteric retrograde)	4	0.50	±0.19	54th	0.12	0.34	0.49	0.65	0.90

IR procedures	Number of systems	Mean, minutes	Standard error of mean	Mean as a percentile	Percentile, minutes				
					5th	25th	50th	75th	95th
Mobile imaging of orthopaedic hip pinning	3	0.98	±0.24	36th	0.57	0.83	1.2	1.2	1.3

1. 2010 Review (7): NRD Fluoroscopy time value recommended
2. 2005 Review (6): NRD Fluoroscopy time value recommended
3. Exam not on survey request list
4. A broadened procedure definition, including the previously reported Hickman Line procedure

FPD and II detector system median fluoroscopy time histograms

Figures E1 to E8 show the distribution of system fluoroscopy time median values received by the 2019 survey for system samples of 10 or more patient values (black blocks). System median values are used so that these plots are equivalent to those in Appendix C for system DAP median values.

The 2019 survey third quartile median fluoroscopy values are shown as a solid line. The third quartile mean fluoroscopy time values of the 2010 review (7), generally adopted as the 2010 NDRLs, are given as a dashed line where available.

Figure E1. Hysterosalpingography

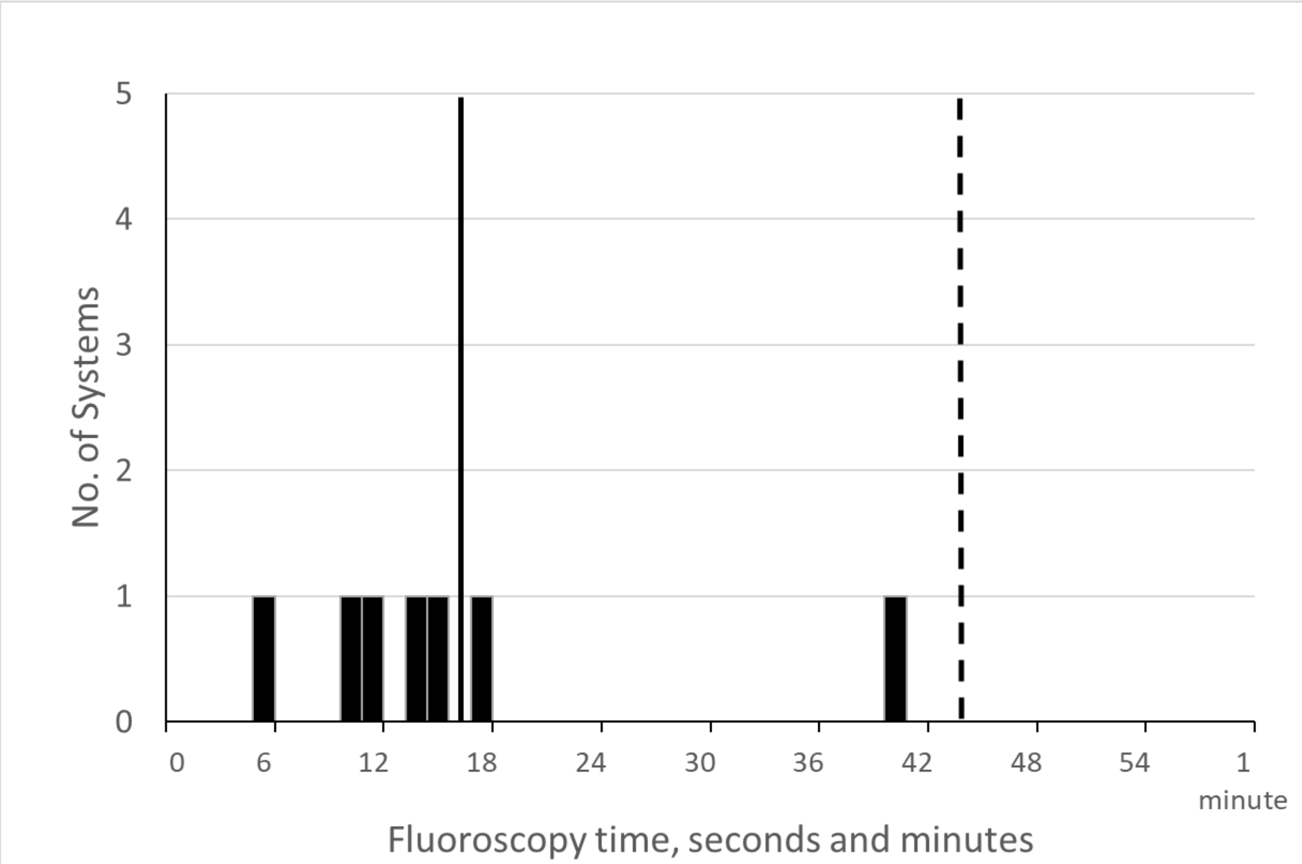


Figure E2. PICC line insertion

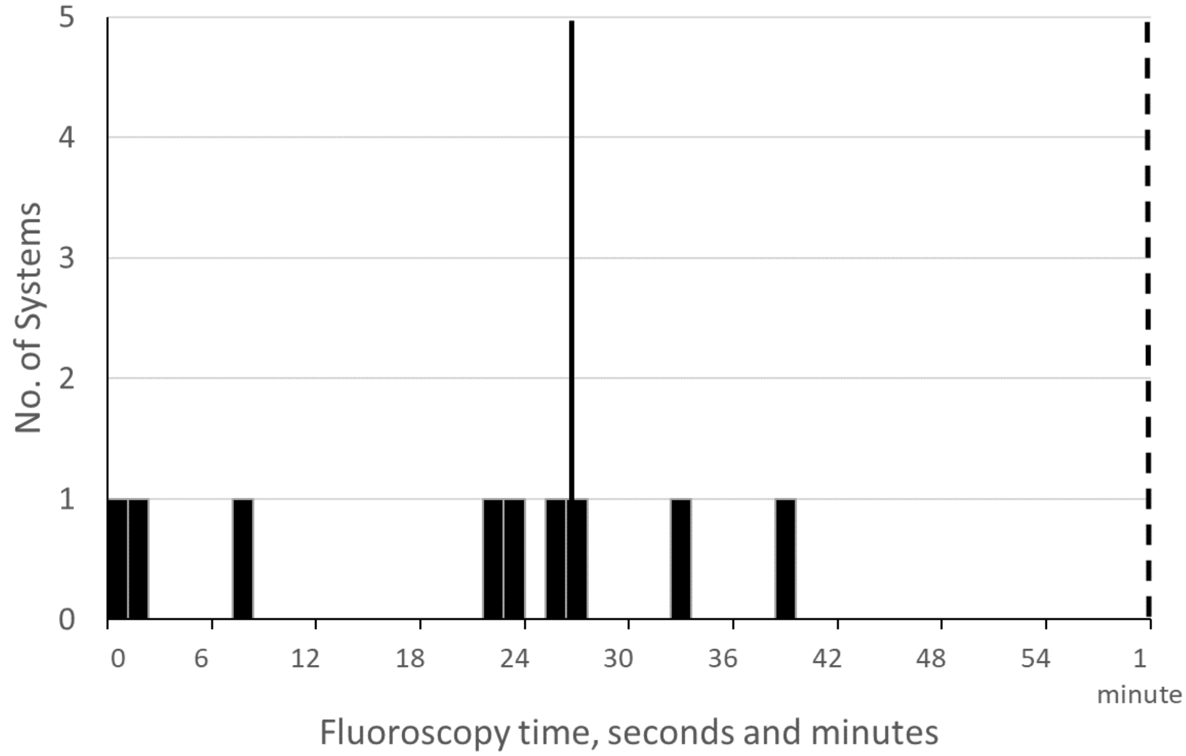


Figure E3. Barium swallow

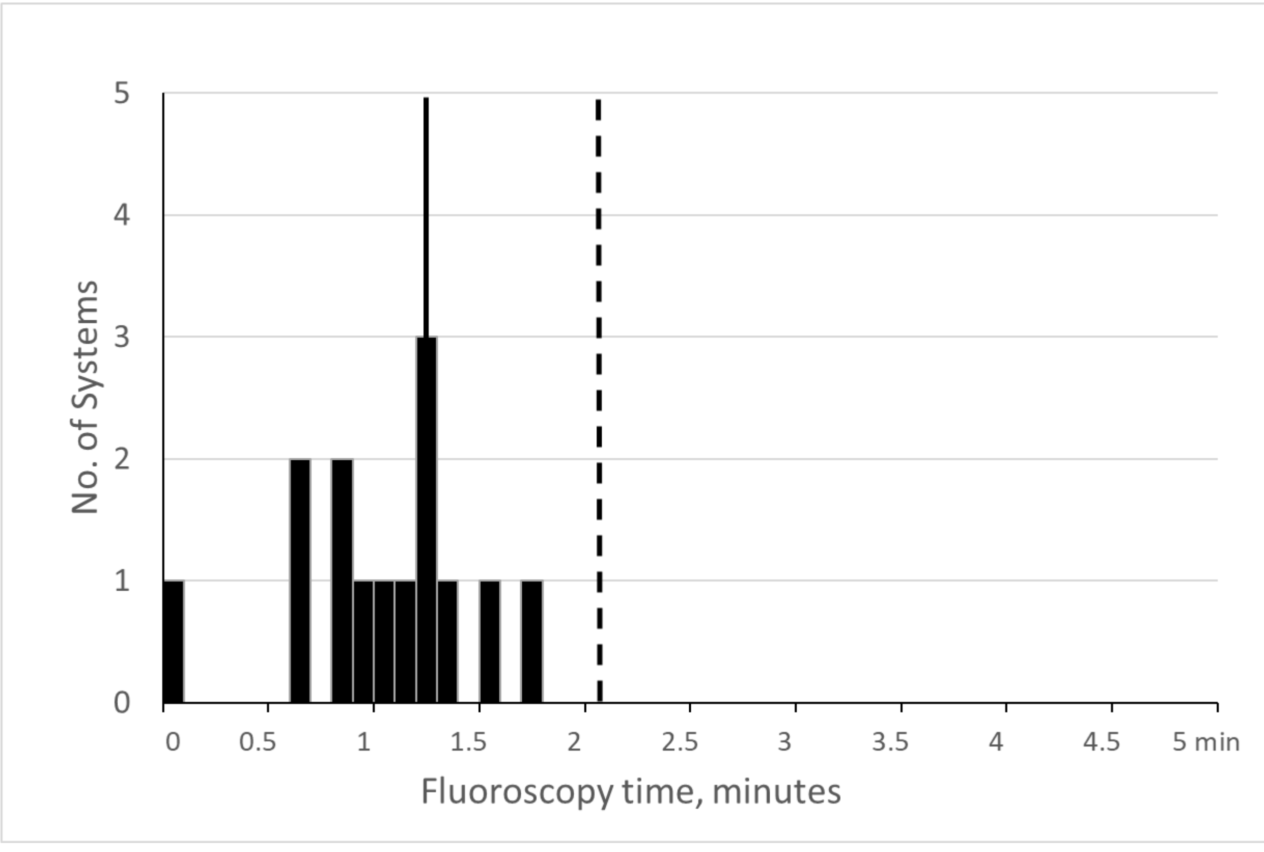


Figure E4. Water soluble contrast swallow

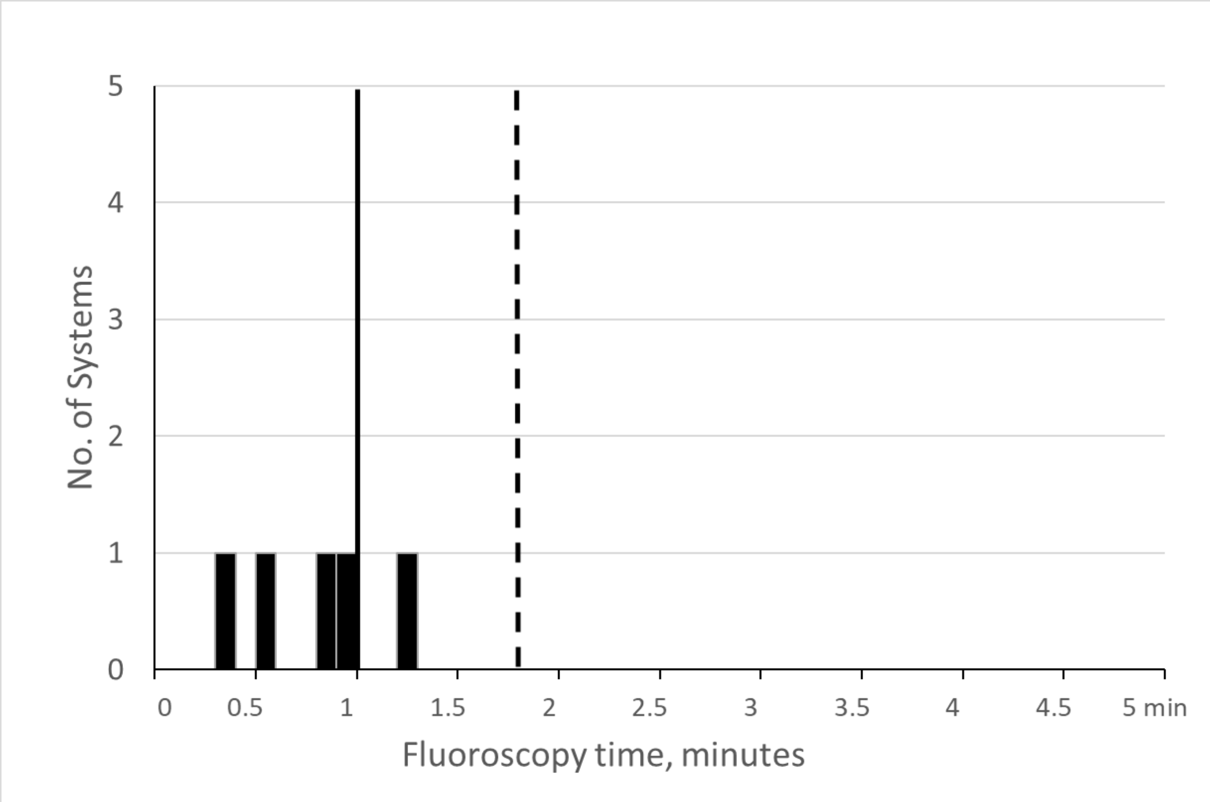


Figure E5. Videofluoroscopy barium swallow

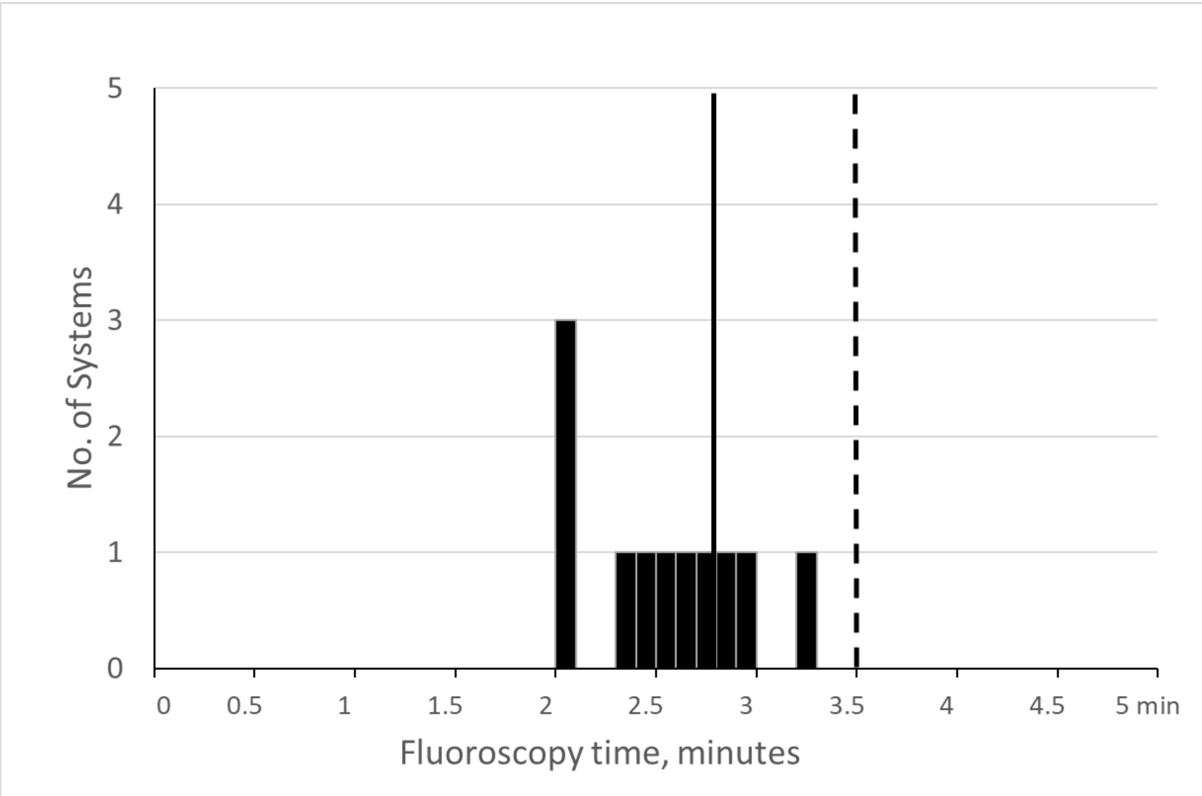


Figure E6. ERCP (diagnostic and interventional)

