DRLs in Action – UK Experience

ICTP-IAEA Workshop on Establishment and Utilization of Diagnostic Reference Levels in Medical Imaging Imaging (smr3333):
18-22 November 2019 **Trieste, Italy**

Sue Edyvean

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Learning Points

- History of UK National Dose Audits
- Context of DRLs in legislation and influence on UK medical radiation culture
- Trends of national DRLs – influence of technology
- Current status of UK with respect to national dose audits

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Long history of monitoring patient dose in UK

1957

JUNE 1957

COMMITTEE ON RADIOLOGICAL HAZARDS TO PATIENTS

By LORD ADRIAN

A Committee was set up last year by the Secretary of State for Scotland and the Minister of Health to review the present practice in diagnostic radiology and the radiotherapy of non-malignant conditions, with the object of considering the hazards involved.

This review was recommended by the Medical Research Council in their report on "The Hazard to Man of Nuclear and Allied Radiations", for they found that medical radiology is in fact the chief source of the extra radiation to which we are now exposed. They emphasised the genetic damage which might be caused by irradiation of the gonads and it is this damage with which our Committee is chiefly concerned. Its importance is difficult to assess but it means that we must not neglect even very small sources of radiation.

Since I fear that our enquiries are bound to add to the work of busy people I hope you will allow me to describe the investigations which we have in mind. Our first requirement is a more accurate estimate of

physicists to make a detailed investigation in a sample group of about 100 hospitals. This will enlarge the excellent surveys which have been carried out already in particular departments, and when it is finished we shall have a figure for the total gonadal radiation in this country which should be at least more accurate than any former estimates, here or elsewhere.

We are told that any exposure of the gonads may induce some mutations and that all mutations are more likely to be harmful than beneficial. But medical radiology must not be unduly hampered; the possible harm to the race must be set against the certain benefit to the individual. We must aim,

Adrian L. Committee on Radiological Hazards to Patients. The British Journal of Radiology. 1957;30(354):285-.

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Long history of monitoring patient dose in UK

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JUNE 1957

COMMITTEE ON RADIOLOGICAL HAZARDS TO PATIENTS

We have already sent out detailed questionnaires to make a census of all medical and dental procedures involving X rays and radioactive substances, and a similar more limited enquiry will be made six months hence to take care of any seasonal fluctuations which might affect the result. To measure the probable dose to the gonads in different radiological procedures we are asking a number of hospital physicists to make a detailed investigation in a sample group of about 100 hospitals. This will enlarge the excellent surveys which have been carried out already in particular depa when it is finished we shall have a fig gonadal radiation in this country whi least more accurate than any former or elsewhere

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Medical Dosimetry Group

- Centre for Radiation Chemicals and Environmental Hazards (CRCE)
- Public Health England
- Harwell, Oxfordshire, UK

Harwell Nuclear Reactors (de-comm.)

Diamond Light source

European Space Laboratory (new build)

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National Patient Dose Audits

- Medical Dosimetry Group
  - Working in the area of patient doses in diagnostic imaging for nearly 50 years
  - One function is to undertake national reviews of patient doses for medical and dental X-ray procedures in the UK

NRPB **1971**

HPA **2005**

PHE **2013**

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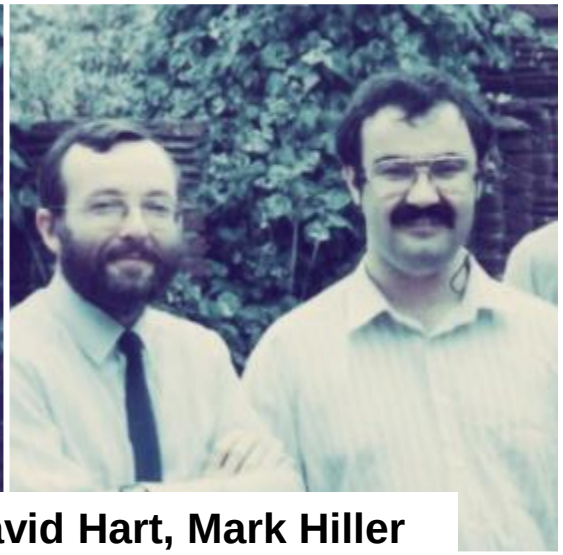
National Patient Dose Audits

- Medical Dosimetry Group
  - Working g for nearly 5
  - One fun doses fo



Barry Wall, Paul Shrimpton, David Hart, Mark Hiller

NRPB 1971

HPA 2005

PHE 2013

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National Patient Dose Audits

- General X-ray, fluoroscopy, Dental

- CT Scanning

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UK National Patient Dose Audits

NRPB

HPA

Conventional X-ray and Fluoroscopy

PHE

1st X-ray survey 1983

Review Review Review Review

National Patient Dose Database (excl CT)

1985 1990 1995 2000 2005 2010 2015

CT CT CT

1st CT survey 1989

2nd CT survey 2003

3rd CT survey 2011 (Published Sept 1st 2014)

Computed Tomography

The British Journal of Radiology, 76 (2003), 361–365
DOI: 10.1259/bjr/18536168

Commentary

The UK National Patient Dose Database: now and in the future

D HART, PhD and B F WALL, BSc

National Radiological Protection Board, Chilton, Didcot, Oxon OX11 0RQ, UK

After the publication of a *National Protocol for Patient Dose Measurements in Diagnostic Radiology* [1] in 1992, NRPB established a National Patient Dose Database (NPDD) to collate measurements of radiation doses to patients from routine X-ray examinations in hospitals throughout the UK. The purpose of the NPDD was to monitor trends in patient doses and to update and extend the national reference doses recommended in the National Protocol. More recently it has provided essential data for an estimate of the UK population dose from medical X-ray examinations [2], and for establishing diagnostic reference levels (DRLs) as required by British legislation [3]. A first review of data collected up to the end of 1995 was published in 1996 as an NRPB report [4]. A second review covering the subsequent 5-year period from January 1996 to December 2000 was published in 2002 [5]. This article summarizes the findings of the second review, and provides guidance on the information needed for subsequent reviews.

under-weight. All doses measured on children were accepted if there was also sufficient information on their size, *e.g.* height and weight, to allow the doses to be adjusted to those for standard sized children according to the methods published by NRPB in 2000 [6].

Results from the current review indicate a continuing downward trend in doses to adults. Generally, there has been a reduction since the 1995 review of about 16% in the mean dose for common radiographs and examinations.

The main purpose for the NPDD has become the provision of national reference doses for common X-ray examinations, based on the rounded third quartile of room mean doses. The latest reference doses are approximately half the size of those established in the mid-1980s that are quoted in the National Protocol [1], and are about 20% lower than those derived from the first review. As well as revising existing reference doses, the second review has made full use of the increased quantity of data by recommending additional national reference doses. For

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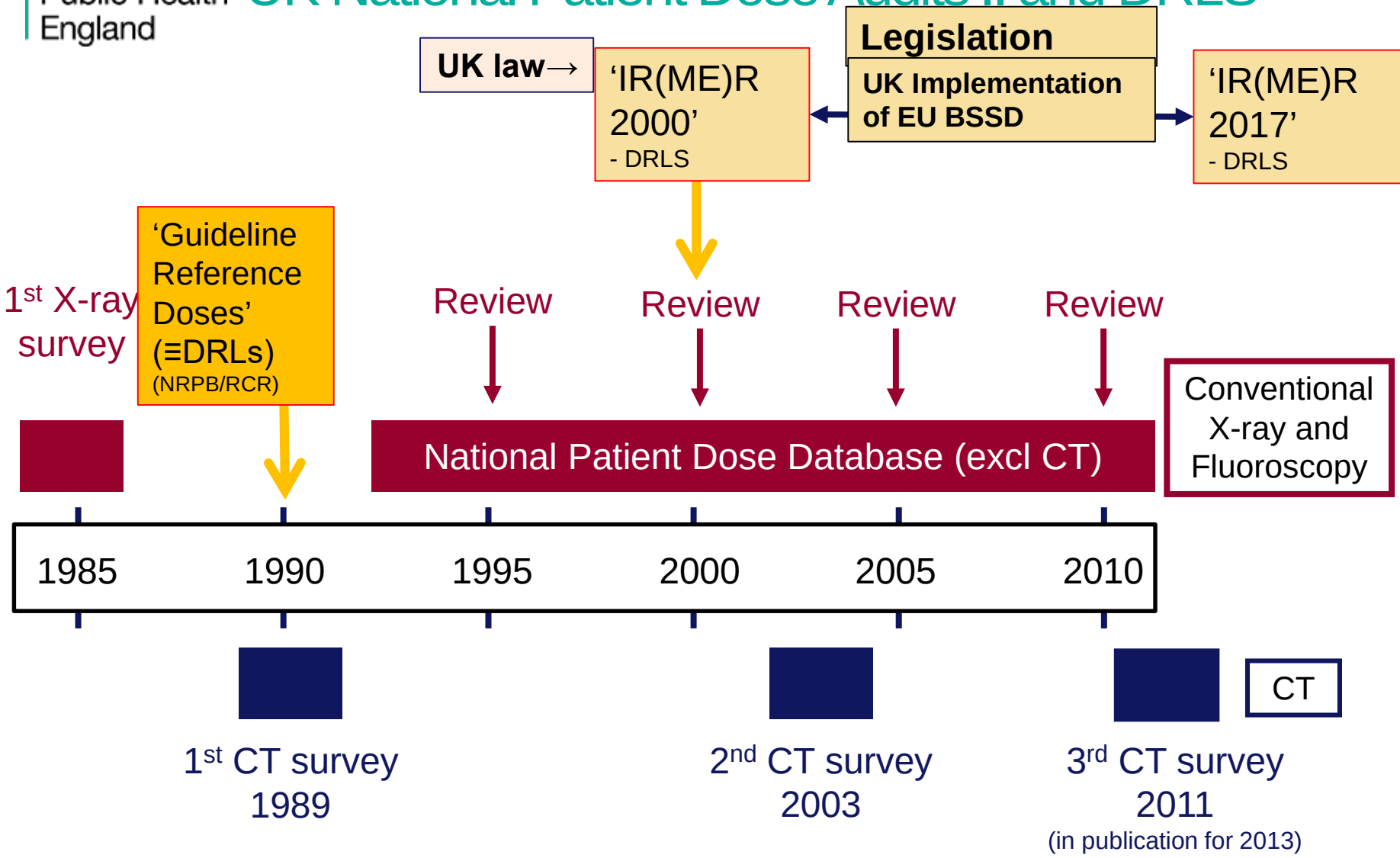
UK National Patient Dose Audits .. and DRLS



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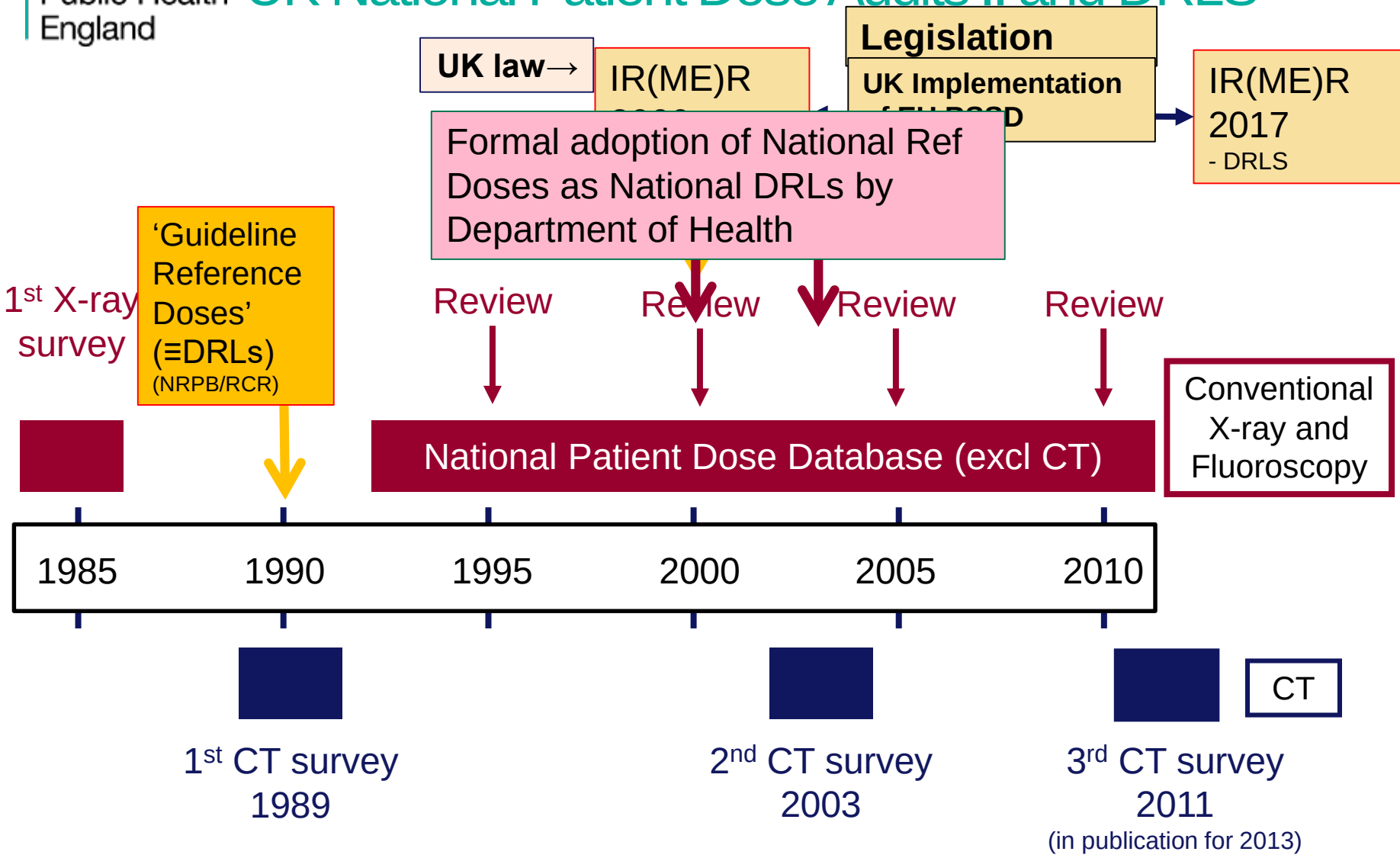
UK National Patient Dose Audits .. and DRLS