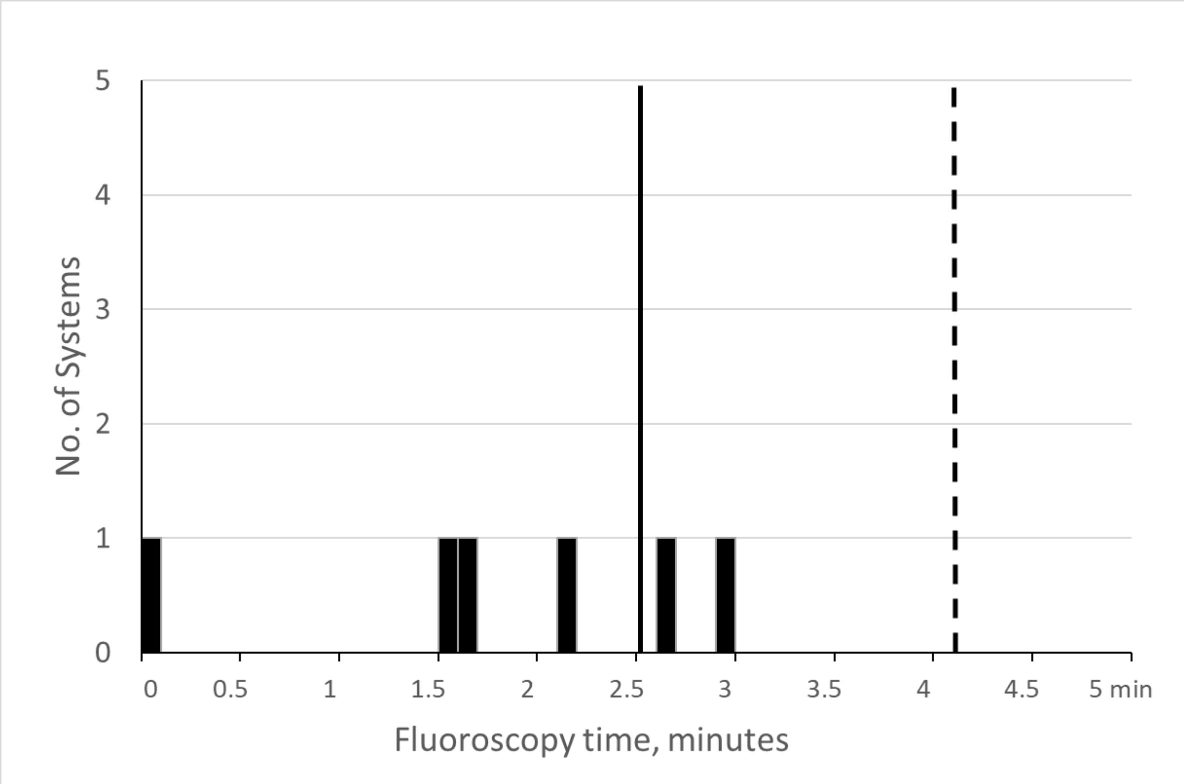


Figure E7. Single and dual chamber pacemaker

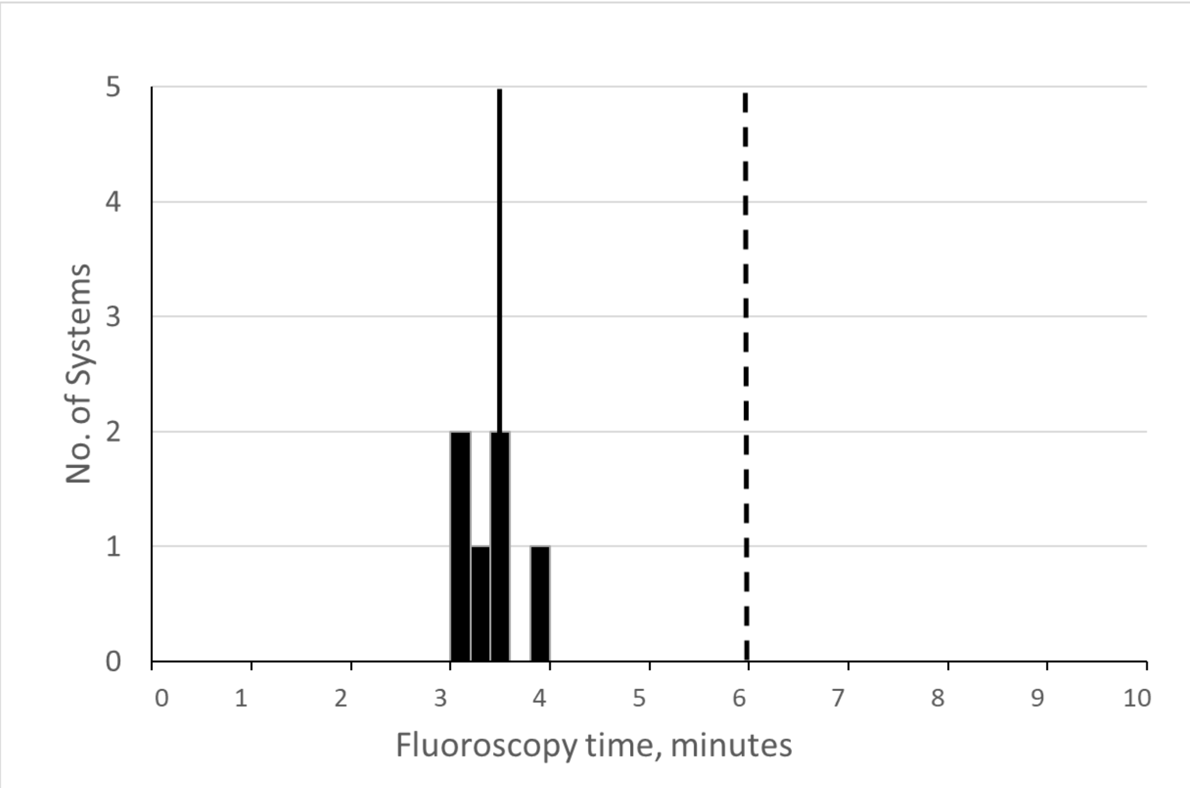
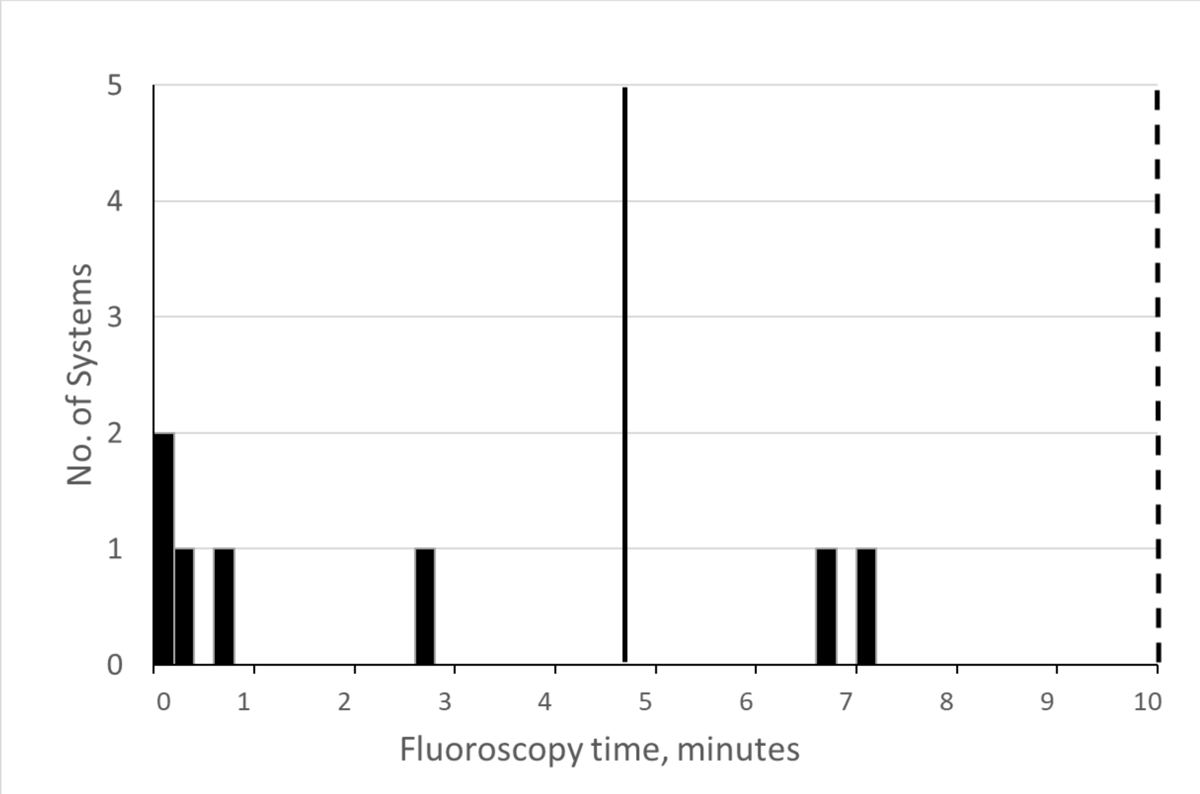


Figure E8. Ureteric stent



Mean fluoroscopy times for 2010 and 2019

Table E7 lists the mean and third quartile system mean fluoroscopy time values for the 2010 and 2019 surveys. Fluoroscopy times are given as minutes and decimal fractions of minutes. The system sample sizes for the 2019 survey are significantly lower than for the 2010 survey and so the 2019 survey's mean and third quartile values have larger associated uncertainties. Caution should also be used in any comparison of values from the 2 surveys because of the ongoing transition in how system data sets are collected (small, curated patient samples to data sets that are representative due to larger samples of patients). However, for most exams and procedures, the 2019 mean and third quartile values of the system mean values are similar to, or less than, the 2010 values.

Note that a decrease in the typical fluoroscopy time for an exam does not, by itself, indicate reduced exposure, as fluoroscopy time, as a parameter, is independent of the exam's exposure conditions.

Table E7. Comparison of fluoroscopy time mean system mean and third quartile system mean values for the 2010 and 2019 surveys

Fluoroscopy examination or IR procedure	2010 survey system sample size	2010 survey mean of system means [note 1]: minutes	2010 survey third quartile system means [note 1]: minutes	2019 survey system sample size	2019 survey mean of system means: minutes	2019 survey third quartile system means: minutes
Angiogram – coronary	120	3.7	4.3	7	4.5	4.7
Barium meal and swallow	61	2.0	2.3	4	1.8	1.9
Water soluble contrast enema	52	1.9	2.0	4	1.1	1.5
Barium swallow	115	1.8	2.1	16	1.3	1.6
Water soluble contrast swallow	34	1.7	1.8	5	1.1	1.1
Videofluoroscopy barium swallow	58	2.9	3.5	11	2.8	3.0
Hysterosalpingography	82	0.63	0.73	7	0.24	0.42
Proctogram	25	1.2	1.3	2	1.5	1.5
Pacemaker (single or dual chamber: permanent)	63	5.1	6	6	4.1	4.5
Insertion of tunnelled central venous catheter	34	1.3	1.5	4	0.82	1.0
Nephrostomy	25	6.7	6.7	4	2.4	3.3
Stent: oesophageal	21	4.2	5	1	6.0	6.0

2010 Survey mean and third quartile values taken from HPA-CRCE-034 (7).

Appendix F: System mean DAP

The 2019 general survey is the first in its series to propose National Diagnostic Reference Level (NDRL) values based on system median dose index values. Previous survey reports recommended National Reference Dose (NRD) values based on system mean dose index values, which were then ratified as NDRL values.

Appendix F provides summaries of exams' system mean DAP distributions for the 2019 survey. This information is used in Appendix G to illustrate trends in DAP values for the 2000, 2005, 2010 (5,6,7) and 2019 surveys, as bar charts in figures G1 to G7, and as rounded third quartile system mean values in tables G1 to G3.

Information from Appendix F is also used in Appendix H, which compares exams' third quartile (75th percentile) system mean and median values from the 2019 survey to show how the change to using system median values has affected the proposed NDRL values. The data is also used in Appendix I, which compares the data from the 2010 and 2019 surveys used to establish NDRLs.

Note that the mean DAP values of successive surveys are not directly comparable. This is mainly because of the ongoing transition in the local method of collecting representative system exam data. In the first surveys the provision of data sets of small numbers of patients of appropriate weight predominated. In subsequent surveys, the submission of representative data sets based on larger patient samples without weight data has increased and dominates in the current survey. Weight data was provided for 70% of patient DAP values in the 2000 survey (5), compared to 0.6% of patient DAP values in this survey.

Table F1. Plain radiography single projections (adult): summary of system mean DAP values (Gy.cm^2) for data sets of 30 or more patients

Plain radiography single projections	Number of systems	Mean, Gy.cm^2	Standard error of mean	Mean as a percentile	Percentile, Gy.cm^2				
					5th	25th	50th	75th	95th
Abdomen: AP [notes 1,2,3]	188	1.8	±0.060	59th	0.84	1.2	1.6	2.2	3.0
Cervical spine AP [note 1]	115	0.090	±0.0032	55th	0.037	0.064	0.087	0.11	0.15
Cervical spine LAT [note 1]	114	0.11	±0.0054	63rd	0.052	0.077	0.10	0.13	0.22
Chest: AP [notes 1,2,4]	91	0.089	±0.0040	58th	0.033	0.064	0.084	0.11	0.16
Chest mobile: AP (ward) [notes 1,2,4]	72	0.12	±0.0054	61st	0.065	0.088	0.11	0.14	0.18
Chest: PA [notes 1,2,3]	301	0.075	±0.0017	53rd	0.034	0.054	0.073	0.090	0.13
Chest: LAT [notes 2,3]	24	0.32	±0.022	61st	0.17	0.24	0.31	0.39	0.48
Foot (single): DP	62	0.019	±0.0013	64th	0.0083	0.012	0.016	0.025	0.040
Hand (single): PA	35	0.018	±0.0017	60th	0.0064	0.012	0.017	0.024	0.039
Hip (single) HBL	27	1.4	±0.15	63rd	0.51	0.72	1.1	2.0	2.7
Knee (single) AP [note 2]	101	0.053	±0.0018	55th	0.030	0.039	0.052	0.060	0.078
Knee (single) LAT [note 2]	95	0.053	±0.0018	57th	0.031	0.041	0.051	0.064	0.080
Lumbar spine: AP [notes 1,2,3]	140	1.5	±0.043	55th	0.85	1.1	1.4	1.7	2.4
Lumbar spine: LAT [notes 1,2,3]	140	2.1	±0.068	56th	1.0	1.4	1.9	2.6	3.5
Pelvis: AP [notes 1,2,3]	237	1.6	±0.041	61st	0.93	1.2	1.5	1.9	2.8

Plain radiography single projections	Number of systems	Mean, Gy.cm^2	Standard error of mean	Mean as a percentile	Percentile, Gy.cm^2				
					5th	25th	50th	75th	95th
Shoulder (single): AP [note 2]	165	0.089	±0.0026	60th	0.048	0.069	0.083	0.10	0.16
Thoracic spine: AP [note 1,2,3]	84	0.60	±0.023	51st	0.31	0.43	0.60	0.73	0.97
Thoracic spine: LAT [note 1,2,3]	93	1.05	±0.050	54th	0.46	0.66	1.00	1.4	1.7

1. 2010 Review (7): National reference dose (NRD) DAP value recommended.
2. 2010 Review (7): NRD ESD value recommended.
3. 2005 Review (6): NRD DAP value recommended.
4. These 2 projections, chest AP and chest AP mobile were not differentiated in previous surveys.

Table F2. Plain radiography examinations (adult): summary of system mean DAP values (Gy.cm²) for system samples of 30 or more patients

Radiography examinations	Number of systems	Mean, Gy.cm²	Standard error of mean	Mean as a percentile	Percentile, Gy.cm²				
					5th	25th	50th	75th	95th
Abdomen [note 1]	39	2.7	±0.17	53rd	1.1	2.1	2.7	3.2	4.2
Cervical spine	96	0.27	±0.015	63rd	0.13	0.17	0.23	0.31	0.55
Chest [note 1]	62	0.15	±0.016	70th	0.051	0.079	0.10	0.15	0.42
Facial bones	19	0.67	±0.061	46th	0.27	0.49	0.70	0.85	1.0
Foot [note 2]	41	0.045	±0.0021	50th	0.026	0.034	0.046	0.056	0.068
Hip (single)	57	2.4	±0.20	63rd	1.0	1.3	1.8	3.0	5.6
Knee (single)	122	0.13	±0.0035	56th	0.074	0.10	0.12	0.15	0.18
Leg length measurement (single leg)	4	0.93	±0.25	75th	0.66	0.69	0.70	0.94	1.5
Lumbar spine [note 1]	116	4.0	±0.13	55th	2.1	2.8	3.8	5.1	6.1
Pelvis	59	2.3	±0.10	63rd	1.3	1.7	2.2	2.7	3.5
Shoulder [note 2]	39	0.21	±0.013	58th	0.11	0.16	0.19	0.25	0.37
Skeletal survey	1	3.3	N/A	N/A	3.3	3.3	3.3	3.3	3.3
Thoracic spine	41	2.0	±0.12	58th	0.96	1.5	1.9	2.5	3.4

1. 2010 Review (7): NRD DAP value recommended.
2. Exam not on survey request list.

Table F3. Simple fluoroscopy examinations (adult): summary of system mean DAP values (Gy.cm^2) for system samples of 30 or more patients

Fluoroscopy examinations	Number of systems	Mean, Gy.cm^2	Standard error of mean	Mean as a percentile	Percentile, Gy.cm^2				
					5th	25th	50th	75th	95th
Angiography – cerebral	8	52	±10.2	74th	25	42	44	53	97
Angiography – coronary [notes 1,2,3]	13	20	±1.7	67th	14	16	18	22	33
Angiography – femoral [notes 1,2]	3	4.7	±0.53	44th	3.8	4.3	4.8	5.2	5.5
Arthrography – hip	6	0.68	±0.28	51st	0.041	0.078	0.61	1.2	1.4
Barium meal and swallow [notes 1,2]	7	8.2	±1.3	64th	4.2	6.4	7.4	10	13
Water soluble contrast enema [notes 1,2]	13	8.2	±1.1	53rd	3.2	5.5	7.6	9.3	15
Barium swallow [notes 1,2]	48	5.3	±0.46	66th	2.2	3.2	4.4	6.3	11
Water soluble contrast swallow [notes 1,2]	15	6.6	±1.1	60th	2.2	3.1	5.9	10	13
Videofluoroscopy barium swallow [note 1]	27	1.1	±0.16	62nd	0.16	0.41	0.87	1.5	2.9
Cystogram [note 3]	7	3.3	±0.65	42nd	0.96	2.2	4.3	4.5	5.1
Hysterosalpingography [notes 1,2]	23	0.58	±0.10	61st	0.13	0.26	0.52	0.71	1.1

Fluoroscopy examinations	Number of systems	Mean, Gy.cm^2	Standard error of mean	Mean as a percentile	Percentile, Gy.cm^2				
					5th	25th	50th	75th	95th
Percutaneous Transhepatic Cholangiography (PCT) [note 3]	6	11	±3.2	66th	4.2	6.7	8.8	12	22
Proctogram [note 1]	7	7.1	±0.60	37th	4.7	6.3	7.8	8.2	8.4

1. 2010 Review (7): NRD DAP value recommended (same NRD used for equivalent barium and water soluble contrast exams).
2. 2005 Review (6): NRD DAP value recommended (same NRD used for equivalent barium and water soluble contrast exams).
3. Exam not on survey request list.

Table F4. Simple IR procedures (adult): summary of system mean DAP values ($Gy.cm^2$) for data sets of 30 or more patients

IR procedures	Number of systems	Mean, $Gy.cm^2$	Standard error of mean	Mean as a percentile	Percentile, $Gy.cm^2$				
					5th	25th	50th	75th	95th
Angioplasty: superficial femoral artery [note 3]	8	12	±2.0	61st	6.3	7.7	9.1	18	19
Cardiac catheter ablation (RF)	11	6.6	±1.1	64th	3.1	4.0	5.4	8.2	13
Endoscopic Retrograde Cholangiopancreatography (ERCP)									
ERCP (diagnostic and interventional) [note 3]	29	6.0	±0.79	60th	1.2	3.2	4.0	8.3	14
Diagnostic ERCP	7	5.6	±2.6	70th	0.54	1.2	2.2	8.9	16
Interventional ERCP	6	5.3	±1.1	55th	2.7	3.4	4.7	7.7	8.3
Heart implants									
Pacemaker (permanent) single or dual chamber [notes 1,2]	26	2.2	±0.23	50th	0.77	1.3	2.2	2.8	4.3
Defibrillator implant (ICD) [note 3]	5	4.2	±1.7	77th	1.7	2.2	2.7	3.7	9.6
Biventricular implantable cardioverter defibrillator [note 3]	5	23	±6.9	69th	12	12	16	25	44
Injections etc.									
Facet joint injection [notes 1,2]	11	1.4	±0.32	47th	0.30	0.45	1.6	2.0	2.9
Fluoro guided injection: hip [note 3]	7	0.27	±0.083	57th	0.049	0.095	0.21	0.43	0.57
Fluoro guided nerve root block [note 3]	6	1.9	±0.49	67th	0.63	1.4	1.7	2.1	3.6

IR procedures	Number of systems	Mean, Gy.cm^2	Standard error of mean	Mean as a percentile	Percentile, Gy.cm^2				
					5th	25th	50th	75th	95th
Line insertions etc.									
Insertion of tunnelled central venous catheter [notes 1,2,4]	19	0.92	±0.27	73rd	0.10	0.32	0.53	1.0	3.4
PICC line insertion	14	0.36	±0.061	43rd	0.065	0.14	0.44	0.52	0.63
Radiologically inserted gastrostomy tube	9	1.8	±0.50	63rd	0.28	0.90	1.2	2.7	4.1
Nephrostomy									
Nephrostomy [notes 1,2]	20	2.8	±0.45	56th	0.65	1.6	2.4	3.3	5.3
Nephrostomy tube replacement	12	1.2	±0.25	58th	0.33	0.56	0.99	1.3	2.8
Stent									
Stent (ureteric) [note 3]	10	4.5	±1.1	70th	1.6	1.9	3.7	5.0	11
Stent (ureteric antegrade)	5	5.7	±2.1	62nd	1.9	2.2	4.1	7.6	12
Stent (ureteric retrograde)	5	2.8	±0.70	64th	1.6	1.8	2.1	3.4	4.9
Oesophageal stent [notes 1,2]	5	4.5	±2.1	63rd	0.87	1.1	2.7	6.1	11
Mobile Imaging of IR procedures									
Mobile imaging of abdomen for Laparoscopic cholecystectomy	4	1.4	±0.39	69th	0.71	1.0	1.2	1.6	2.3
Mobile imaging of cervical spine for laminectomy	2	0.51	±0.093	50th	0.42	0.46	0.51	0.55	0.59

IR procedures	**Number of systems**	**Mean, Gy.cm²**	**Standard error of mean**	**Mean as a percentile**	**Percentile, Gy.cm²**				
					5th	**25th**	**50th**	**75th**	**95th**
Mobile imaging of lumbar spine for laminectomy	11	1.1	±0.15	61.8%	0.47	0.82	1.0	1.4	1.9
Mobile imaging of orthopaedic hip pinning	11	1.1	±0.22	61.6%	0.33	0.57	0.65	1.7	2.2

1. 2010 Review (7): NRD DAP value recommended.
2. 2005 Review (6): NRD DAP value recommended.
3. Procedure not on survey request list.
4. A broadened procedure definition, which includes the previously reported Hickman Line procedure.

Appendix G: Trends in survey data

This appendix presents information on the trends of system mean DAP values and survey demographics.

Trends in system mean DAP

Whilst the NDRL values proposed in this report are based on median values, 2019 survey data was also analysed using system mean values (Appendix F) to enable comparison with previous surveys. This approach is used due to the limited availability of system median values for previous surveys.

In each of the following sections, following the practice of previous reports (7), the figures show trends using the mean of system mean DAP values, whilst the tables show the trend using the rounded third quartiles of system mean DAP values (figures G1 to G7, tables G1 to G3). For the 2000, 2005 and 2010 surveys, the third quartile system mean values were the basis of recommended DAP NRD values, which were then adopted as NDRLs.

The comparison of successive surveys may be influenced by factors other than changes in doses received by patients, such as the ongoing transition in the local method of collecting representative system exam data. In the first surveys the provision of data sets of small numbers of patients of appropriate weight predominated. In subsequent surveys, the submission of representative data sets based on larger patient samples without weight data has increased and accounts for most data received in the current survey. Weight data was provided for 70% of patient DAP values in the 2000 survey (5), 58% in 2005 survey (6), 36% for the 2010 survey (7), compared to 0.6% of patient DAP values in this survey.

Trends in system mean DAP for plain radiography single projections

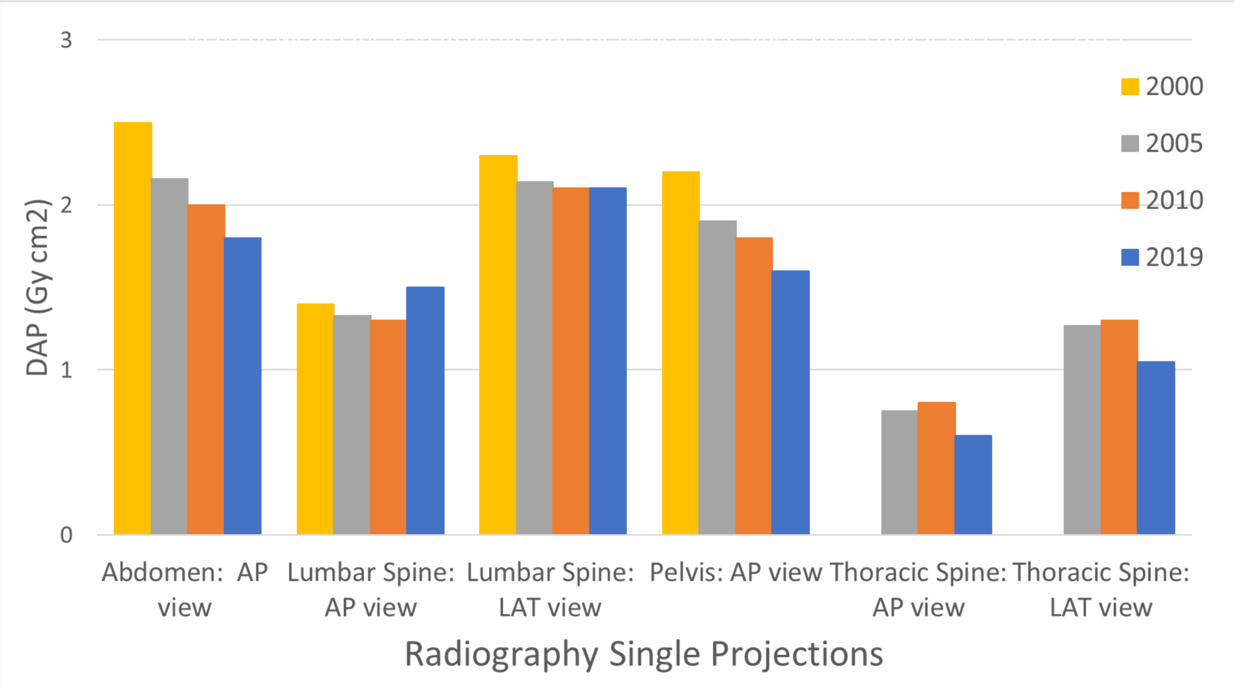
Figures G1 and G2 show the trends in exam mean values determined from the distribution of individual system mean DAP values for plain radiography single projections. Table G1 shows the trend in the projections' third quartile system mean DAP values for the last 4 surveys, where those values are available.

Figure G1, with a vertical axis maximum of 3 Gy.cm^2, illustrates higher dose projections, most of which have had their DAP values monitored since the 2000 survey (5).

Figure G2, with a vertical axis maximum of 0.4 Gy.cm^2, illustrates lower dose projections, for which DAP values have generally only been monitored in more recent surveys. In Figure G2 the striped entries for chest lateral, knee AP, knee lateral and shoulder AP represent mean values based on limited data from the 2010 survey.

Figures G1 and G2 show that the 2019 survey mean system mean DAP values are, in most cases, the lowest recorded survey DAP values, with the exceptions being lumbar spine AP, and lumbar spine lateral in Figure G1 and chest lateral in Figure G2.

Figure G1. Trends on mean system mean DAP (Gy.cm²) for higher dose radiography projections



Lumbar spine AP is the only projection whose 2019 survey mean DAP value exceeds all previous survey values (Figure G1). However, the mean DAP value for lumbar spine lateral for the 2019 survey is the same as for the 2010 survey (7) and both projections have marginally higher third quartile values in 2019 survey than in 2010 survey (Table G1). Possible explanations for this discrepancy in trend were explored:

- substantial data sets were received for both projections for both the 2010 and 2019 surveys, so this is not due to small sample sizes
- if the increase had been due to the upward drift in the typical size of a UK patient, similar trends would be expected in the DAP values for other projections such as those for the abdomen and the thoracic spine, but that is not seen
- the shift in system sample collection, from small, curated data sets with patient weight information to larger data sets with minimal weight information was considered but this trend would equally apply to other projections and so is unlikely to be a cause
- alternatively, the increase could be as a consequence of the shift to direct digital systems, and the option to digitally crop images rather than collimate appropriately, although it is unclear from the data why this is not reflected in other examinations

The last suggestion is somewhat supported by the data for the current, 2019, survey when reviewing the comparison of CR and DR third quartile median DAP values (Table 18). Lumbar spine AP values are 10% higher for DR detector systems than for CR. However, for lumbar spine lateral the DR values are 7% lower than CR, and for other body projections DR values are at least 20% lower.

Figure G2. Trends in mean system mean DAP (Gy.cm^2) for lower dose radiography projections

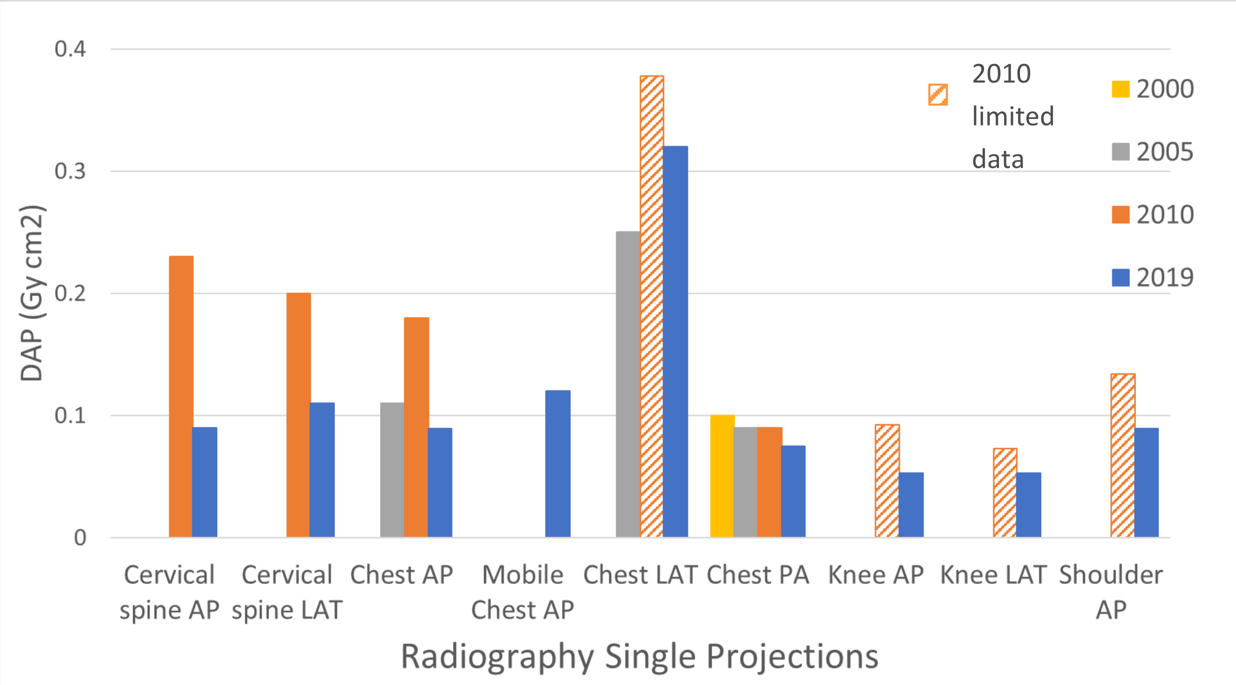


Figure G2 shows mean DAP trends for lower dose projections. Chest PA DAP has been reported since the 2000 survey (5), chest AP and chest lateral DAP were first included in the 2005 survey (6) and the other projections in the 2010 survey (7) (cervical spine AP and lateral, knee AP and lateral, and shoulder AP). Doses for most of these projections were previously monitored using Entrance Surface Dose (ESD). Limited DAP data received by the 2010 survey for chest lateral, knee AP, knee lateral and shoulder AP have been used to provide some indication of dose trend.

For chest lateral projections (Figure G2 and Table G1), the 2010 (7) and 2019 surveys' mean and third quartile DAP values suggest that the typical DAP values have increased since the 2005 survey (6). Student's unpaired 2-tailed t-test indicates that the 2010 and 2019 survey mean system mean DAP values are statistically higher than the 2005 survey value, but are not statistically different from each other. This finding may be influenced by changes in system sample collection methods as discussed elsewhere.

The sample sizes in all 3 surveys for chest lateral projections are low compared to those of other chest projections considered by the surveys, indicating that it is a less commonly performed chest projection. For chest lateral, the 2005 survey recommended National Reference Dose (NRD) and the 2019 survey proposed NDRL were based on the data of 23 and 24 radiography systems respectively, but the number of patients represented increased from less than 300 in the 2005 survey to over 10,000 in the 2019 survey sample. The 2010 survey did not recommend an NRD value for chest lateral.

Table G1 shows that for all projections, except for lumbar spine AP and lumbar spine lateral, the 2019 survey third quartile values are lower than the 2010 survey values, although the decrease is not statistically significant in all cases. The average decrease in third quartile values between the 2 surveys is −13%.