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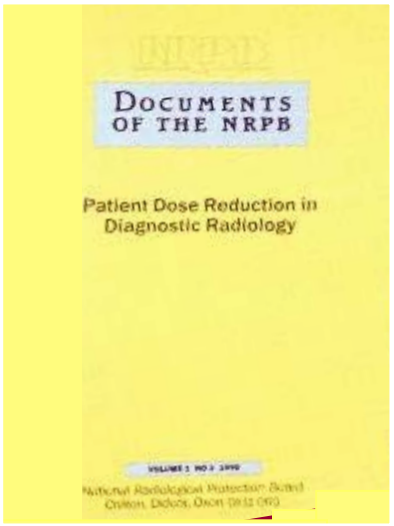
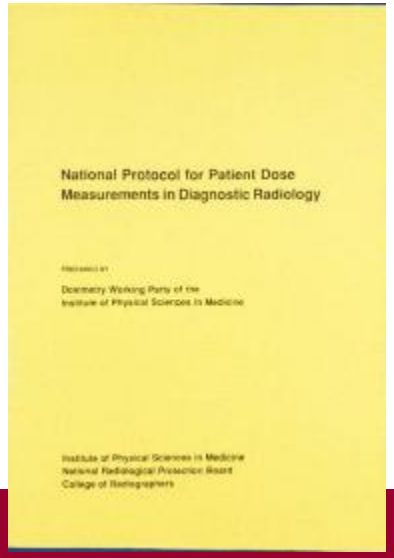
National Dose Audits and DRLs

- Various working parties produced guidance on data to be submitted to national surveys – involving medical physics, radiographer and radiologist professional body representatives
- And how DRLs were to be used in response to the UK ionising radiation in medicine (IRMER 2000) regulations

1990



1992



2004

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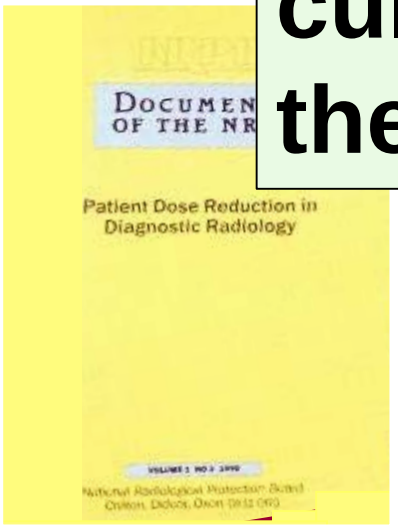
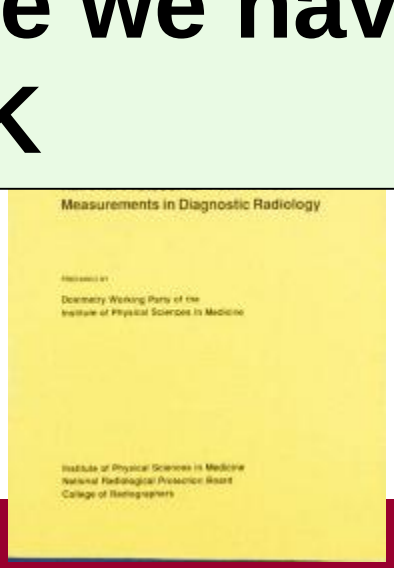
National Dose Audits and DRLs

- Various working parties produced guidance on data to be submitted to national surveys – involving medical physics, radiographer and radiologist professional body representatives
- And how I[illegible]K ionising radiation i[illegible]

Set the scene for the radiation protection culture we have today in the UK

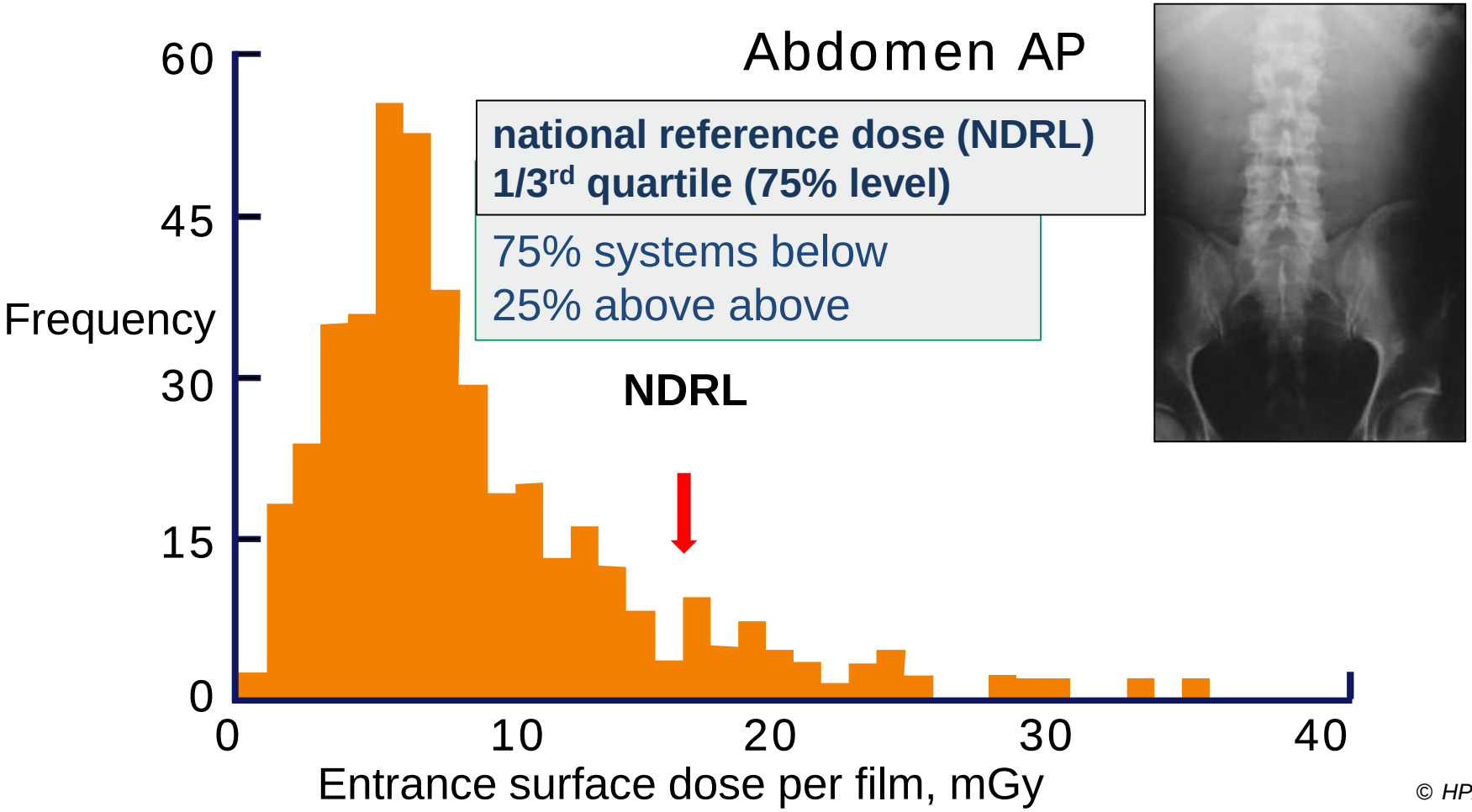
1990





National Reference Dose – National DRL

Early NRPB Patient Dose Survey (England)



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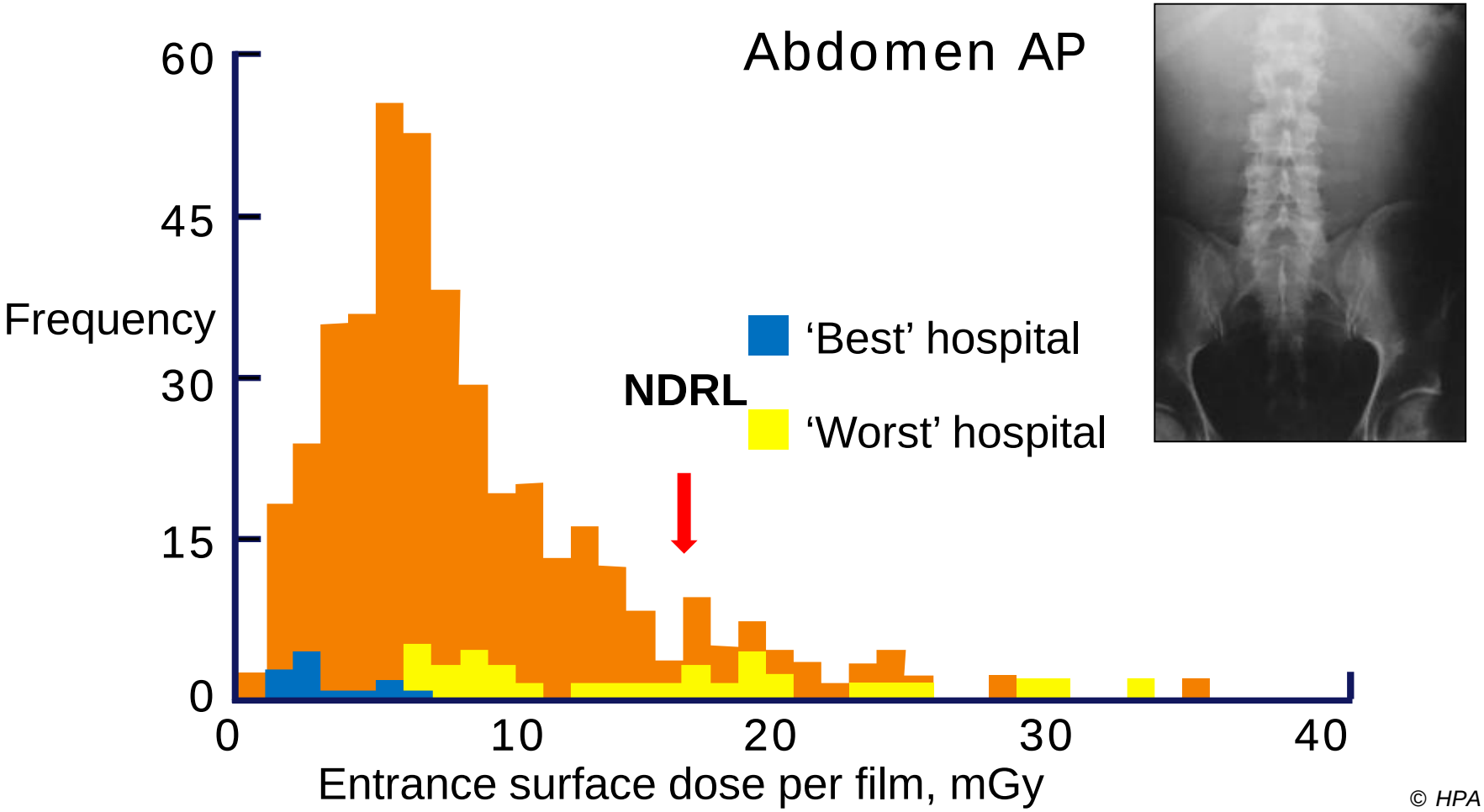