Table G1. Plain radiography single projections: rounded third quartile system mean DAP values (Gy.cm²) from current and previous reviews of national patient dose data

Plain radiography single projections	Rounded third quartile system mean DAP values				Percent change from 2010 to 2019
	2000 survey	2005 survey	2010 survey	2019 survey	
Abdomen AP	3.1	2.6	2.5	2.2	−12%
Cervical spine AP			0.15	0.11	−27%
Cervical spine LAT			0.16	0.13	−13%
Chest AP		0.12	0.15	0.11	−26%
Chest AP mobile			0.15	0.14	−9%
Chest PA	0.12	0.11	0.10	0.090	−10%
Chest LAT		0.31	0.40	0.39	−2%
Foot (single) DP			0.030	0.025	−18%
Hand (single) PA			0.025	0.024	−6%
Knee (single) AP			0.12	0.060	−50%
Knee (single) LAT			0.067	0.064	−4%
Lumbar spine AP	1.6	1.6	1.5	1.7	+13%
Lumbar spine LAT	2.8	2.5	2.5	2.6	+4%
Pelvis AP	2.7	2.1	2.2	1.9	−14%
Shoulder (single) AP			0.12	0.10	−13%
Thoracic spine AP		0.93	1.0	0.73	−27%
Thoracic spine LAT		1.4	1.5	1.4	−7%

Trends in system mean DAP for plain radiography examinations

The 2010 survey was the first survey to report on plain radiography examinations. Figures G3 and G4 show the means of system mean DAP values, and Table G2, the third quartile system mean DAP values, for radiography examinations in the 2010 and 2019 surveys.

Figure G3 shows the higher dose radiography examinations, for which the mean DAP values decreased significantly. Both surveys received robust amounts of data for these examinations.

Figure G3. Trends in mean system mean DAP (Gy.cm^2) for higher dose radiography examinations

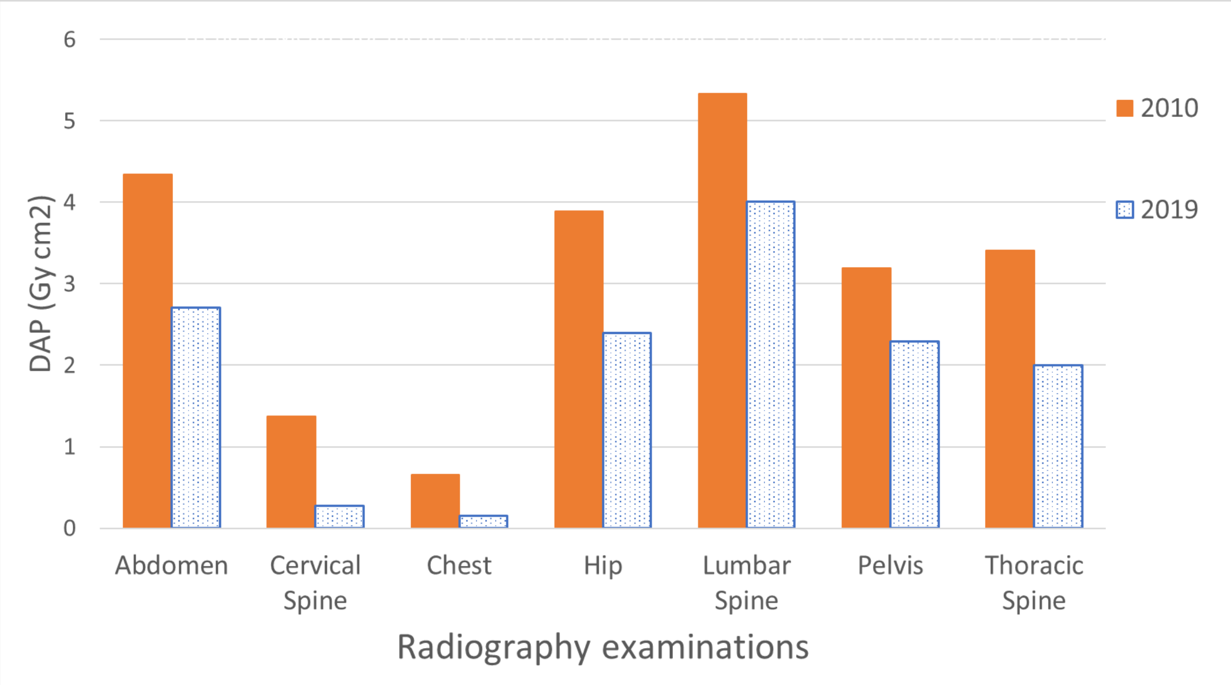


Figure G4. Trends in mean system mean DAP (Gy.cm^2) for lower dose radiography examinations of extremities

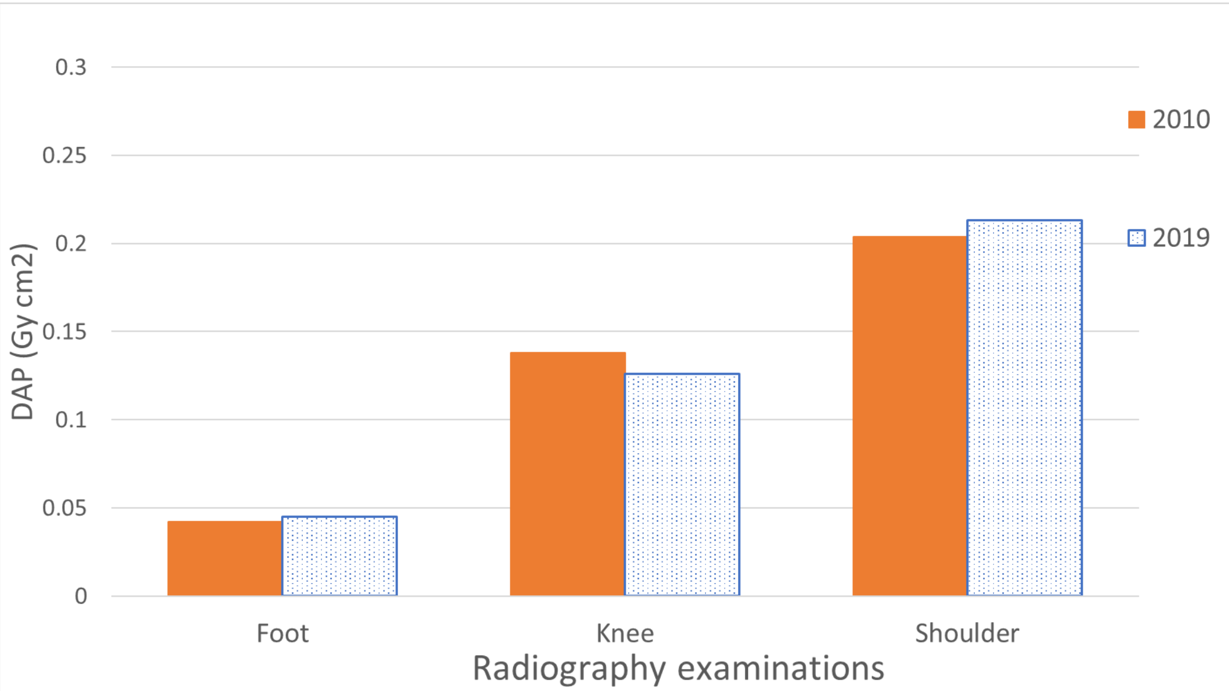


Figure G4 shows the equivalent trend for the lower DAP examinations, which are of peripheral parts of the body. While DAP received from the examinations in Figure G4 are low, these exams are of some of the most imaged parts of the body. DID data for 2019 (31) indicates that the knee is the second most frequently X-rayed part of the body after the chest, with foot, shoulder, and hand all within the top 10. Therefore, it is useful to know the typical DAP values received from these exams. The minor changes in the mean DAP of the foot, knee and shoulder examinations are not statistically significant according to Student's unpaired 2-tailed t-test.

Table G2 shows the third quartiles of system mean DAP values for plain radiography examinations for the 2010 and 2019 surveys, with an average decrease in third quartile system mean DAP values between the 2010 and 2019 surveys of −28%. These results reflect those seen for the examination's mean values, with only the foot examination having a higher third quartile value for 2019 survey than 2010 survey, and the knee and shoulder examinations third quartile values having the smallest percentage decreases.

Table G2. Plain radiography examinations: rounded third quartile system mean DAP values (Gy.cm^2) from current and previous reviews of national patient dose data

Plain radiography examinations	Rounded third quartile system mean DAP values				Percent change from 2010 to 2019
	2000 survey	2005 survey	2010 survey	2019 survey	
Abdomen			4.4	3.2	−27%
Cervical spine			1.4	0.31	−78%
Chest			0.3	0.15	−49%
Foot			0.047	0.056	+19%
Hip			4.7	3.0	−36%
Knee			0.16	0.15	−6%
Lumbar spine			6	5.1	−16%
Pelvis			4.3	2.7	−36%
Shoulder			0.27	0.25	−5%
Thoracic spine			4.4	2.5	−44%

Trends in system mean DAP for fluoroscopy and IR

Table G3 shows trends in third quartile system mean DAP values for the last 4 surveys for fluoroscopy examinations and IR procedures, where that information is available. For the examinations and procedures shown in Table G3 the average decrease of third quartile values between the 2010 and 2019 surveys is −40%, but ranges from +60% (WSC swallow) to −79% (radiologically inserted gastrostomy tube). Water soluble contrast swallow is the only entry in Table G3 for which the 2019 third quartile system mean DAP value is higher than the 2010 third quartile value.

Table G3. Rounded third quartile system mean DAP values (Gy.cm^2) from current and previous reviews of national patient dose data

Fluoroscopy examinations and Interventional radiology procedures	Rounded third quartile system mean DAP values				Percent change from 2010 to 2019
	2000 survey	2005 survey	2010 survey	2019 survey	
Angiography – coronary	36	29	31	22	−31%
Barium meal and swallow		11	10	10	−2%
Barium swallow	10	8.1	7.5	6.3	−15%
Water soluble contrast enema	26	20	13	9.3	−28%
Water soluble contrast swallow	14	9.8	6.4	10	+60%
Videofluoroscopy barium swallow			3.4	1.5	−56%
Hysterosalpingography	4.3	2.8	1.9	0.71	−63%
ERCP (diagnostic and interventional)	19	17	11	8.3	−27%
Pacemaker: permanent (single or dual chamber)	27	11	7	2.8	−60%
Insertion of tunnelled central venous catheter [note 1]	4.1	3	3	1.0	−66%
PICC line insertion			0.88	0.52	−41%
Radiologically inserted gastrostomy tube		13	13	2.7	−79%
Nephrostomy	19	14	13	3.3	−75%
Stent: ureteric (antegrade and retrograde)	32	38	16	5.0	−69%

1. A broadened procedure definition, including the previously reported Hickman Line procedure.

Figures G5 to G7 show the trends of exams' mean DAP values for selections of fluoroscopy examinations and IR procedures. The exam mean values are determined from the distribution of individual systems' mean DAP values for these exams. In figures G5 to G7, striped columns indicate exams for which limited data was received by the 2019 survey. In these cases, mean DAP values for system data sets with a sample size of 10 or more patients have been included to provide some indication of dose trends, but the data should be treated with extra caution.

In previous reviews the same NDRL value was given for similar barium and water soluble contrast exams. Separate NDRL values for barium exams and water soluble contrast exams are proposed by this survey to encourage optimisation of each exam for its specific contrast medium.

In Figure G5 and Table G3, the barium and water soluble contrast (WSC) examinations generally show decreased or unchanged mean and third quartile DAP values. Student's unpaired 2-tailed t-test indicates that there is no statistical change in the mean DAP values of barium meal and swallow, barium swallow and WSC swallow between the 2010 and 2019 surveys. While the 2019 survey third quartile system mean value for WSC swallow is higher than the 2010 survey value (Table G3), this increase is not supported by either its mean value shown in Figure G5, or by its third quartile system median value, which is very similar to that of barium swallow (5.3 and 5.0 Gy.cm^2 respectively, Table H3).

Figure G5. Trend in mean system mean DAP (Gy.cm^2) for barium and water soluble contrast fluoroscopy examinations

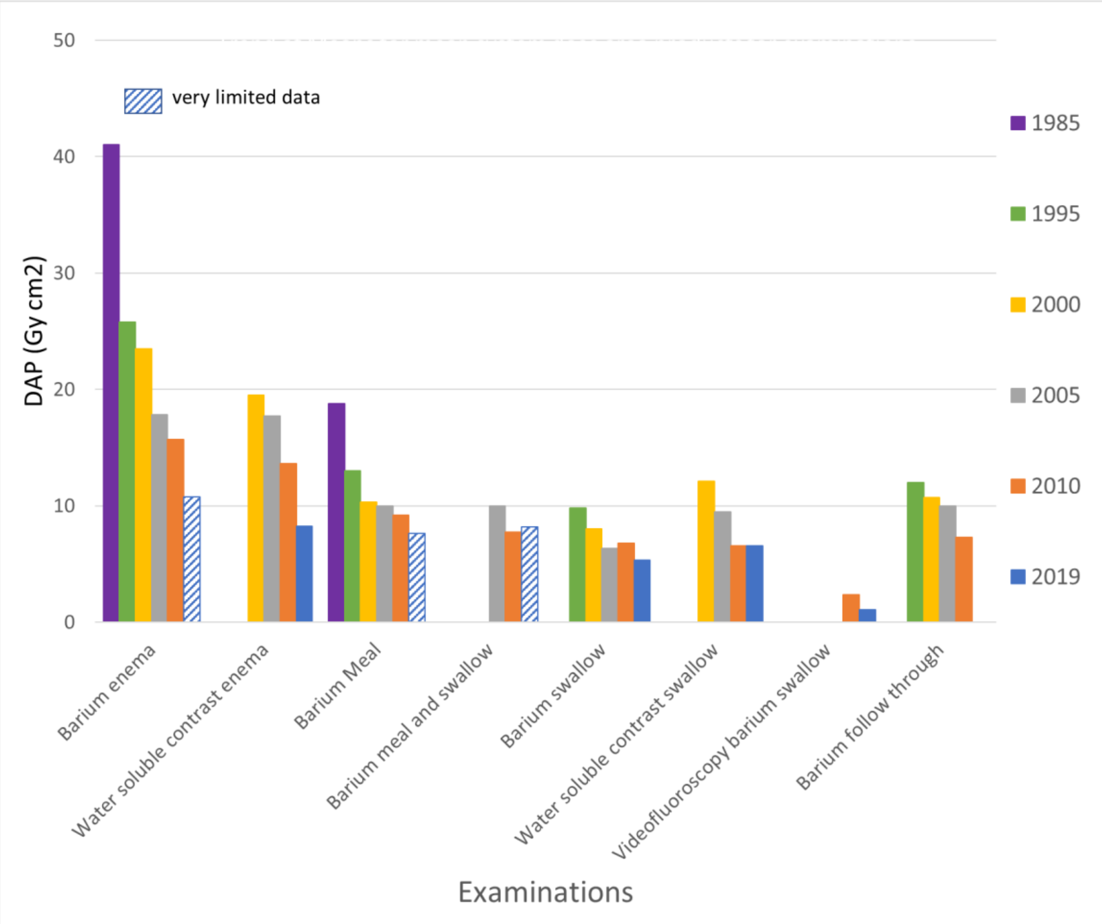


Figure G6 displays the trend in mean DAP for 4 fluoroscopy examinations.

The 2019 survey received a robust data sample for hysterosalpingography (HSG), the only requested exam of the four. The exam shows a continuing trend of decreasing mean DAP in both Figure G6 and Table G3.

The 2019 survey received small voluntary data samples for nephrostogram, sialogram and T-tube cholangiogram, which all featured in previous surveys. Their 2019 mean DAP values shown in Figure G6 should be treated with caution because they are based on small samples. For the same reason, these exams were not included in Table G3. Larger data samples are required to confirm the trends in mean DAP for these exams.

Figure G6. Trend in mean system mean DAP (Gy.cm²) for 4 fluoroscopy examinations

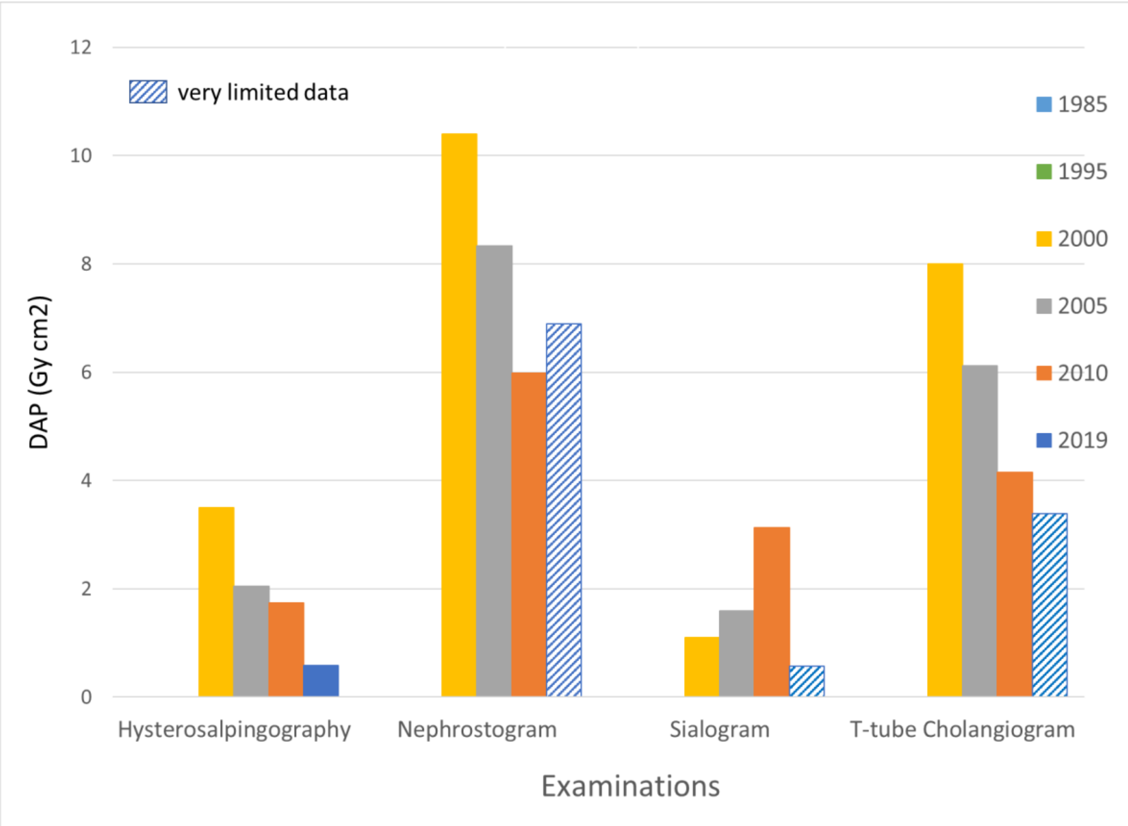


Figure G7 illustrates the trends in mean DAP for the 2 historically high dose fluoroscopy examinations, coronary and femoral angiography, and 4 simple IR procedures, all requested by the 2019 survey. For both angiograms, the 2019 survey data shows a decrease in mean DAP from the 2010 survey data, with the values the lowest recorded by the survey series.

For femoral angiography, in Figure G7, the 2019 survey value (8.6 Gy.cm²) is the mean of the mean DAP values of all 6 femoral angiography data sets received (all samples of 20 or more patients) and so differs from the mean value for the 3 system samples of 30 or more patients given in Table F3 (4.7 Gy.cm²). The apparent decrease by a factor of 5 from the mean DAP value of 46 Gy.cm² in the 2010 survey is in strong contrast to the trend of increasing mean DAP values of the 2000, 2005 and 2010 surveys. This may be entirely due to the small size of the

2019 survey sample. A larger data sample is required to confirm the decrease in mean DAP for femoral angiography suggested by the 2019 survey.

Figure G7. Trend in mean system mean DAP (Gy.cm^2) for angiograms and IR procedures

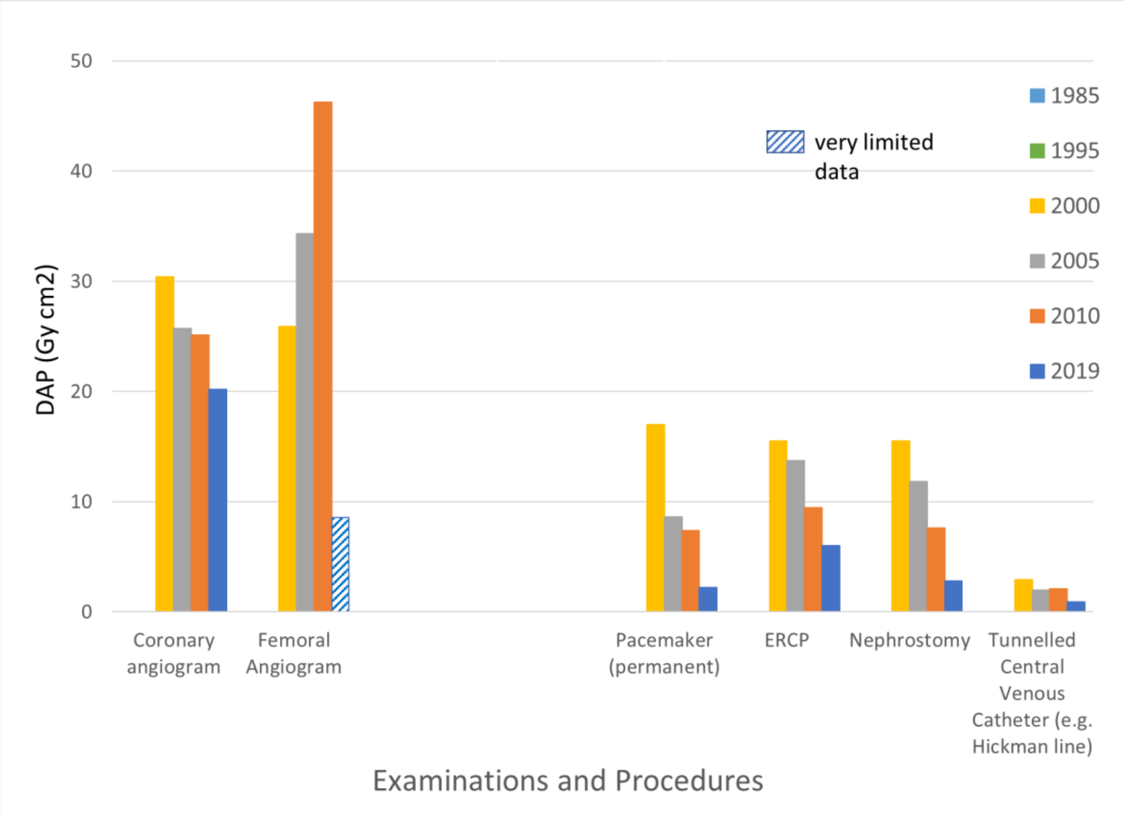


Figure G7 also shows a strong trend of decreasing mean DAP values for 4 IR procedures, permanent implant of single or dual chamber heart pacemakers (pacemaker (permanent)), diagnostic and interventional endoscopic retrograde cholangiopancreatography (ERCP), nephrostomy (as opposed to nephrostogram in Figure G6), and insertion of a tunnelled central venous catheter, which are compared to data for Hickman line insertions in previous surveys. Table G3 shows a similar downward trend in third quartile system mean DAP for these procedures. For procedures as well defined as implanting a permanent heart pacemaker, the decrease in mean DAP indicates reduced DAP to patients through improved optimisation and utilisation of fluoroscopy systems. In 2019, DID records indicates that over 20,000 permanent pacemaker instillations, 3,000 ERCP, 10,000 nephrostomies and 6,000 tunnelled central venous catheter insertions were performed for NHS England (31). These values may well be underestimates, excluding instances where these procedures were combined with others and so included in a different category by DID (32,33,35).

Trends in survey participation by patient, system and hospital

Trends in participation in the general survey can be tracked by the numbers of participating hospitals, and the radiography and fluoroscopy systems for which data was received, and the global number of patient dose index values received per exam. These measures of participation are approximate as they can be affected by external factors that change between surveys, such as NHS reorganisations and centralisation of facilities.

The number of system exam data sets, and their patient sample sizes, received by General surveys have tended to increase in successive reviews as the automation of diagnostic imaging data collection has progressed. Received data has shifted from being predominantly prospective data sets of a set number of patients of an appropriate physique to being larger retrospective data sets retrieved from electronic record software platforms.

For some specific examinations the number of received system exam data sets and their patient samples sizes have fallen, reflecting the decrease in the national number of those exams performed. The designation of head CT as the default exam for diagnosing head injuries (26,27) is mirrored by the large fall in the number of skull AP and skull lateral projections performed, causing them not to be included in this survey's requested exam list. A relatively low number of requested facial bone exam system data sets were received by the survey. Similarly, for fluoroscopy, barium enema was not a requested exam, as it is increasingly being replaced by imaging methods such as CT virtual colonoscopy. In 2019, DID recorded fewer than 800 adult patient barium enema studies performed for NHS England, as opposed to over 5,000 adult studies for WSC enema (31).

Provision of plain radiography single projections

Automation of data collection has caused patient DAP sample sizes for named radiography projections represented in the survey to have increased significantly for all projections since the 2010 review. However, for the 2019 survey, the numbers of hospitals and radiography systems providing data for higher dose single projections, which have been included in general surveys since the 2000 or 2005 reviews (5,6), are close to, or slightly down on, the 2010 review numbers (7). Conversely, hospital and radiography system numbers have risen significantly for cervical spine AP and lateral, chest AP, and knee AP and lateral. Chest AP (mobile) was monitored as a separate projection for the first time in this review. These trends are shown in figures G8 to G10.

Figure G8. Plain radiography single projections: trend since 2000 review in patient DAP value numbers received

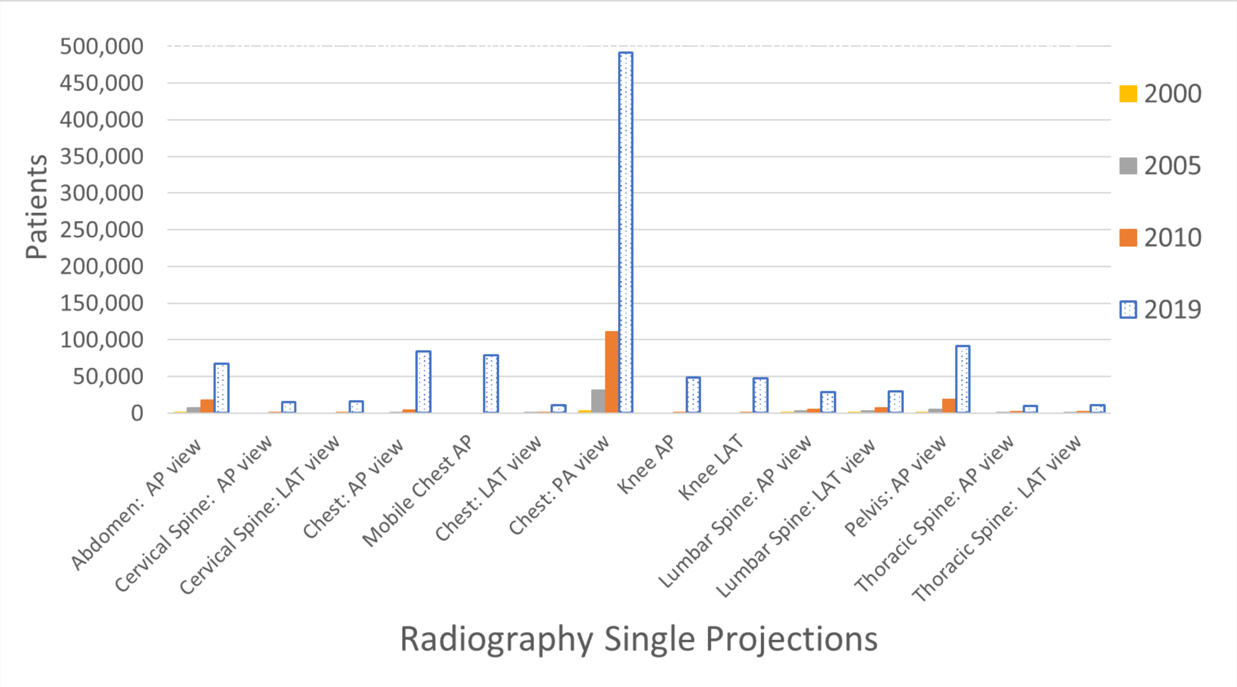


Figure G9. Plain radiography single projections: trend since 2000 review of radiography systems providing DAP values

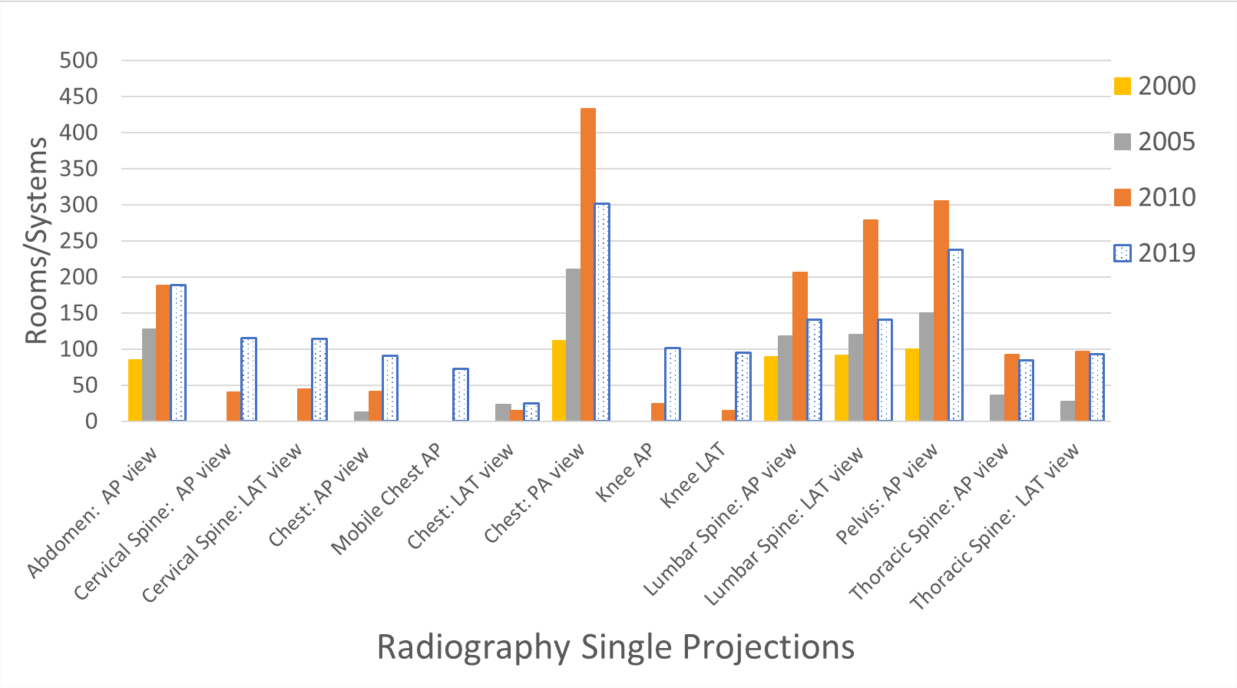
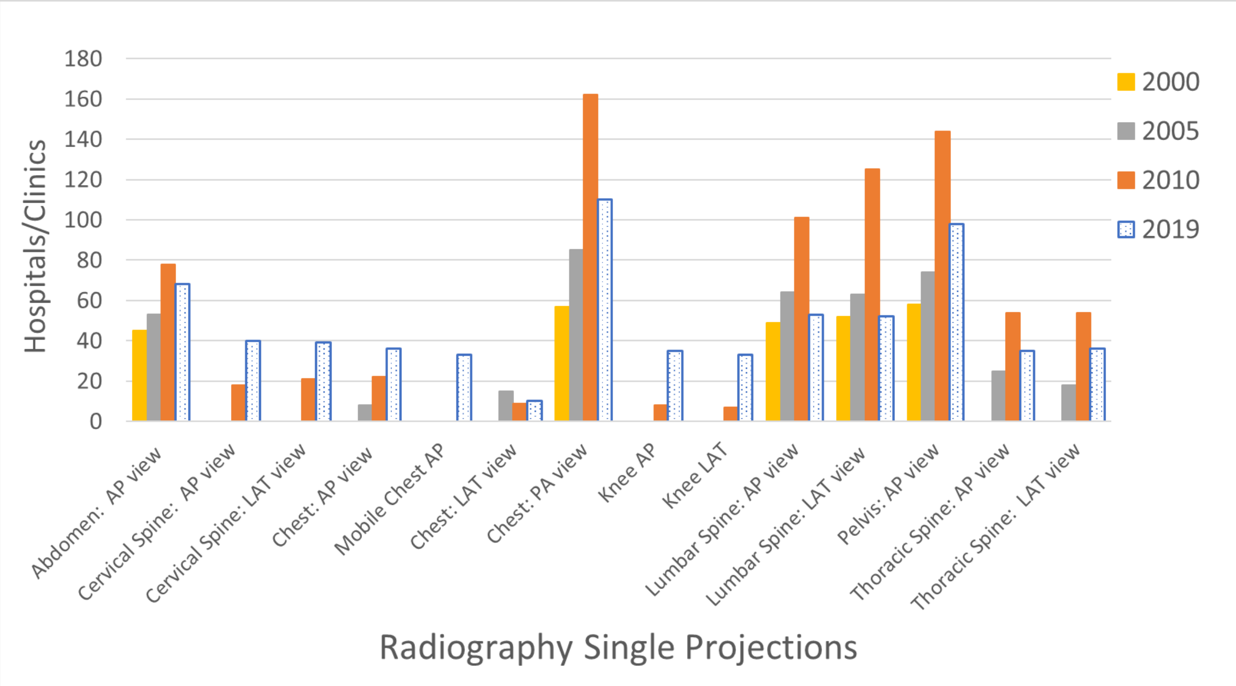


Figure G10. Plain radiography single projections: trend since 2000 review of hospitals providing DAP values



Provision of plain radiography examinations

The 2010 review (7) was the first to include plain radiography examinations, recommending National Reference Doses (NRD) for abdomen, chest, and lumbar spine, and giving information on hip, pelvis, and thoracic spine. The patient sample, hospital, and radiography system contributions to the 2019 review were similar in number for abdomen and hand and increased notably in all categories for all other examinations for which significant data samples was received as shown in figures G11 to G13.