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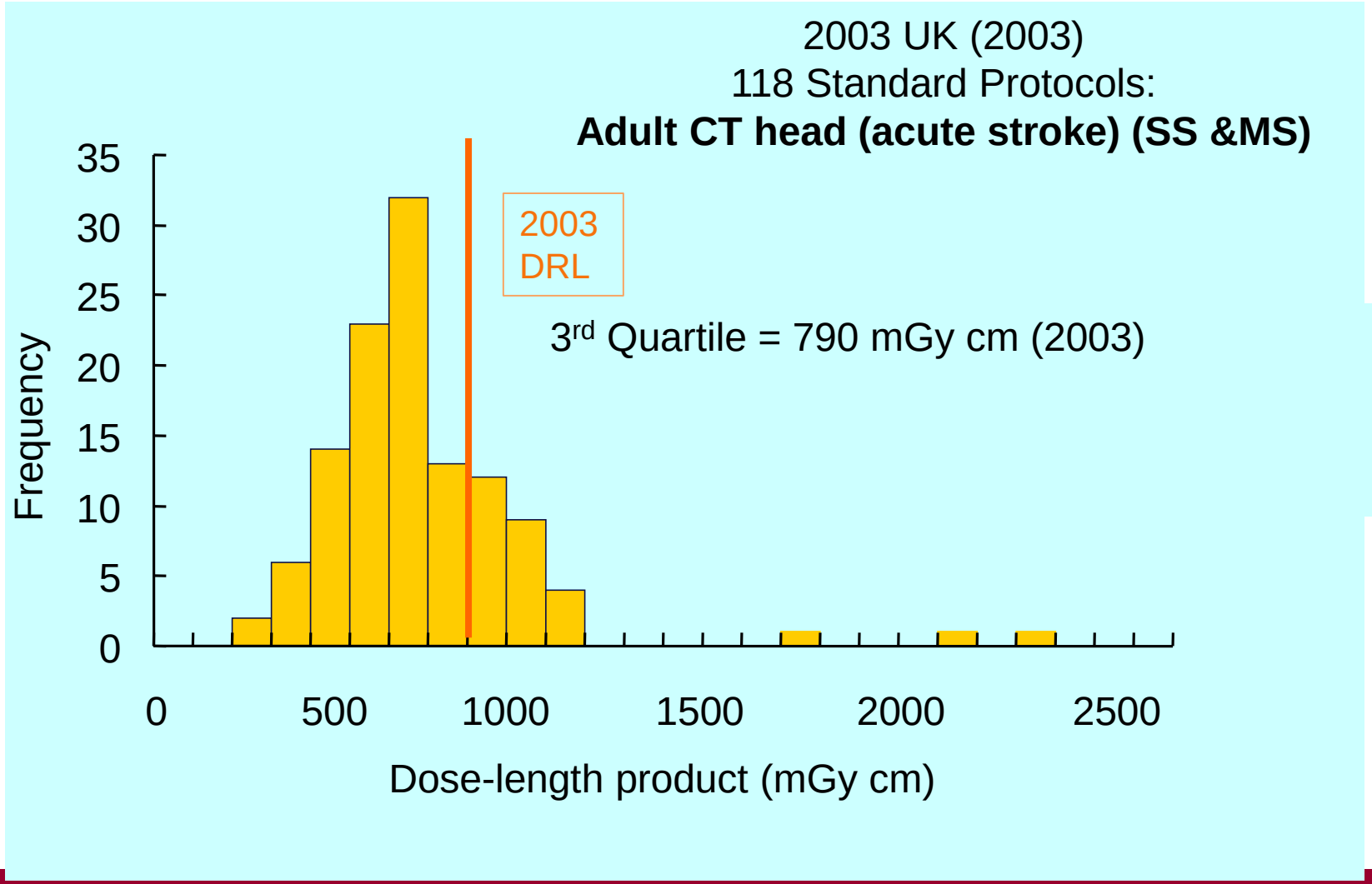
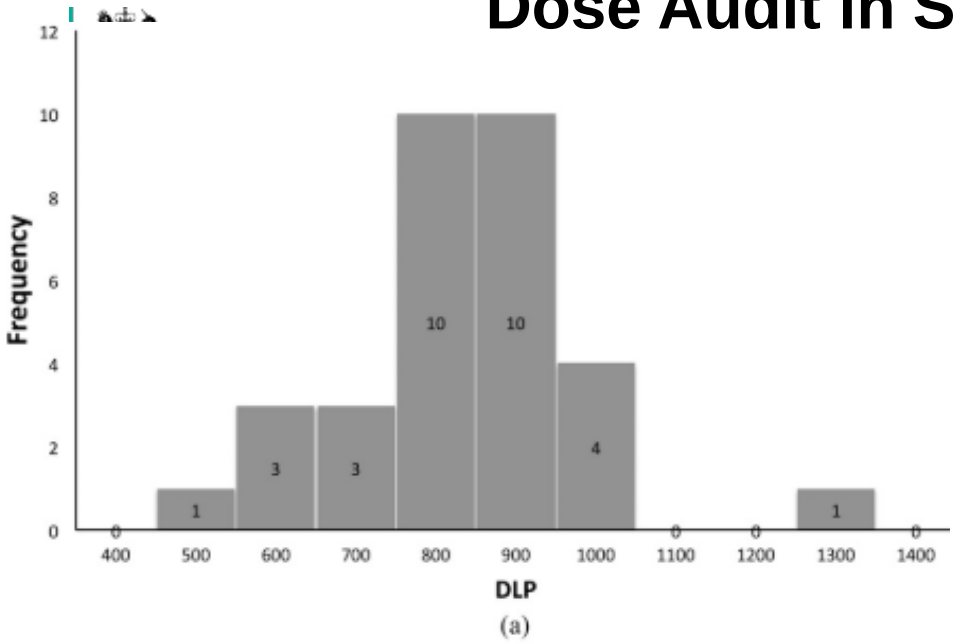
National Reference Doses/NDRLs



Dose Audit in Scotland 2014 - CT



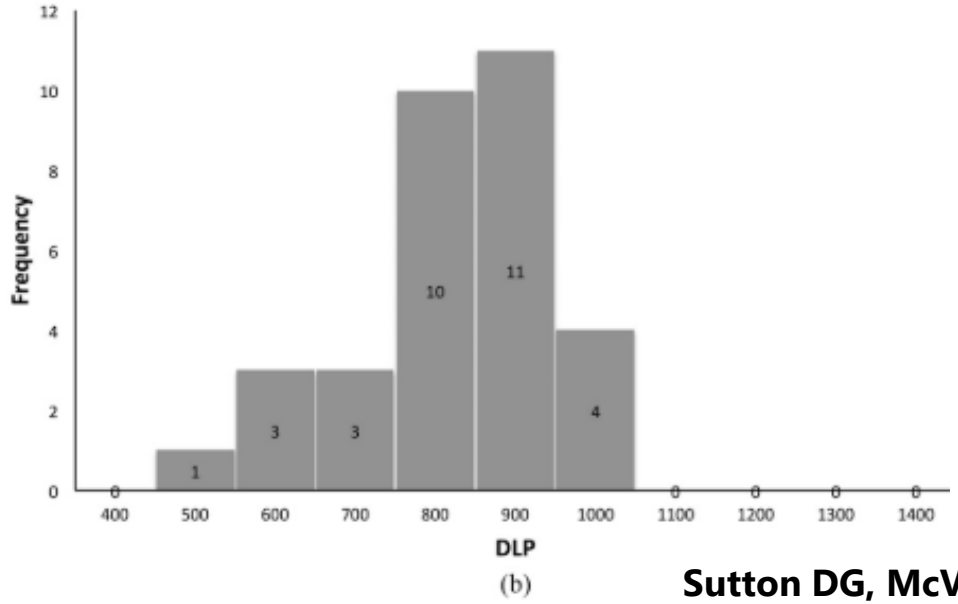


Figure 3.

(a) Distribution of mean dose–length product (DLP) before re-audit of scanner. Numbers in bars indicate the number of scanners in each bin.
- Mean DLP is 780mGycm;
- median DLP, 790mGy cm;
- third quartile DLP, 837 mGy cm.

(b) Distribution of mean DLP following re-audit of scanner 3. Numbers in bars indicate the number of scanners in each bin.
- Mean DLP is 770 mGy cm;
- median DLP, 790 mGycm;
- third quartile DLP, 837 mGycm.

Sutton DG, McVey S, Gentle D, Hince AJ, MacDonald N, McCallum S. CT chest abdomen pelvis doses in Scotland: has the DRL had its day? Br J Radiol. 2014;87(1041):20140157.

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Awareness and Optimisation

The application of DRLs, as an essential element within a coherent framework for managing patient dose, has undoubtedly helped both to

- raise awareness of levels of dose in routine practice and also
- to promote and facilitate improvements towards optimization

Chapter 3: Dose Assessment in the Management of Patient Protection in Diagnostic and Interventional Radiology
Paul C. Shrimpton and Kwan-Hoong Ng

L. Lau and K.-H. Ng (eds.), Radiological Safety and Quality: Paradigms in Leadership and Innovation, DOI 10.1007/978-94-007-7256-4_3,

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IRMER 2017 (UK Implementation of EU BSSD)

(Similar wording to IRMER 2000)

Employer's duties: establishment of general procedures, protocols and quality assurance programmes

Regulation (6) 5 (c): (paraphrased)

hospital ***~ radiographer***

The employer needs to 'regularly review and make available to the operator' DRLs in respect of exposures for

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Diagnostic and interventional procedures using ionising radiation - where appropriate and practical

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^*With regard to National or European Levels – where available*

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Diagnostic and interventional procedures using ionising radiation - where appropriate and practical

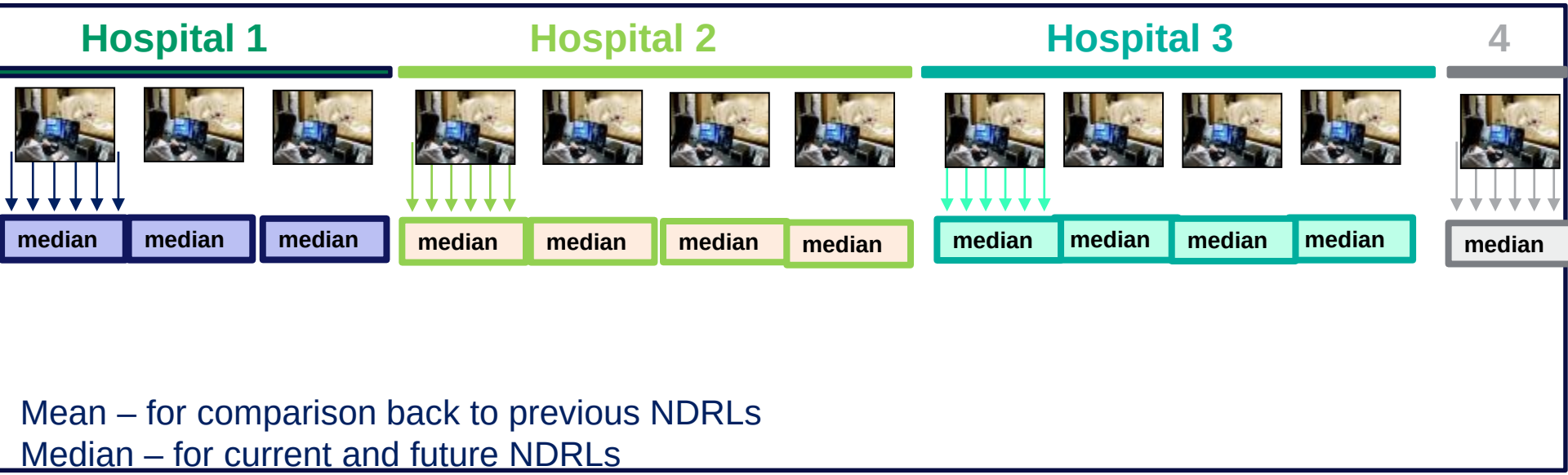
Regulators check that they are set and how they use them

^ *With regard to National or European Levels – where available*

Dose Audits for DRLs - National

- Dose indicator (e.g. DAP,ESD (x-ray) or CTDI,DLP (CT))
  - Sample of standard size/weight patients
  - common examinations (e.g. chest CT) or high dose

- Calculate the (mean and) median value for each x-ray system, each exam

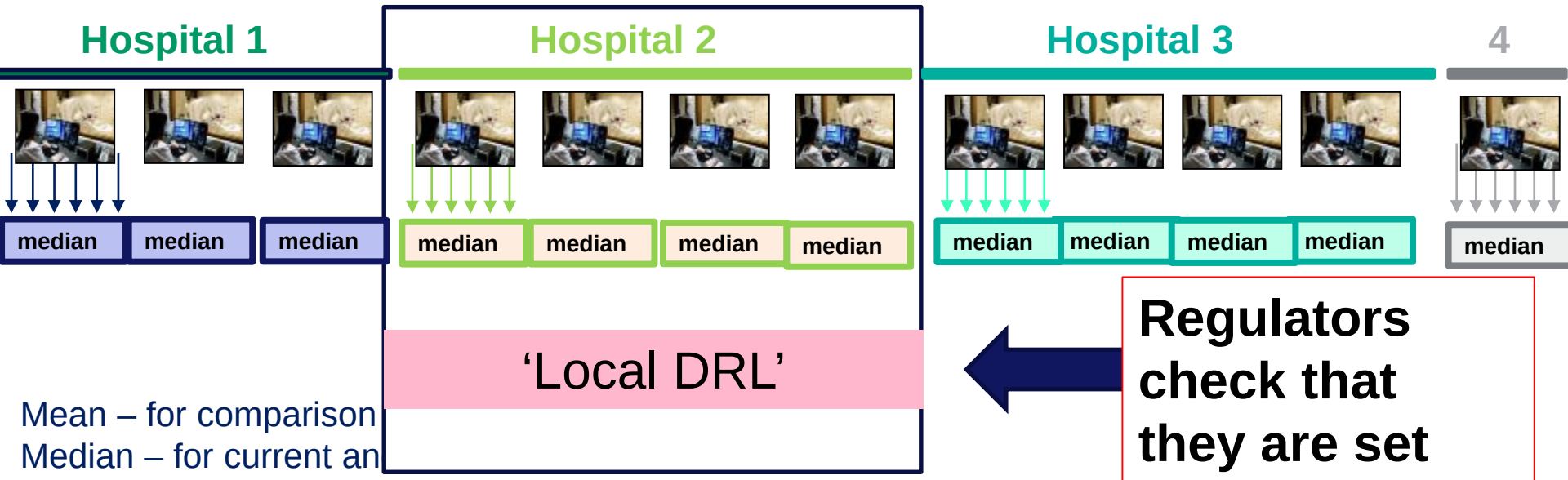


Mean – for comparison back to previous NDRLs
Median – for current and future NDRLs

Dose Audits for DRLs - Locally

- Dose indicator (e.g. DAP,ESD or CTDI,DLP)
  - Sample of standard size/weight patients
  - common examinations (e.g. chest CT) or high dose

- Calculate the (mean and) median value for each x-ray system, each exam



Dose Audits for DRLs - Nationally

- Dose indicator (e.g. DAP,ESD or CTDI,DLP)
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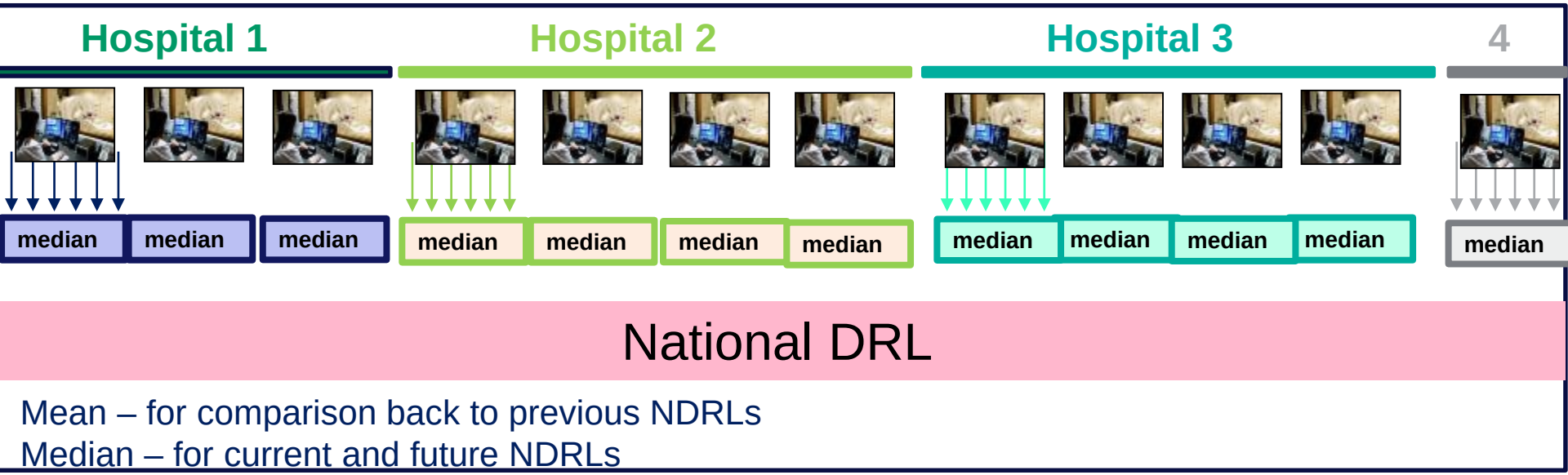

Mean – for comparison back to previous NDRLs
Median – for current and future NDRLs

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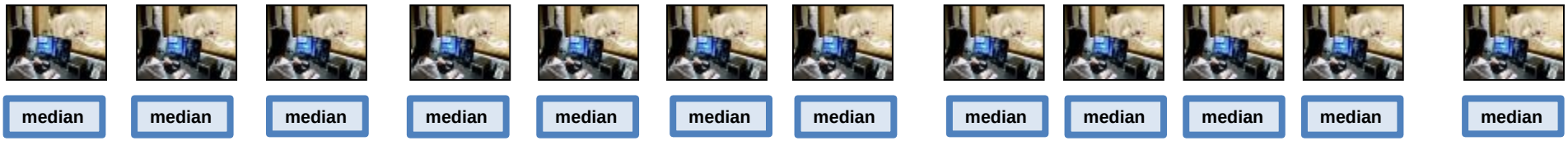
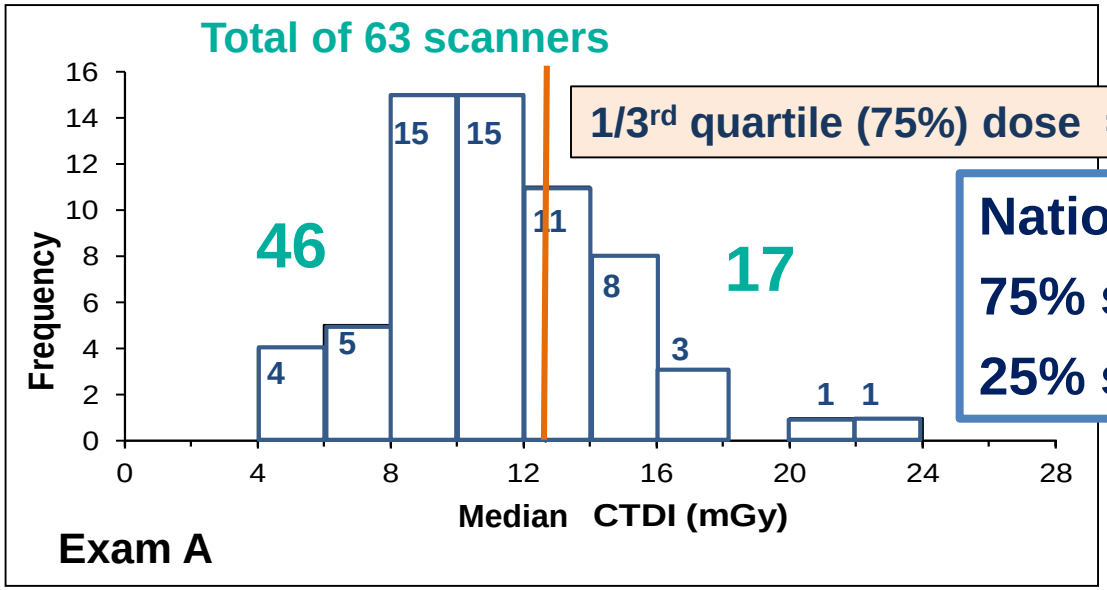
National DRLS

- Look at the distribution of doses (median/mean) from all systems
- Find a dose value – where 75% of systems are below that value





1/3rd quartile (75%) dose = NDRL

National DRL(dose):

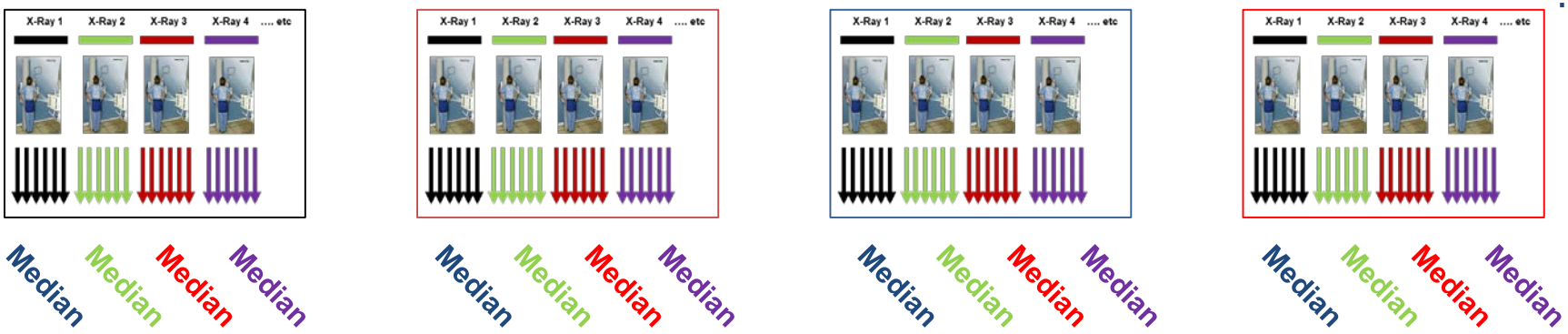
75% scanners below

25% scanners above

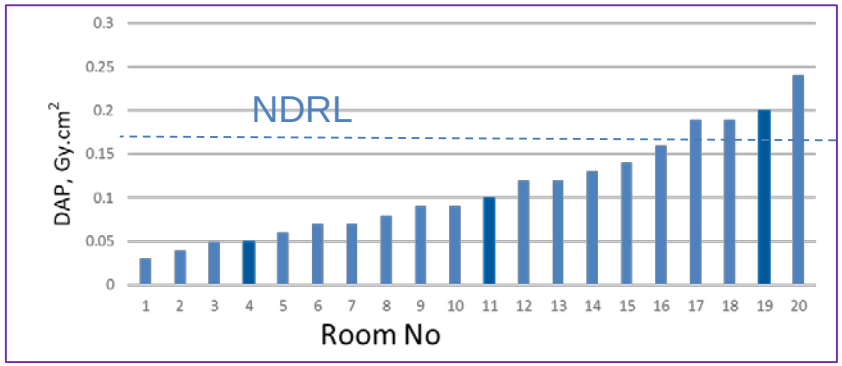
National DRLs

- **Dose index measured for each patient; median for each system obtained:**

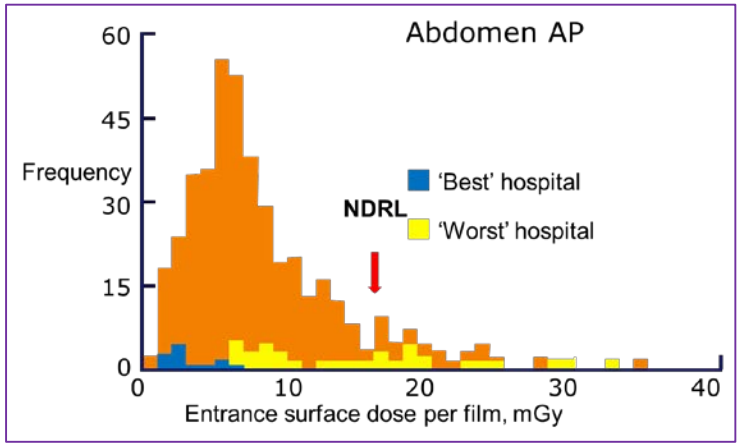
Hospital 1 **Hospital 2** **Hospital 3** **Hospital 4** **etc. etc. ……**