Figure G11. Plain radiography examinations: 2010 to 2019 trends in number of patient DAP values received

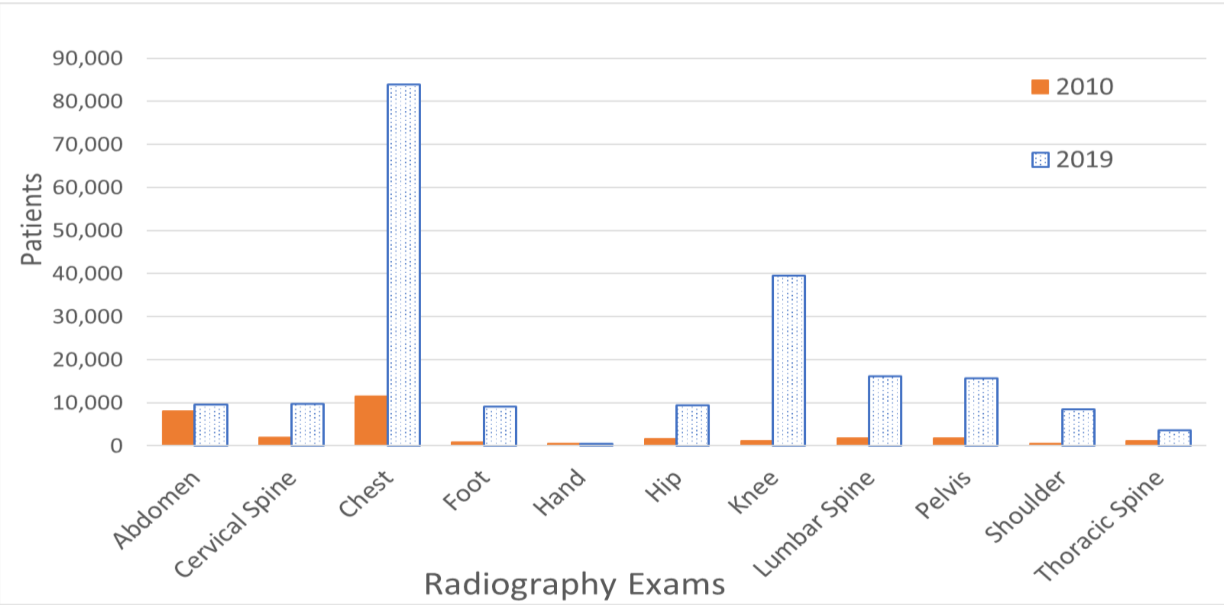


Figure G12. Plain radiography examinations: 2010 to 2019 trends in systems providing DAP values

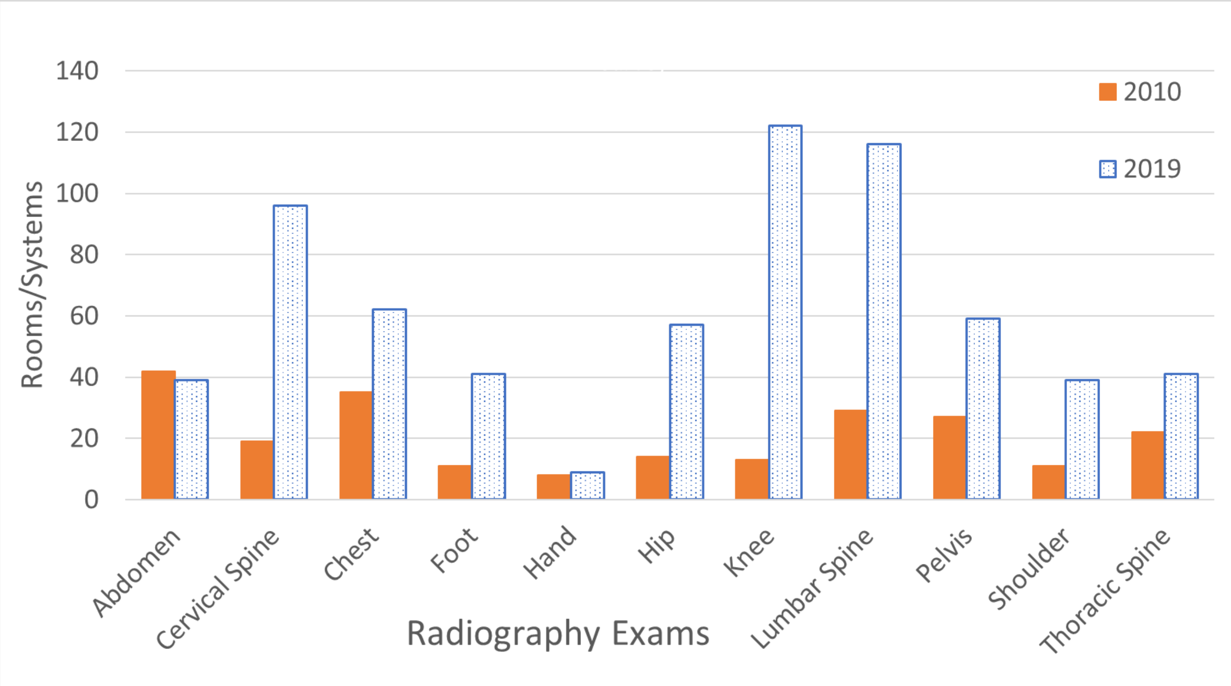
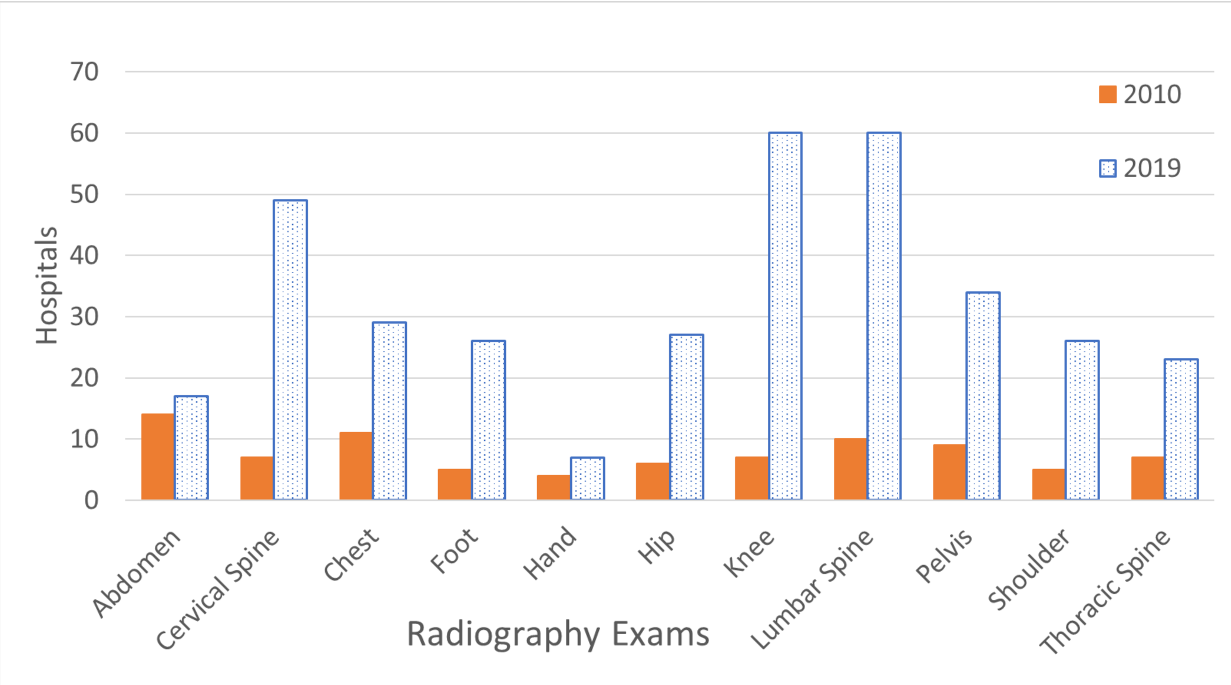


Figure G13. Plain radiography examinations: 2010 to 2019 trends in hospitals providing DAP values



Provision of simple fluoroscopy examinations and IR procedures

For most fluoroscopy examinations and IR procedures, participation, as measured by hospitals and fluoroscopy systems, was lower in the 2019 survey than in the preceding 3 surveys. It is possible that potential participants were deterred by the statement that the survey was focusing on ‘simple’ examinations and procedures, or that this was just one survey too many in a relatively short period of time. Fluoroscopy and IR are also the modalities where protocols are evolving fastest as techniques and technology develop and fewer generic procedures are performed. The fall in the amount of coronary and femoral angiogram data received may be an example of the continuing development of alternative, less invasive, CT and MRI examinations and of highly specific fluoroscopy examinations and IR procedures from one original general protocol. The trends for fluoroscopy exams and IR procedures in patient numbers, contributing fluoroscopy and hospitals are shown in figures G14 to G22.

Figure G14. Barium and water soluble contrast exams: trends in number of patient DAP values received

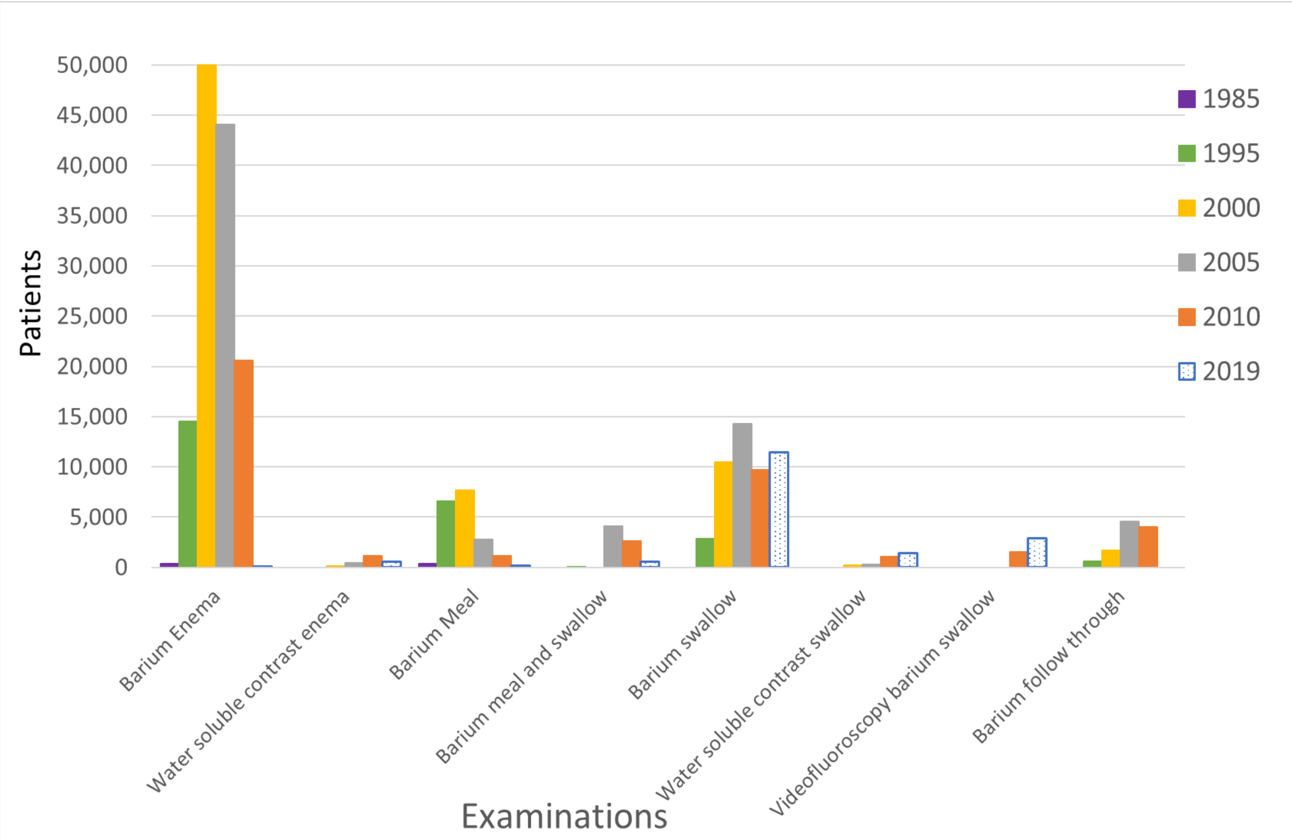


Figure G15. Trends in number of patient DAP values received for 4 fluoroscopy exams

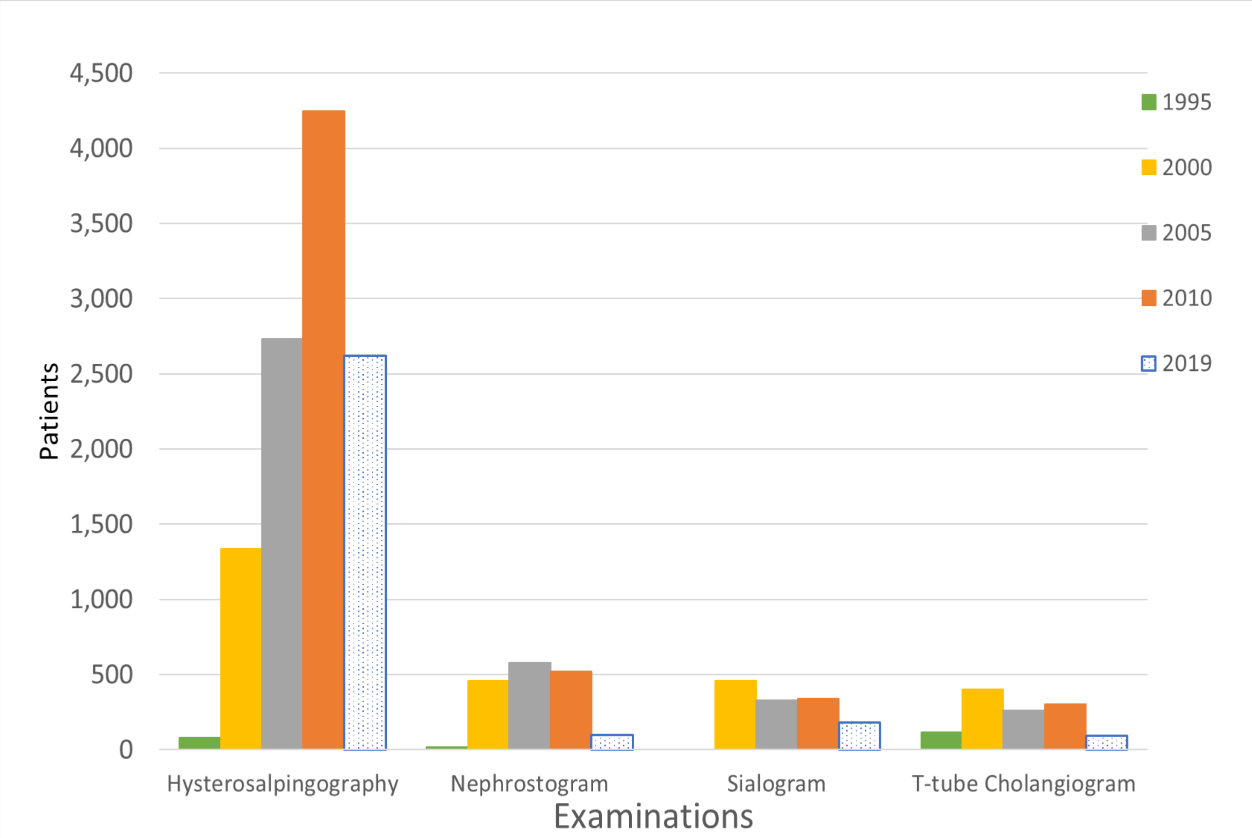


Figure G16. Trends in numbers of patient DAP values received for angiograms and IR

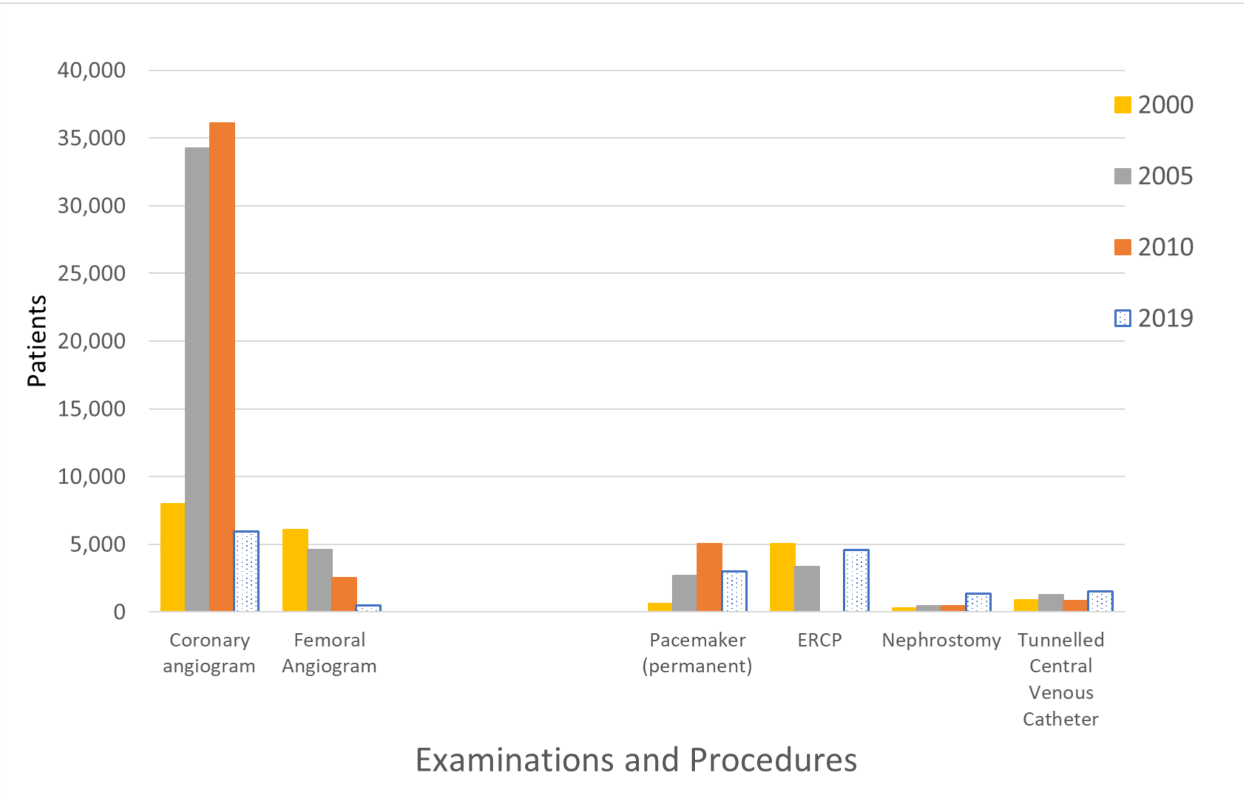


Figure G17. Trend in number of systems contributing DAP values for barium and water soluble contrast exams