- **Show data in two ways (DRL shown in each case – 3rd quartile):**



a) Room versus increasing dose index (DAP in this example)



b) No. of rooms for a given dose index bin (ESD in this example)

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Patient dose survey and optimisation

Review again in 3 years time

Collect data on DRL quantities for patients 60-80 kg

Calculate median dose for exam

Compare median dose with DRL value

< DRL value

> DRL value

Review technique, exposure settings and equipment performance results

Recommend optimisation strategy and work with radiographers to implement changes

ICRP 135, Martin 2016

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- Public Health England – Executive Agency of Department of Health and Social Care
- Providing Scientific Advice to Government
- Public Health England – covers UK for radiation matters
  - i.e. England, Scotland, Wales, Northern Ireland

United Kingdom

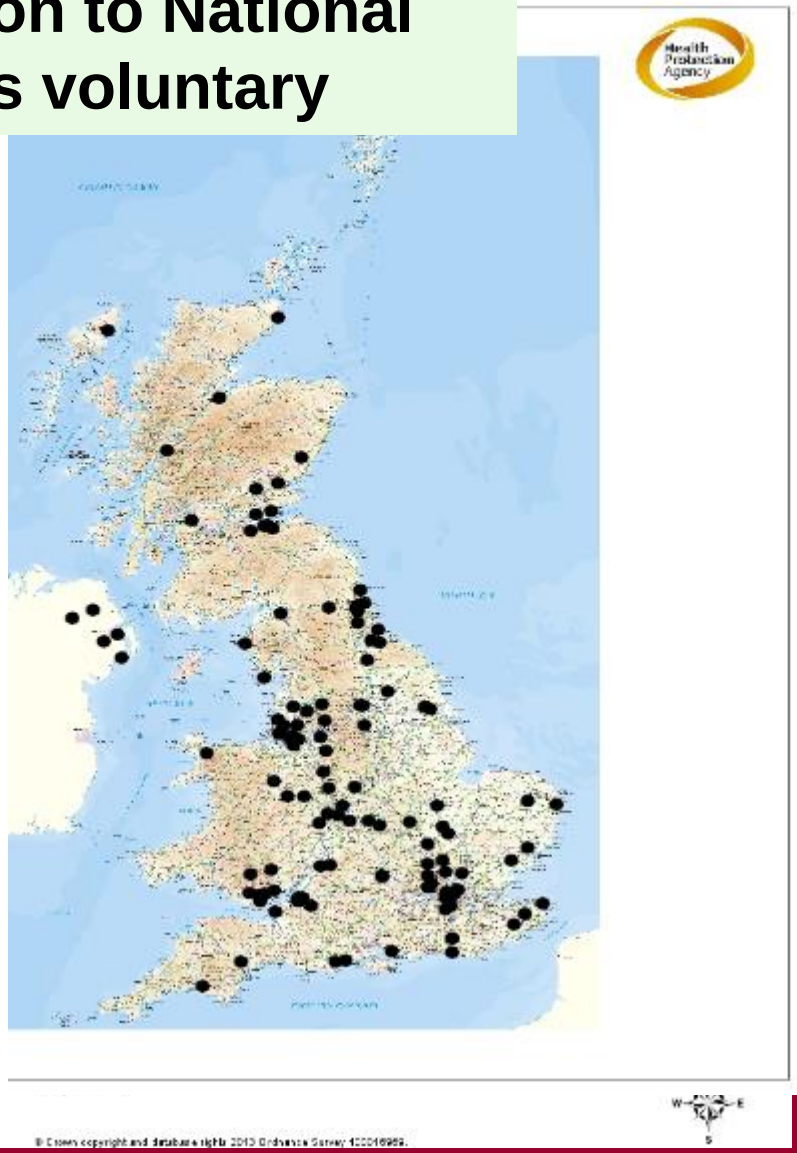
Submission Data – CT 2011 Survey

Submission to National Surveys is voluntary

- UK Wide data
- Reasonable geographical spread
  - 127 hospitals
- More NHS (public) than private
- 30% of scanners in UK

Survey	Year	Sample size	
		No.	% of UK
First	1989	144	83
Second	2003	126	27
Third	2011	183	30

- 1st survey in 1989 – dose levels in CT were unknown (hence 83%)



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- Trends in National DRLs (National Reference Doses)

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Advantage in Regular Review

- Trends identified
- Ideally every 5 years, or more often with changes in technology

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National Dose Audits - Trends

"Over the last 25 years, UK national DRLs for conventional x-ray procedures have in general fallen by a factor of 2 [10]"

[10] Hart D, Hillier MC, Shrimpton PC (2012) Report HPA-CRCE-034: doses to patients from radiographic and fluoroscopic x-ray imaging procedures in the UK – 2010 review. Health Protection Agency, Chilton

Table 3.2 Trends in UK national diagnostic reference levels for some radiographic procedures on adult patients.

	UK National DRL for entrance surface dose (mGy)				
Radiographic procedure	1985	1995	2000	2005	2010
Skull AP/PA	5	4	3	2	1.8
Skull LAT	3	2	1.5	1.3	1.1
Chest PA	0.3	0.2	0.2	0.15	0.15
Chest LAT	1.5	0.7	1	0.6	0.5
Thoracic spine AP	7	5	3.5	4	3.5
Thoracic spine LAT	20	16	10	7	7
Lumbar spine AP	10	7	6	5	5.7
Lumbar spine LAT	30	20	14	11	10
Lumbar spine LSJ	40	35	26	26	–
Abdomen AP	10	7	6	4	4
Pelvis AP	10	5	4	4	4

AP Antero-posterior, *PA* Postero-anterior, *LAT* Lateral, *LSJ* Lumbo-sacral joint

Table 3.3 Trends in UK national diagnostic reference levels for some fluoroscopic procedures on adult patients

	UK National DRL for dose-area product (Gy cm^2)				
Procedure	1985	1995	2000	2005	2010
Intravenous urography	40	23	16	14	14
Barium meal	25	17	13	14	12
Barium enema	60	32	31	24	21

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National Dose Audits - Trends

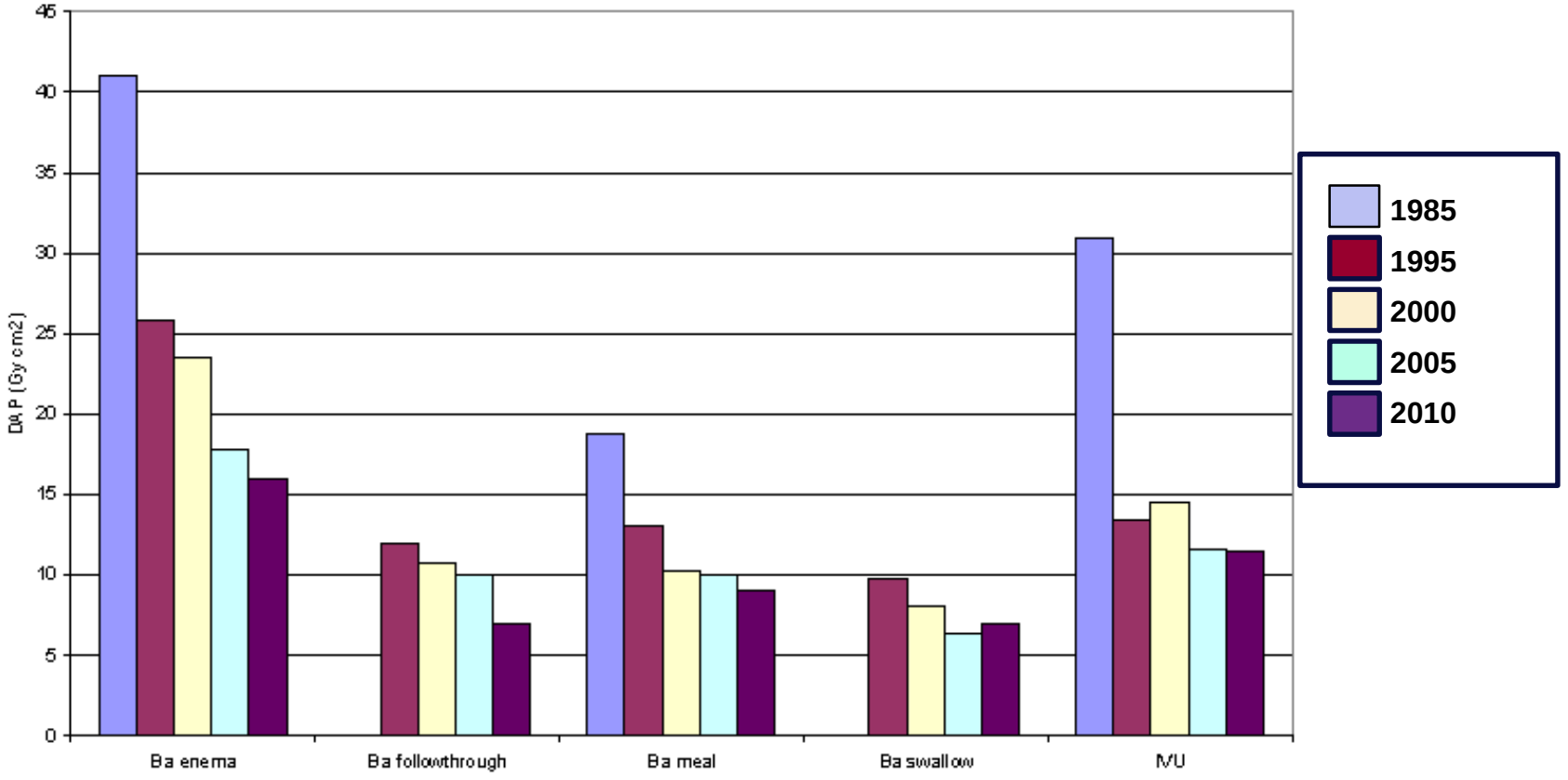

FIGURE 13 Mean room dose-area product per examination (adults)

'Doses to patients from radiographic and fluoroscopic x-ray imaging in the UK – 2010 review'. Hart et al. Report HPA-CRCE-034 (2012).

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National Dose Audits - Trends

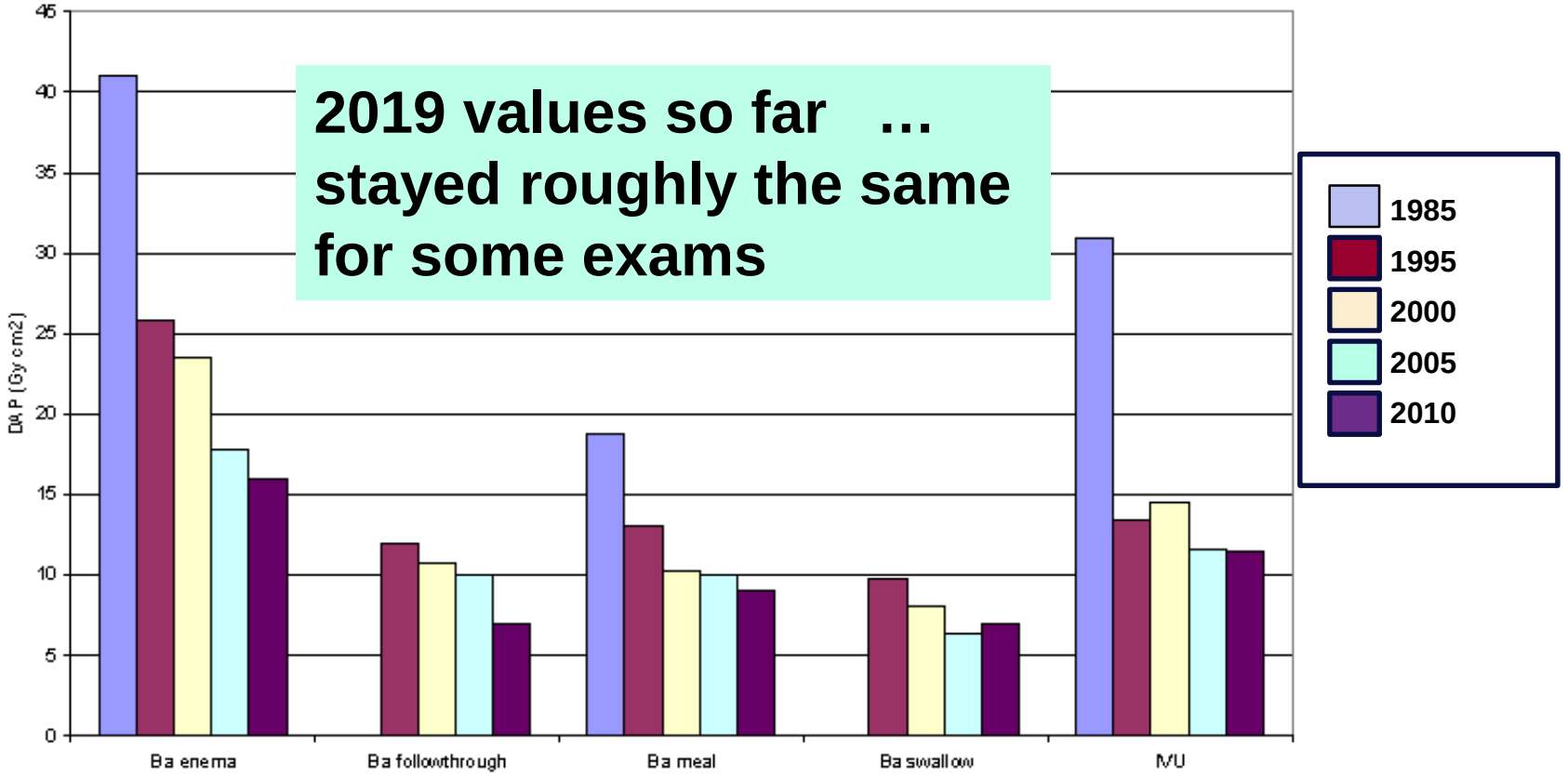

FIGURE 13 Mean room dose-area product per examination (adults)