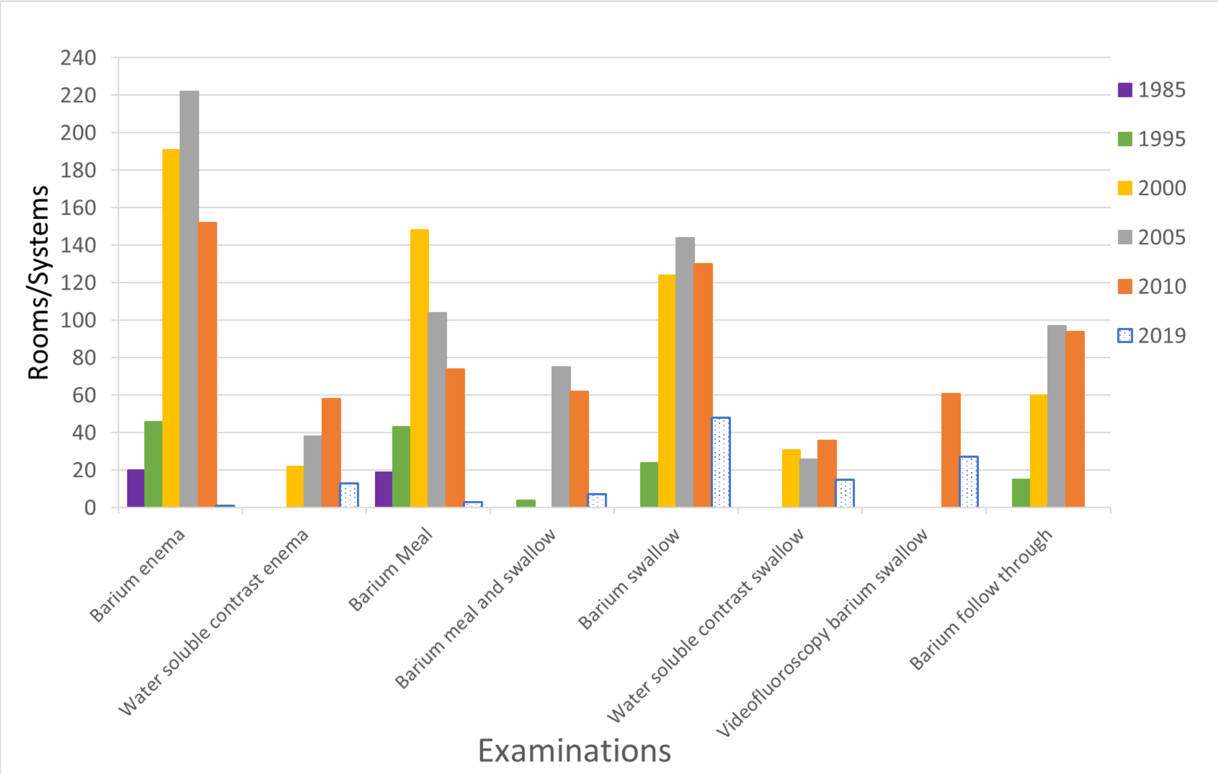


Figure G18. Trend in number of systems contributing DAP values for 4 fluoroscopy exams

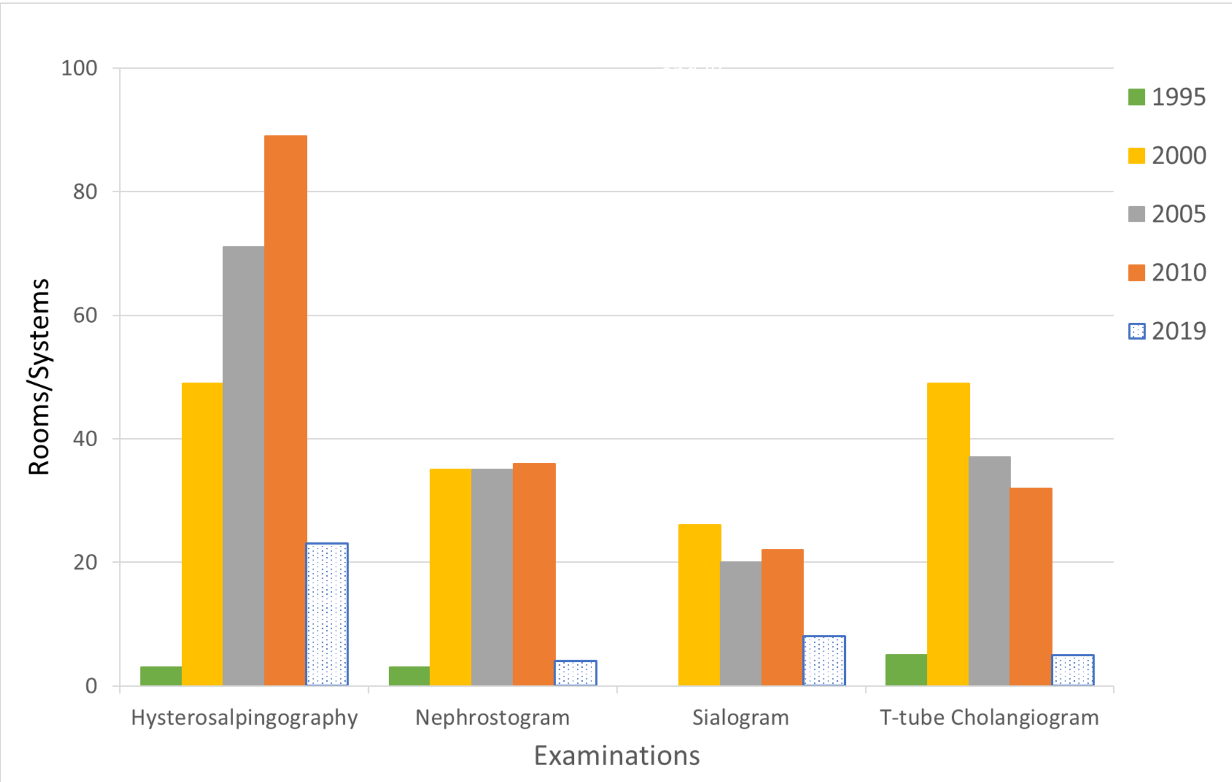


Figure G19. Trend in number of systems contributing DAP values for angiograms and IR

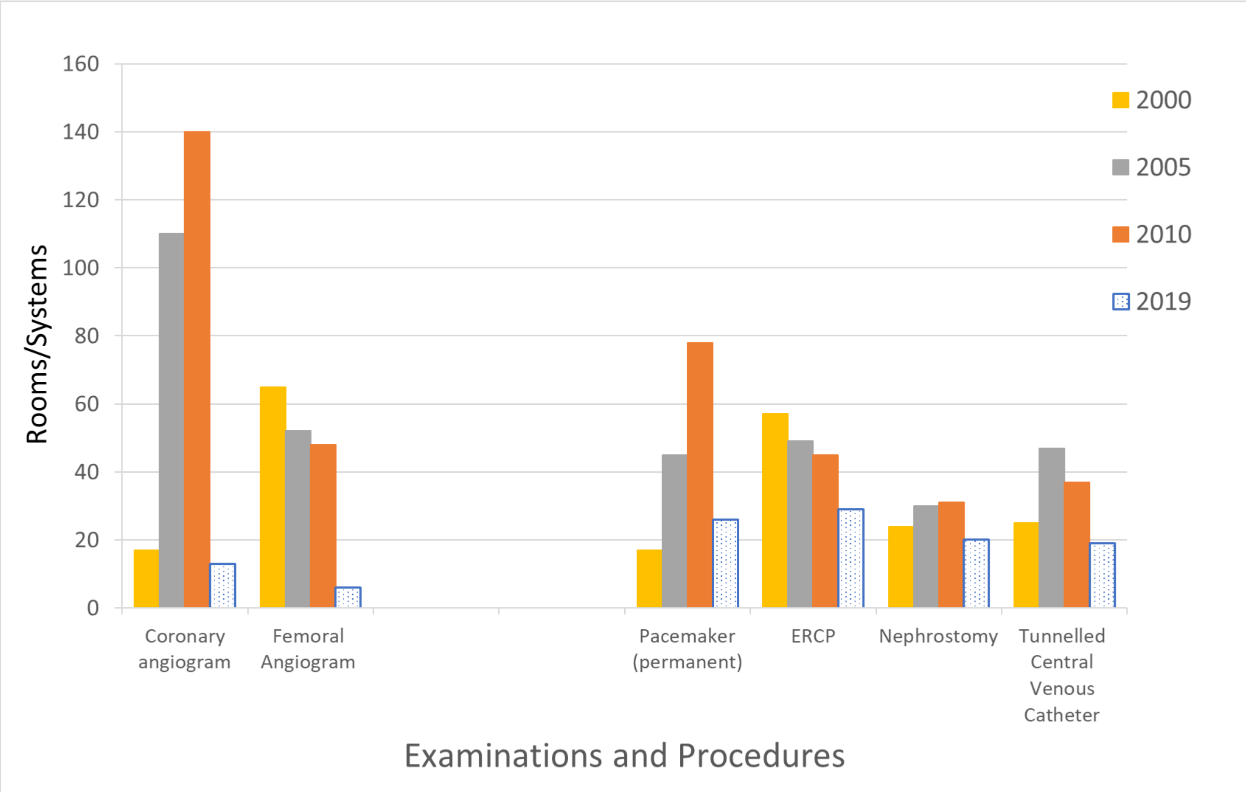


Figure G20. Trend in number of hospitals contributing DAP data for barium and water soluble contrast exams

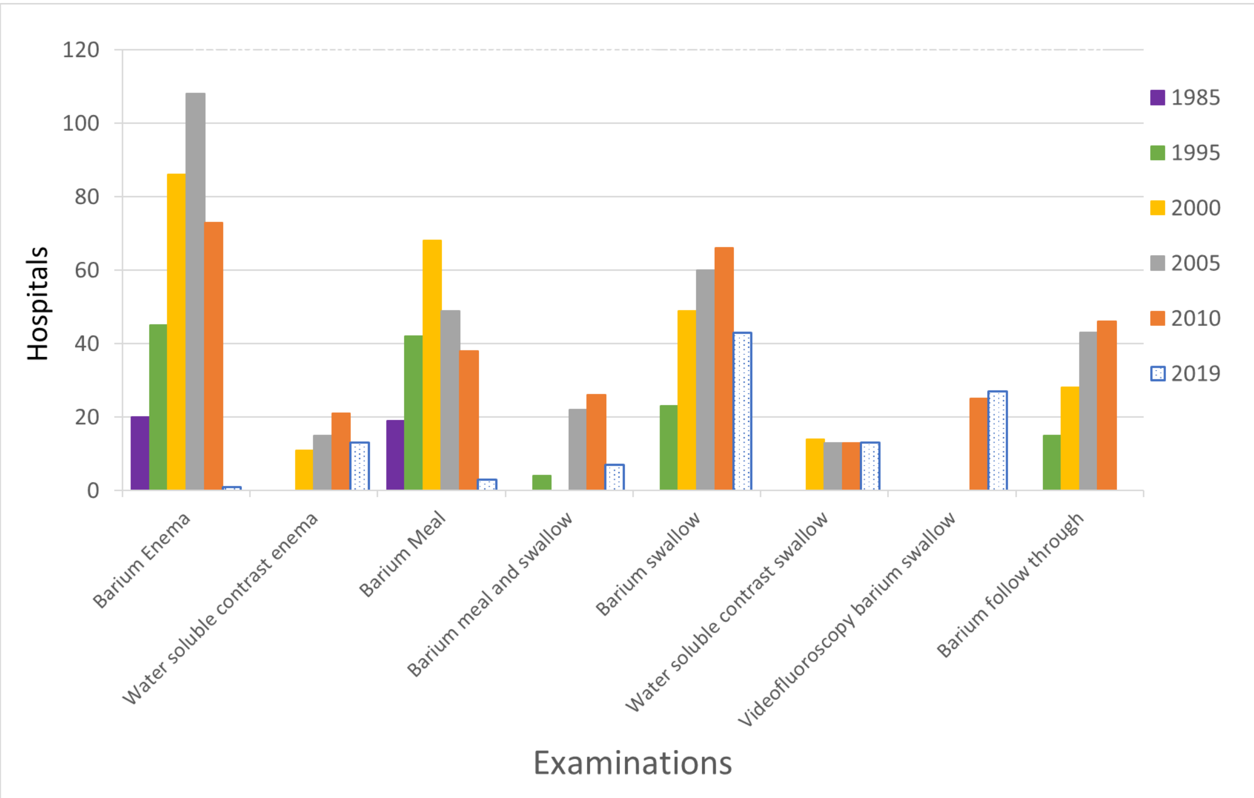


Figure G21. Trends in number of hospitals contributing DAP data for 4 fluoroscopy exams

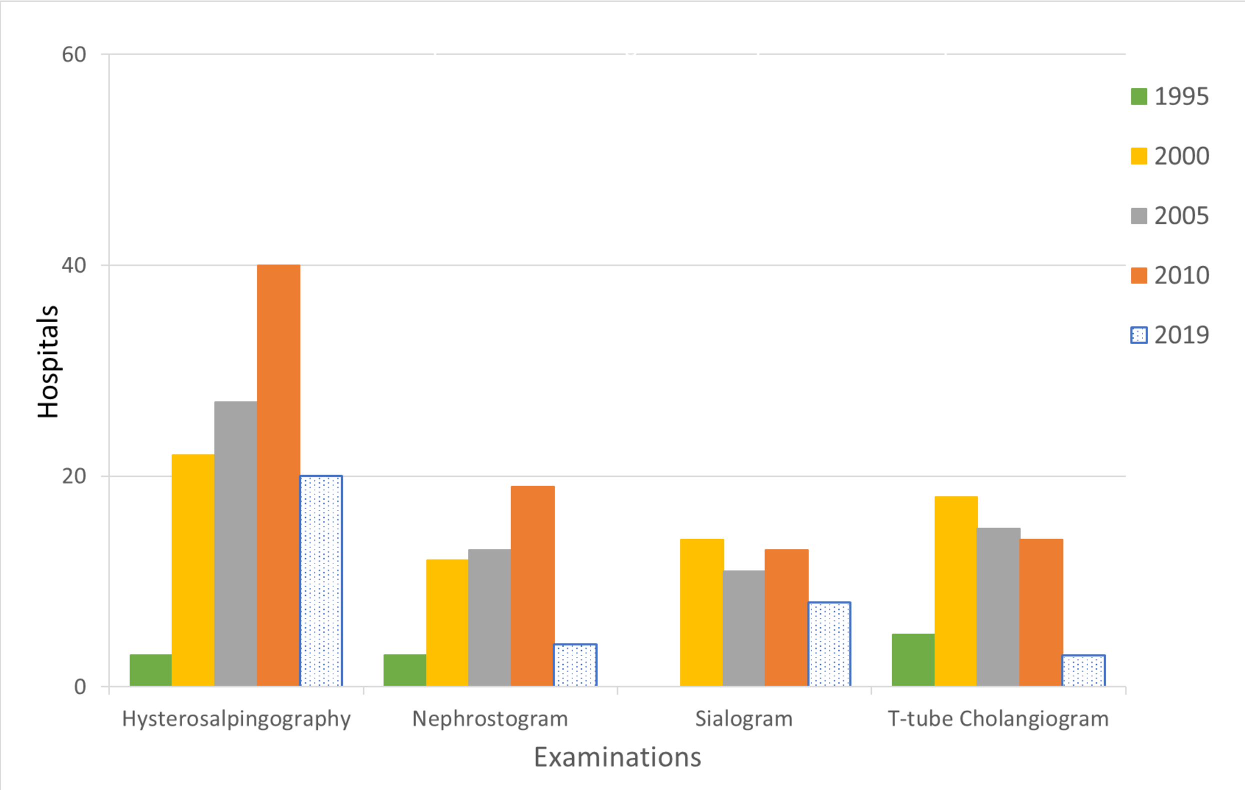
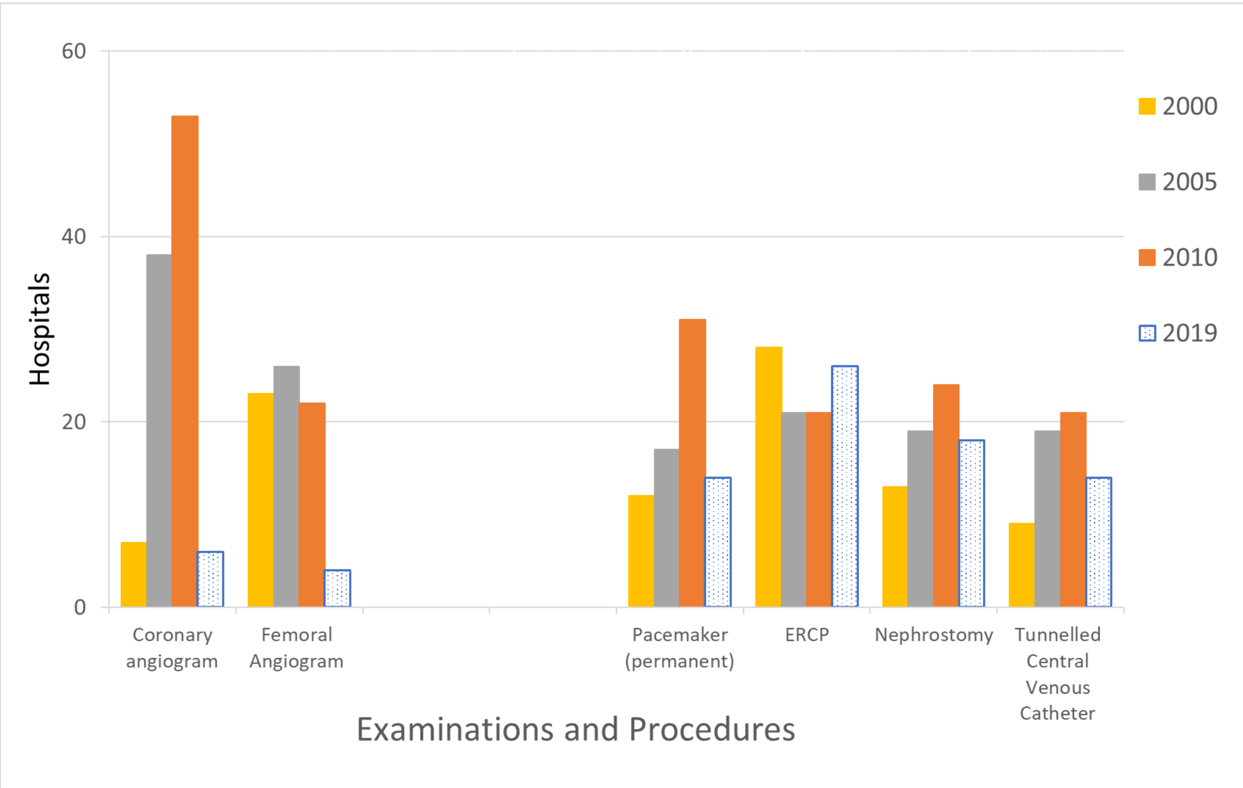


Figure G22. Trends in number of hospitals contributing DAP data for angiograms and IR



Appendix H: Use of median versus mean DAP

This report proposes NDRL values based on the third quartile of national distributions of system median DAP values (see Discussion chapter). This appendix shows how the change from using system mean dose index values to using system median dose index values for DRLs affects third quartile DAP value, for each named exam, on which the proposed UK NDRL values are based.

Plain radiography single projections

Table H1. Plain radiography single projections: comparison of 2019 survey third quartile values for system mean and system median DAP distributions

Radiography projection	Third quartile of system means, Gy.cm^2	Third quartile of system medians, Gy.cm^2	Third quartile median – mean %diff.
Abdomen AP	2.2	1.7	−21%
Cervical spine AP	0.11	0.096	−12%
Cervical spine LAT	0.13	0.11	−18%
Chest AP	0.11	0.092	−17%
Chest AP mobile	0.14	0.11	−19%
Chest PA	0.090	0.077	−14%
Chest LAT	0.39	0.34	−14%
Foot (single) DP	0.025	0.023	−8%
Hand (single) PA	0.024	0.022	−9%
Hip (single) horizontal beam LAT	2.0	1.6	−18%
Knee (single) AP	0.060	0.054	−10%
Knee (single) LAT	0.064	0.056	−13%
Lumbar spine AP	1.7	1.4	−20%
Lumbar spine LAT	2.6	2.1	−20%
Pelvis AP	1.9	1.6	−17%
Shoulder (single) AP	0.10	0.090	−11%
Thoracic spine AP	0.73	0.61	−17%
Thoracic spine LAT	1.4	0.95	−32%

Table H1 lists the third quartile values for system mean and system median DAP distributions for plain radiography single projections from the 2019 survey, and the percentage difference of those values.

All third quartile system median DAP values are lower than the third quartile system mean DAP values, with an average difference of -16%. The biggest percentage differences in mean and median values were for the projections for which the X-ray beam traversed the greatest depth or density of tissue, with the largest differences for thoracic spine lateral (−32%), abdomen AP (−21%), lumbar spine AP and lumbar spine lateral (both −20%). Conversely, the smallest differences were for extremities, notably foot DP (−8%) and hand PA (−9%).

Plain radiography examinations

Table H2 shows the difference in third quartile system mean and system median DAP values for plain radiography examinations. The third quartiles of the examinations' system median DAP distributions are all lower than the third quartiles of the exams' system mean DAP distributions. The average difference is −21%, compared to −16% for single projections. This is expected as the variation in projection combinations used for individual examinations combines with the variation in DAP of the component projections, causing additional diversity to the DAP distributions of examinations compared to single projections, and hence, usually, a larger difference between mean and median DAP values.

Table H2. Plain radiography examinations: comparison of 2019 survey third quartile values for system mean and system median DAP distributions

Plain radiography examinations	Third quartile of system means, $Gy.cm^2$	Third quartile of system medians $Gy.cm^2$	Third quartile median – mean %diff.
Abdomen	3.2	2.0	−36%
Cervical spine	0.31	0.24	−23%
Chest	0.15	0.12	−20%
Facial Bones	0.85	0.82	−3%
Foot	0.056	0.049	−13%
Hip	3.0	2.2	−27%
Knee	0.15	0.13	−13%
Lumbar spine	5.1	3.9	−22%
Pelvis	2.7	1.9	−32%
Shoulder	0.25	0.20	−22%
Thoracic spine	2.5	2.0	−21%

Plain radiography examinations generally had a comparable pattern of percentage differences between system mean and system median third quartile values to that of single projections, with abdomen (−36%) and pelvis (−32%) having the largest differences, and smaller differences for extremities (foot and knee, both −13%). However, the smallest difference was for facial bones examination (−3%).

Fluoroscopy examinations

Table H3 presents data for a limited number of fluoroscopy examinations, showing the difference of their third quartile system mean and system median DAP values. For the listed exams the average difference between the third quartile values of system mean distributions and system median distributions was approximately −20%. The largest difference is seen for WSC swallow (−48%), which arises from the unexpectedly high WSC swallow third quartile of system mean DAP values (10 $Gy.cm^2$), compared to the exam's much lower third quartile of system median values. It is notable that the third quartile values for the barium swallow and the WSC swallow system median distributions are close (5.0 and 5.3 $Gy.cm^2$ respectively), so this may be an example of median values being more typical of a sample than mean values.

Table H3. Fluoroscopy examinations: comparison of 2019 survey third quartile values for system mean and system median DAP distributions

Fluoroscopy examinations	Third quartile system means, $Gy.cm^2$	Third quartile system medians $Gy.cm^2$	Third quartile median – mean %diff.
Barium swallow	6.3	5.0	−21%
Water soluble contrast swallow	10	5.3	−48%
Videofluoroscopy barium swallow	1.5	1.2	−19%
Water soluble contrast enema	9.3	8.2	−11%
Hysterosalpingography	0.71	0.55	−22%

Interventional radiology procedures

For the IR procedures given in Table H4 all third quartile DAP values of the system median DAP distributions are lower than the third quartile values of the system mean DAP distributions. The average difference for these IR procedures is −44%, compared to the average difference for the plain radiography single projections of −16%. The larger difference between the mean and median third quartile values of IR procedures compared to plain radiography single projections is consistent with the more complex and variable nature of IR procedures compared to imaging a single projection.

Table H4. IR procedures: comparison of 2019 survey third quartile values for system mean and system median DAP distributions

Interventional radiology procedures	Third quartile system means $Gy.cm^2$	Third quartile system medians $Gy.cm^2$	Third quartile: median – mean %diff.
ERCP (diagnostic and interventional)	8.3	6.4	−23%
Pacemaker: permanent (single or dual chamber)	2.8	1.7	−40%
Insertion of tunnelled central venous catheter	1.0	0.65	−36%
PICC line insertion	0.52	0.31	−40%
Radiologically inserted gastrostomy tube	2.7	1.3	−53%
Nephrostomy	3.3	1.5	−56%
Nephrostomy tube replacement	1.3	0.52	−60%
Stent: ureteric (antegrade and retrograde)	5.0	3.0	−40%

Appendix I: Comparison of 2010 and 2019 survey data used for proposing NDRLs

This appendix compares the values from the 2010 and 2019 surveys used to propose NDRL values. For the 2010 survey (7), these were the recommended National Reference Dose (NRD) values, based on the third quartiles of the system mean DAP distributions. For the current, 2019 survey, they are the third quartiles of the system median DAP distributions, which are being proposed as revised NDRLs.

This 2019 survey report proposes NDRLs for some examinations for which NRDs were not recommended by the 2010 survey but for which substantial data was received. These examinations have also been included.

The mean DAP values of successive surveys are not directly comparable but can give some indication of trends. These differences arise due to the continual transition in the local method of collecting representative system exam data from small datasets to large data sets. In the first surveys the provision of data sets of small numbers of patients of appropriate weight predominated. In subsequent surveys, the submission of representative data sets based on larger patient samples without weight data has increased and dominates in the current survey.

Appendix G provides information on the percentage differences of 2010 and 2019 third quartile system mean DAP values, thus providing a like for like comparison of doses. Appendix H provides information on the percentage difference of 2019 survey third quartile system mean and median DAP values, thereby providing an indication of the effect of the move to using system median values.

Plain radiography single projections

For the plain radiography single projections shown in Table I1, the proposed NDRL values are, on average, approximately 30% lower than the NDRL values established from the 2010 survey (7).

Table I1. Single radiography projections: comparison of 2010 survey third quartile system mean DAP values to 2019 survey third quartile system mean and median DAP values

Plain radiography single projection	2010 survey	2019 survey	2019 survey	
	Third quartile system means, Gy.cm²	Third quartile system means, Gy.cm²	Third quartile system medians, Gy.cm²	% Difference [note 1]
	A [note 2]	B	C	C vs A
Abdomen AP	2.5	2.2	1.7	−30%
Cervical spine AP	0.15	0.11	0.096	−36%
Cervical spine LAT	0.15	0.13	0.11	−29%
Chest AP [note 3]	0.15	0.11	0.092	−39%
Chest AP mobile [note 3]	0.15	0.14	0.11	−26%
Chest PA	0.10	0.09	0.077	−23%
Lumbar spine AP	1.5	1.7	1.4	−10%
Lumbar spine LAT	2.5	2.6	2.1	−17%
Pelvis AP	2.2	1.9	1.6	−28%
Thoracic spine AP	1.0	0.73	0.61	−39%
Thoracic spine LAT	1.5	1.4	0.95	−37%

1. 2019 third quartile median values minus 2010 third quartile mean values as per cent of 2010 third quartile mean values, (100 × (C-A)/A).
2. 2010 recommended National Reference Doses, adopted as NDRLs based on third quartile values taken from HPA-CRCE-034 (7).
3. The 2010 survey did not differentiate between Chest AP and Chest AP mobile projections.

Plain radiography examinations

Table I2 shows the change in values from 2010 survey third quartile system mean DAP values to 2019 system median DAP values for plain radiography examinations. Entries are given for the 3 plain radiography examinations for which the 2010 survey review recommended NRDs. These values were adopted as NDRLs. The 3 additional plain radiography examinations that are included in Table I2 were featured in the 2010 report's Table 14 'Summary of data on other examinations and interventional procedures (adults)' (7).

Table I2. Plain radiography examinations: comparison of 2010 survey third quartile system mean DAP values to 2019 survey third quartile system mean and median DAP values

Plain radiography examinations	2010 survey	2019 survey	2019 survey	
	Third quartile system means, Gy.cm^2	Third quartile system means, Gy.cm^2	Third quartile system medians Gy.cm^2	% Difference [note 1]
	A	B	C	C vs A
Abdomen [note 2]	4.4	3.2	2.0	−54%
Chest [note 2]	0.3	0.15	0.12	−59%
Lumbar spine [note 2]	6	5.1	3.9	−34%
Hip [note 3]	4.7	3.0	2.2	−53%
Pelvis [note 3]	4.3	2.7	1.9	−57%
Thoracic spine [note 3]	4.4	2.5	2.0	−55%

1. 2019 third quartile median values minus 2010 third quartile mean values as per cent of 2010 third quartile mean values, (100 × (C-A)/A).
2. 2010 recommended National Reference Doses, adopted as NDRLs, based on third quartile values taken from HPA-CRCE-034 (7).
3. 2010 third quartile system mean values for additional plain radiography examinations included in Table 14 of HPA-CRCE-034 (7).

With the exception of lumbar spine, the 2019 survey proposed NDRL values are all of the order of 50% lower than the examinations' 2010 third quartile system mean values. The smaller decrease of −34% for lumbar spine is in line with smaller than average decreases seen for the plain radiography single projections lumbar spine AP and lateral given in Table I1.

Fluoroscopy examinations

Table I3 presents data for a limited number of fluoroscopy examinations showing the change of DAP for examinations between the 2010 and 2019 surveys and the effect of the move to NDRL values based on system median DAP distributions. All exams experienced an overall decrease in proposed NDRL value, averaging −45%, but ranging between −17% and −70%.

Table I3. Fluoroscopy examinations: comparison of 2010 survey third quartile system mean DAP values to 2019 survey third quartile system mean and median DAP values

Fluoroscopy examinations	2010 survey	2019 survey	2019 survey	
	Third quartile system means, Gy.cm2	Third quartile system means, Gy.cm2	Third quartile system medians Gy.cm2	% Difference [note 1]
	A	B	C	C vs A
Barium swallow [note 2]	7.5	6.3	5.0	−33%
Videofluoroscopy barium swallow [note 2]	3.4	1.5	1.2	−65%
Hysterosalpingography [note 2]	1.9	0.71	0.55	−71%
Water soluble contrast enema [note 3]	13	9.3	8.2	−37%
Water soluble contrast swallow [note 3]	6.4	10	5.3	−17%

1. 2019 third quartile median values minus 2010 third quartile mean values as per cent of 2010 third quartile mean values, (100 × (C-A)/A).
2. 2010 recommended National Reference Doses, adopted as NDRLs, based on third quartile values taken from HPA-CRCE-034 (7).
3. 2010 third quartile system mean values specific to these water soluble contrast examinations from Table 8 of HPA-CRCE-034 (7) rather than the recommended NDR based on both barium and water soluble examinations.

In Table I3, the 2010 survey third quartile system mean values given for 2 water soluble contrast (WSC) exams, WSC swallow and WSC enema, are the values that the 2010 survey assessed for those specific examinations (Table 8 of HPA-CRCE-034 (7)) and not the notably higher 2010 NDRL values which were to be used for both them and their barium exam equivalents (7.5 Gy.cm^2 for barium or WCS Swallow and 21 Gy.cm^2 for barium or WCS enema).

WSC swallow is the only fluoroscopy examination for which the 2019 survey third quartile of the system mean distribution is higher than the 2010 value. This is discussed in Appendix G.

Interventional radiology procedures

The IR procedures presented in Table I4 all exhibit large decreases in the third quartiles of system DAP distributions between the 2010 and 2019 surveys. The average decrease in DAP values between the 2010 survey third quartile system mean DAP and the 2019 survey third quartile system median DAP values is 75%. The significant decrease in third quartile system mean DAP values between the 2010 and 2019 surveys indicates a strong trend in the improvement of patient dose exposure, optimisation, and technical expertise in performing the procedures.

Table I4. IR procedures: comparison of 2010 survey third quartile system mean DAP values to 2019 survey third quartile system mean and median DAP values

Interventional radiology procedures	2010 survey	2019 survey	2019 survey	
	Third quartile system means, Gy.cm2	Third quartile system means, Gy.cm2	Third quartile system medians Gy.cm2	% Difference [note 1]
	A	B	C	C vs A
Insertion of tunnelled central venous catheter [notes 2 and 3]	3	1.0	0.65	−78%
Nephrostomy [note 2]	13	3.3	1.5	−89%
Pacemaker: permanent (single or dual chamber) [note 2]	7	2.8	1.7	−76%
ERCP (Diagnostic and Interventional) [note 4]	11	8.3	6.4	−44%
Radiologically Inserted gastrostomy tube [note 4]	13	2.7	1.3	−90%
Stent: ureteric (antegrade and retrograde) [note 4]	16	5.0	3.0	−81%

1. 2019 third quartile median values minus 2010 third quartile mean values as per cent of 2010 third quartile mean values, (100 × (C-A)/A).
2. 2010 recommended National Reference Doses, adopted as NDRLs, based on third quartile values taken from HPA-CRCE-034 (7).
3. A broadened procedure definition, which includes the previously reported Hickman Line procedure.
4. 2010 third quartile system mean values for additional plain radiography examinations included in Table 14 of HPA-CRCE-034 (7).

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Prepared by: JRH Smith, MC Hillier, J Holroyd and S Edyvean
For queries relating to this document, please contact: medicalradiationdoses@UKHSA.gov.uk

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