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Trends for Eight Common Radiographs

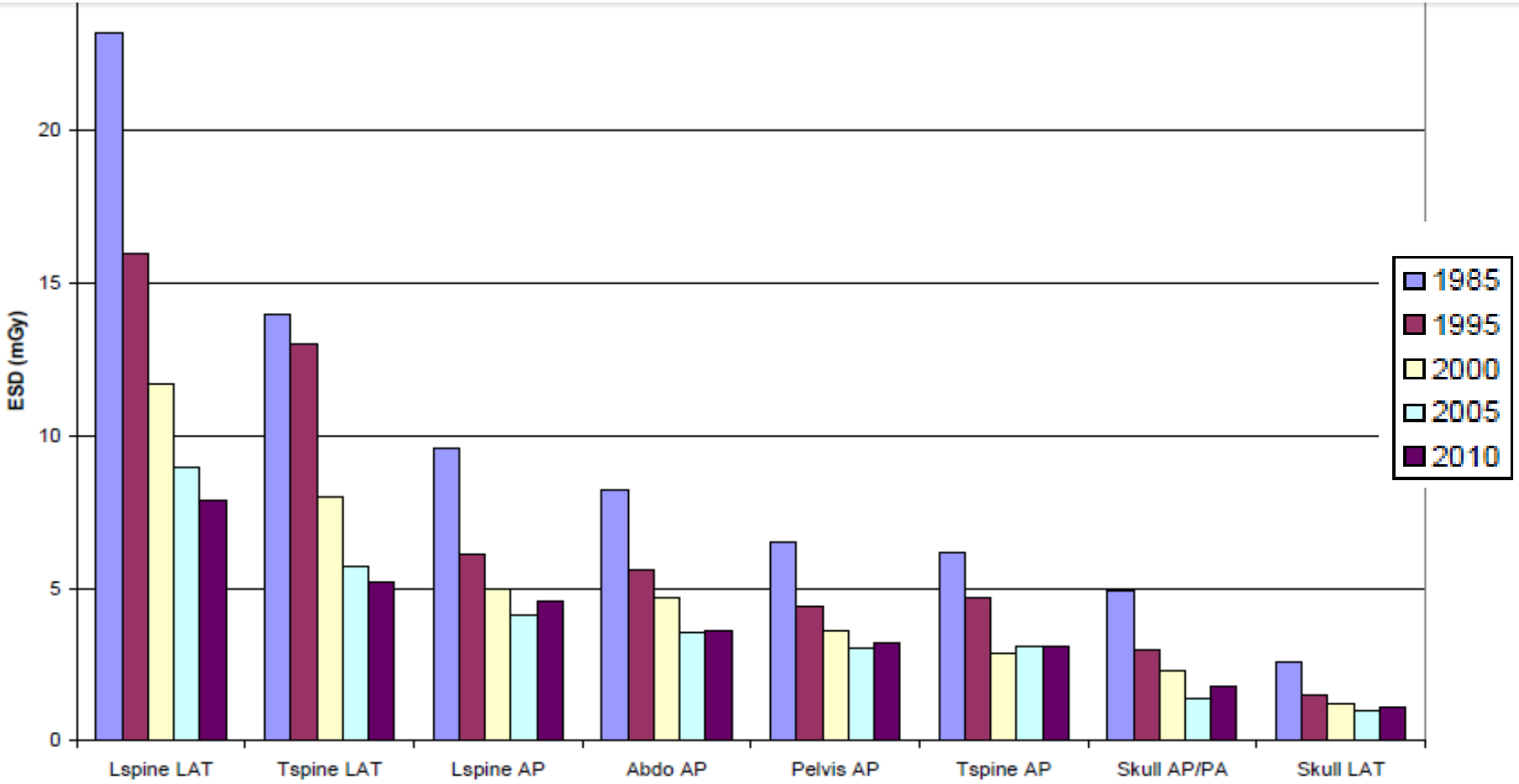

FIGURE 11 Mean room entrance surface dose per radiograph (adults)

HPA-CRCE-34

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National Dose Audits - Trends

The situation in CT is less clear due to significant changes in technology – which brought diagnostic imaging advantages, but sometimes initially with higher dose

CT Technological advances, 1985 - 2014

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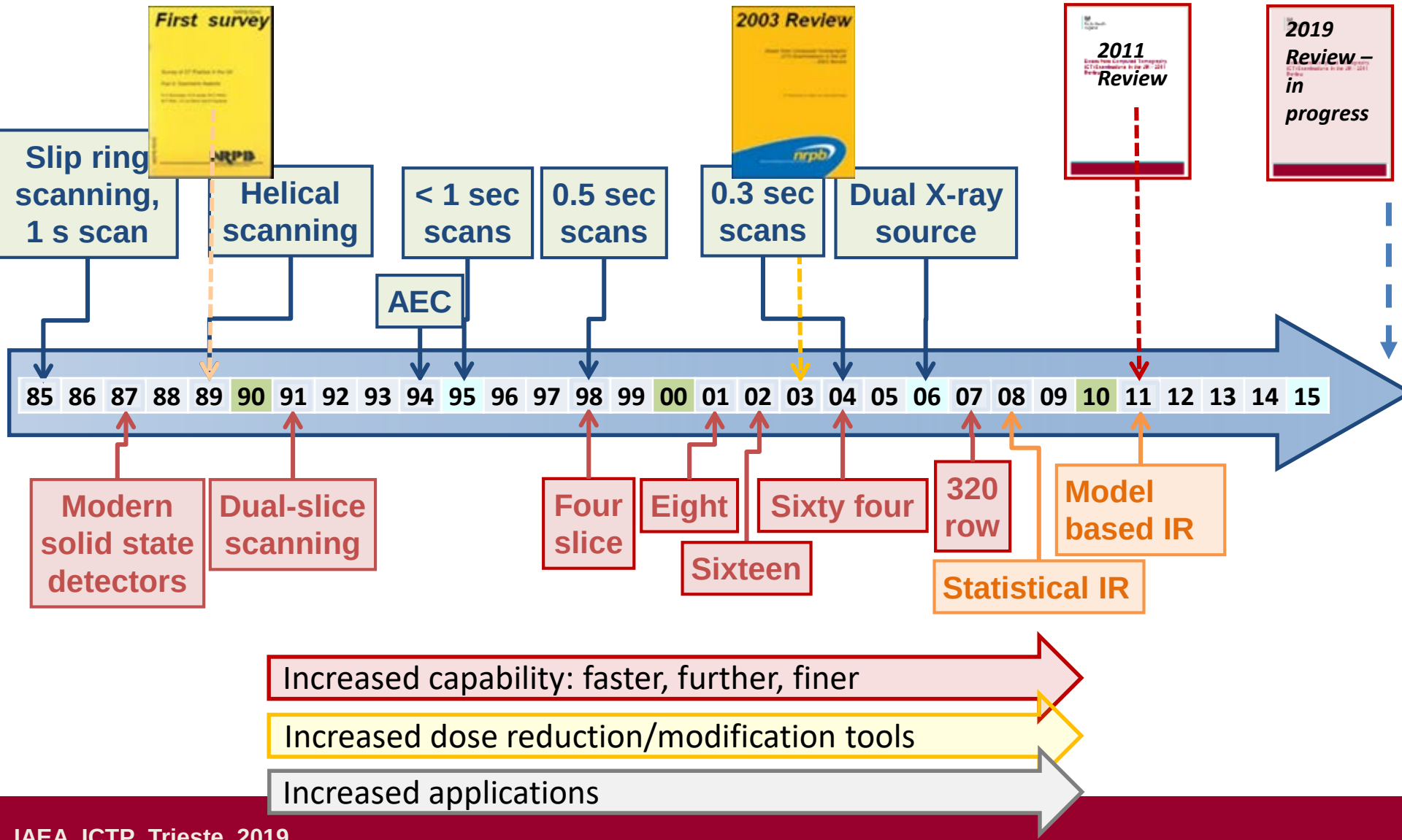

Increased capability: faster, further, finer

Increased dose reduction/modification tools

Increased applications

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Effect of New Technology

- New technology – clinical exam changes modality
  - Head x-ray : CT head
  - Barium enema : CT colonography
- Changed technology – trends harder to follow
  - CT single slice →helical → multi-slice → wide beam multi-slice
  - Automatic Exposure Control (AEC)
  - First multi-slice gave higher doses (penumbra not used for imaging)

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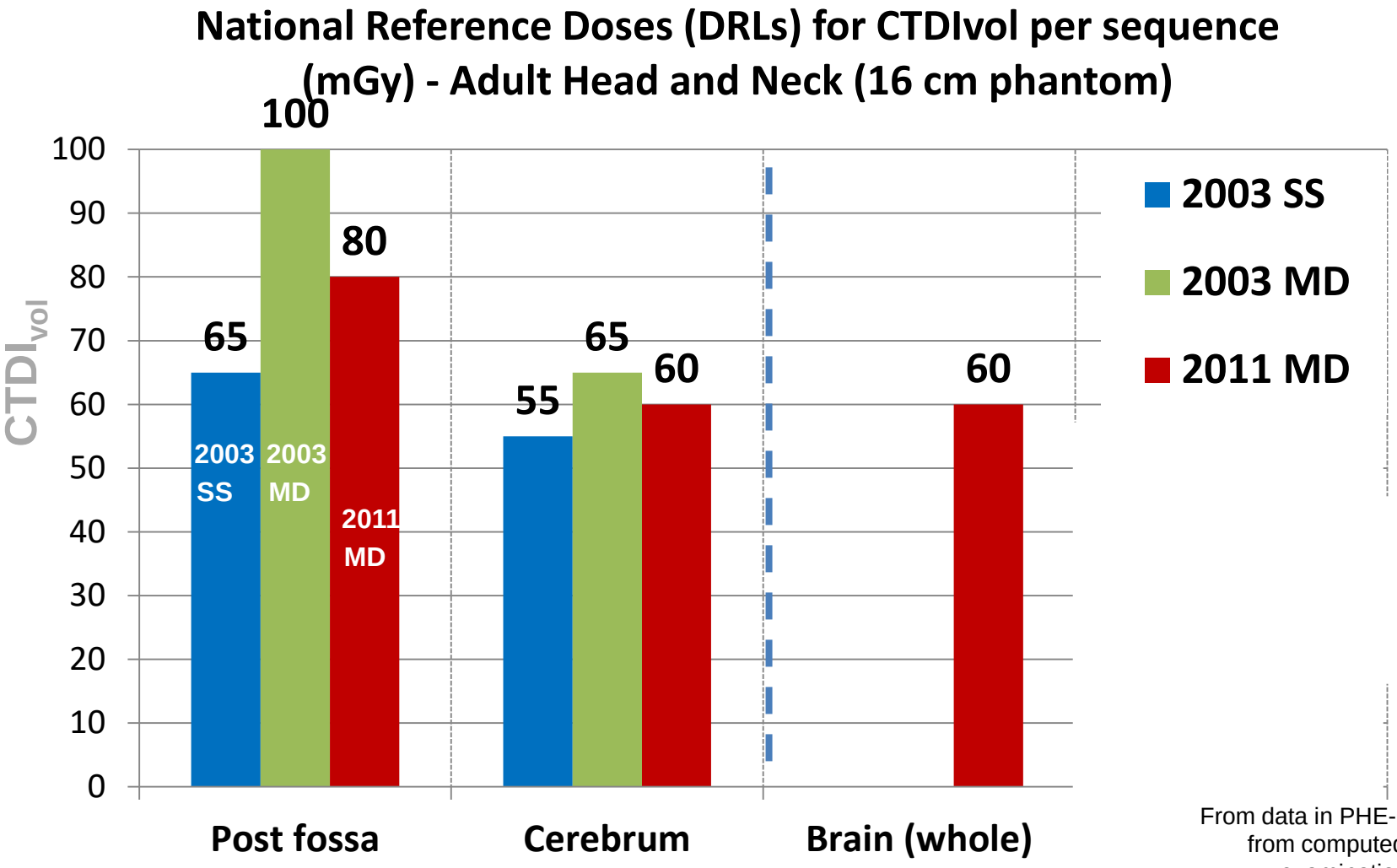
$CTDI_{vol}$, Adult Head & Neck



From data in PHE-CRCE-013: Doses from computed tomography (CT) examinations in the UK (2011 Review)

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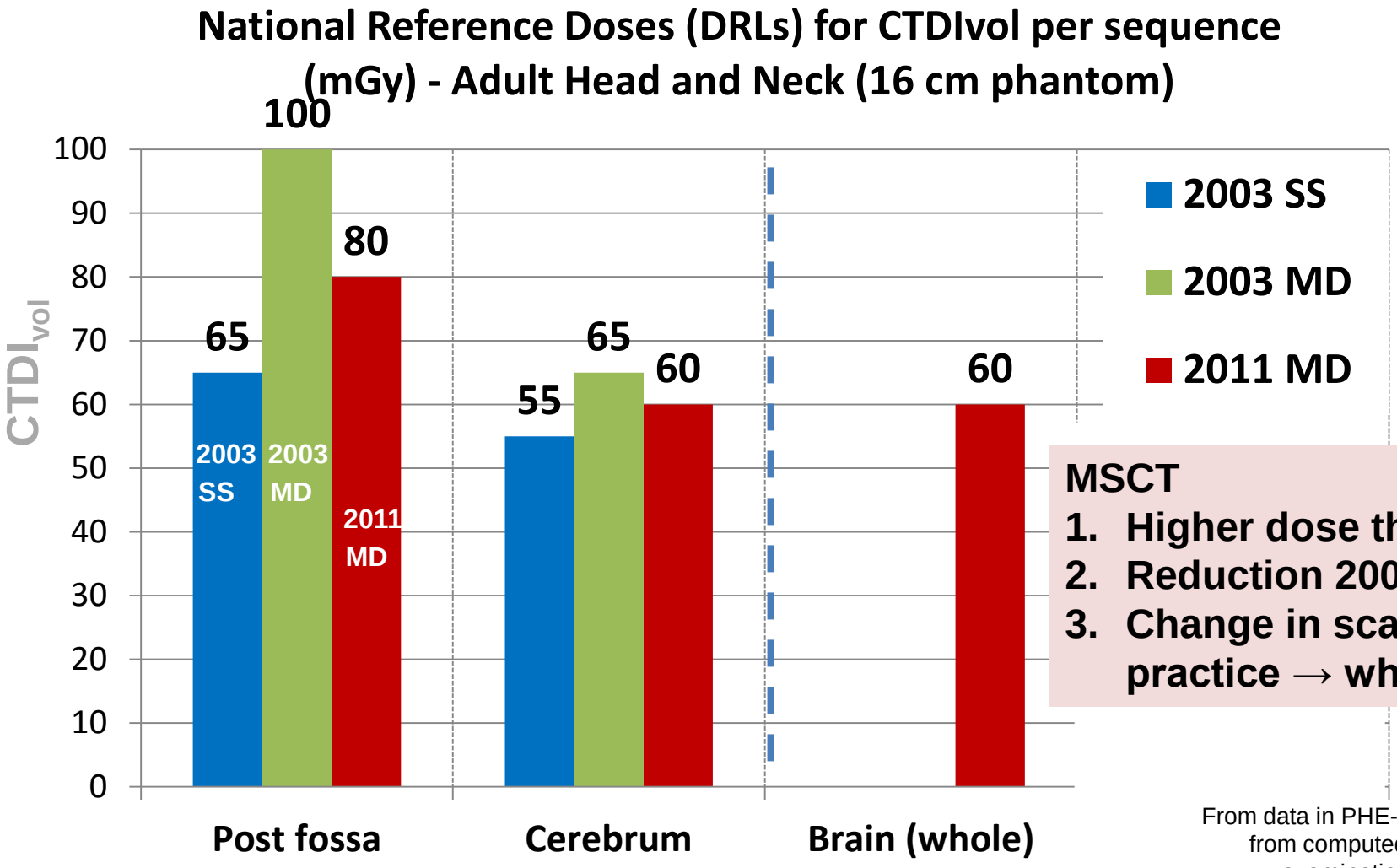
$CTDI_{vol}$, Adult Head & Neck



MSCT

1. **Higher dose than ss**
2. **Reduction 2003 – 2011**
3. **Change in scan practice → whole brain**

From data in PHE-CRCE-013: Doses from computed tomography (CT) examinations in the UK (2011 Review)

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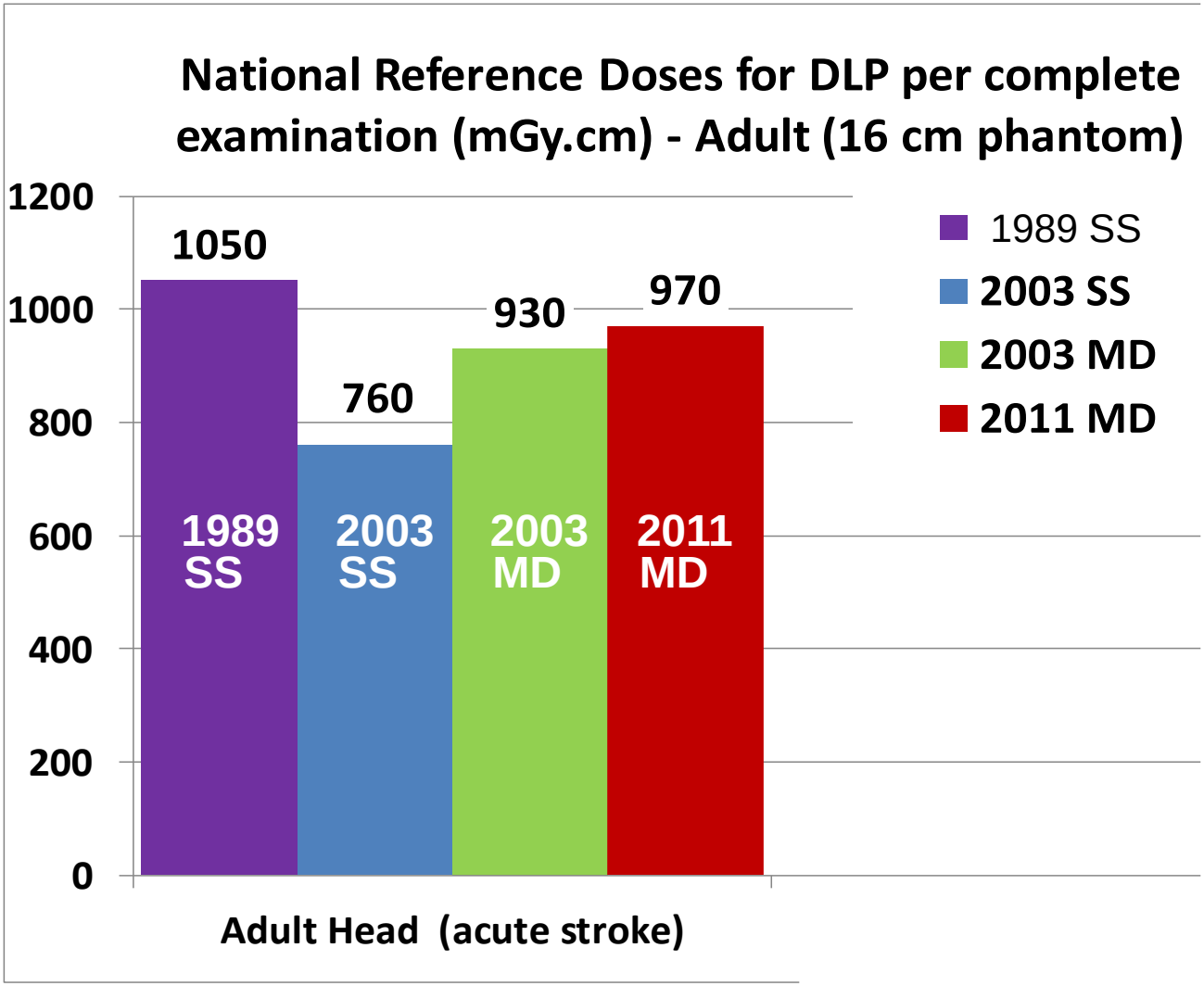
DLP, Adult Head – Complete Exam

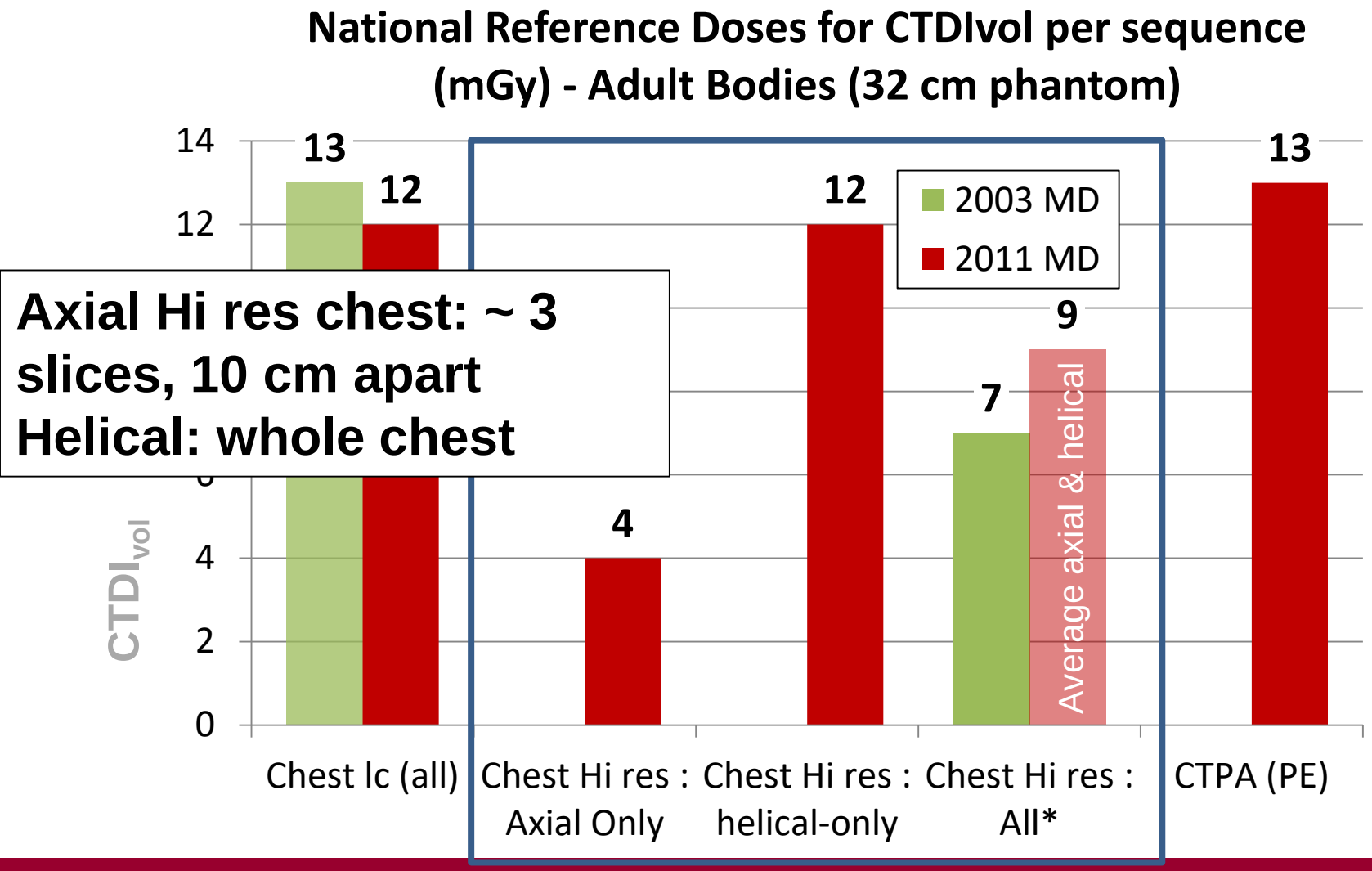
DLP



From data in PHE-CRCE-013: Doses from computed tomography (CT) examinations in the UK (2011 Review)

Public Health England

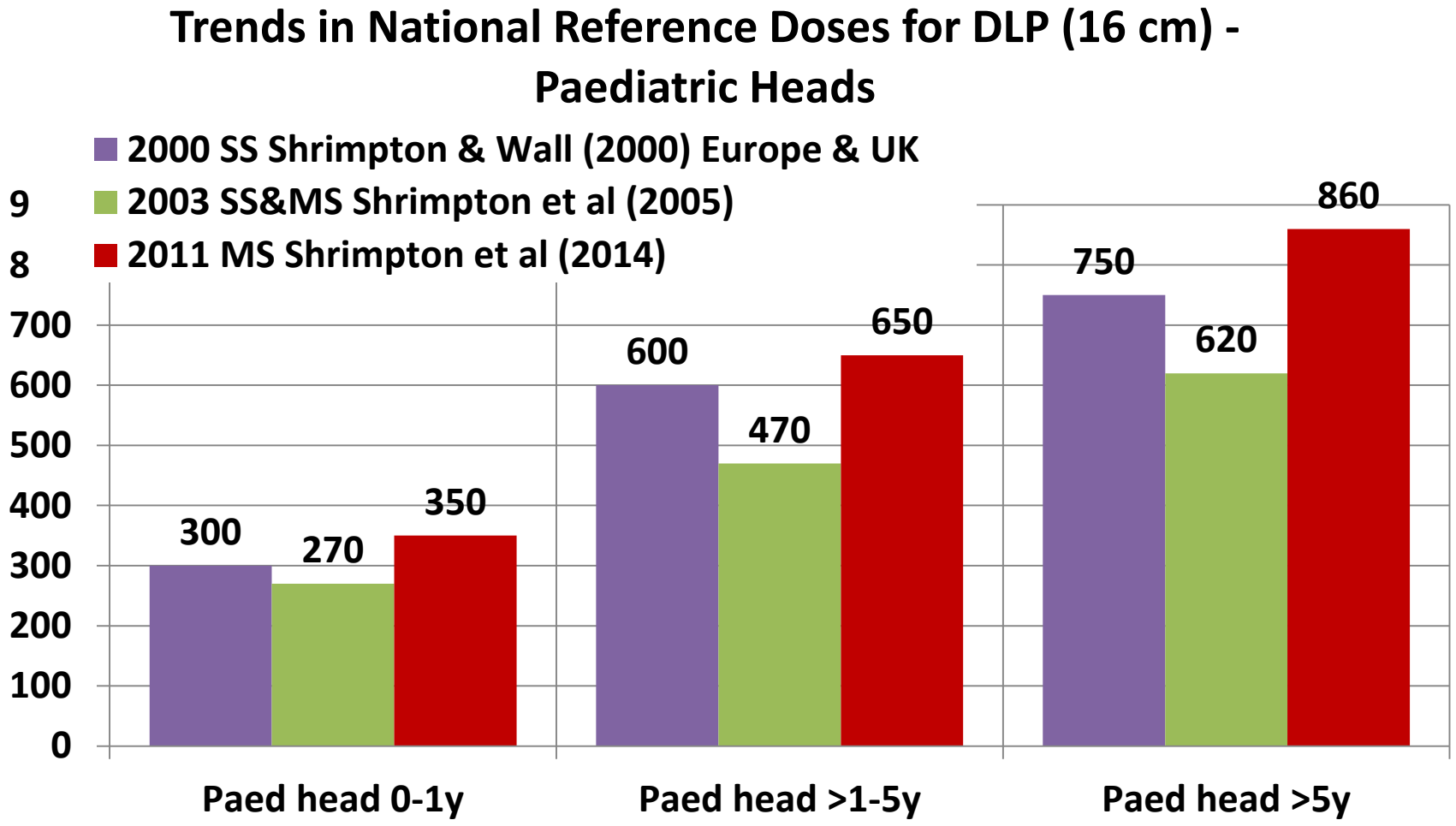
$CTDI_{vol}$, Adult Chest



Axial Hi res chest: ~ 3 slices, 10 cm apart
Helical: whole chest

Public Health England

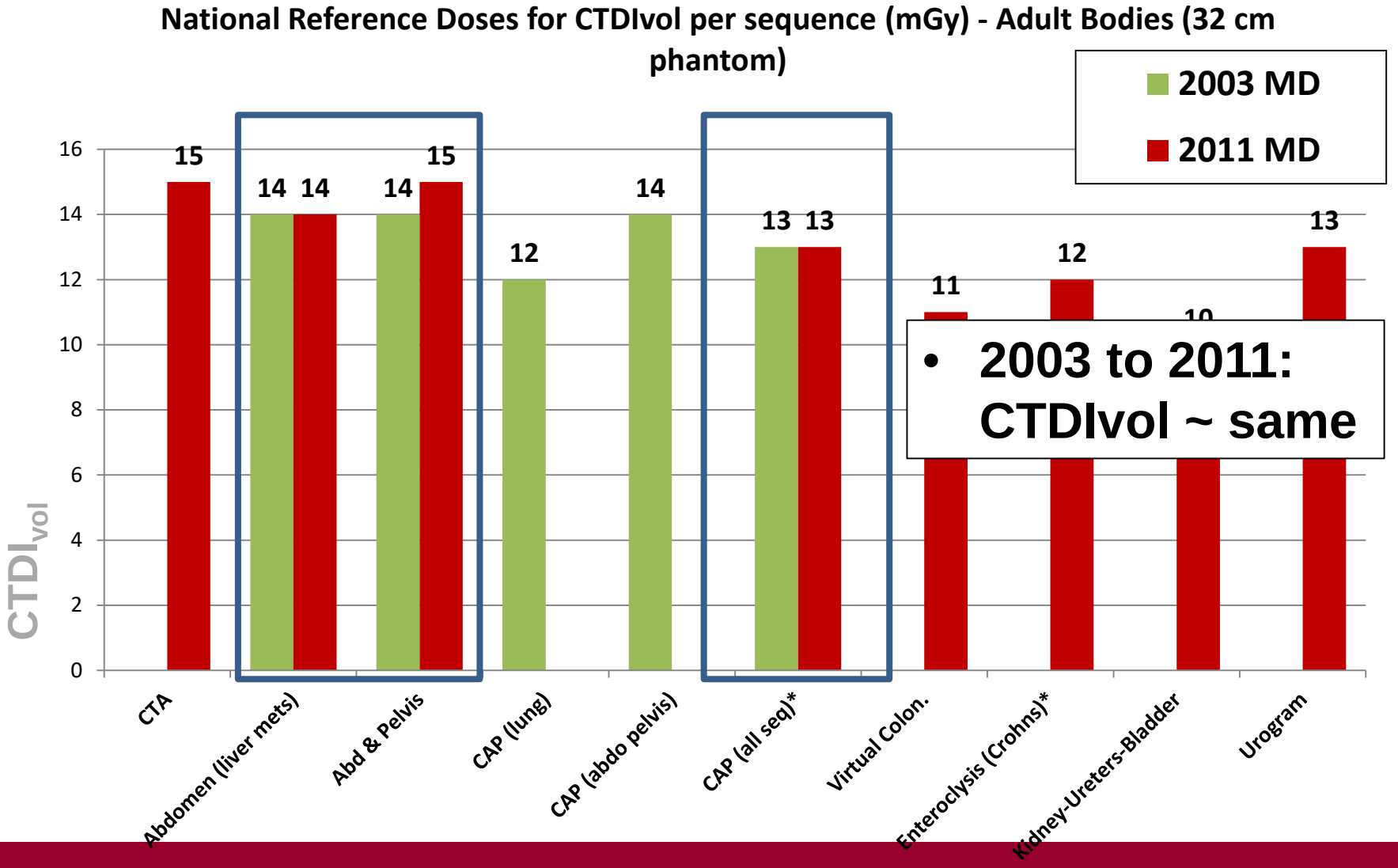
DLP, Paediatric Heads



[e]Note: Slight differences in age banding between surveys underlying the three sets of reference doses.

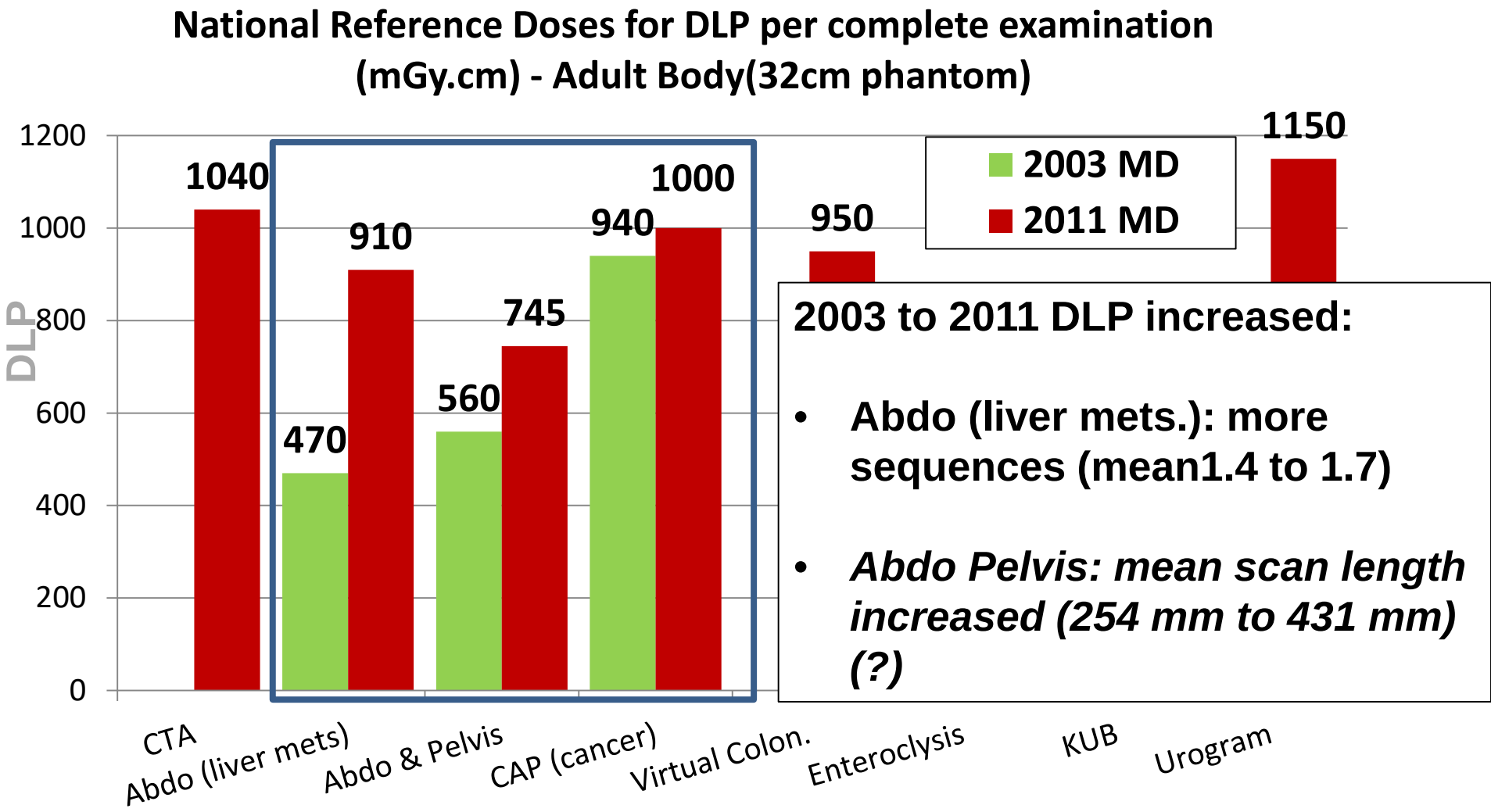
Public Health England

$CTDI_{vol}$, Adult Abdo/Pelvis (& CAP)



Public Health England

DLP Adult Abdo/Pelvis (&CAP)



2003 to 2011 DLP increased:

- **Abdo (liver mets.): more sequences (mean1.4 to 1.7)**
- ***Abdo Pelvis: mean scan length increased (254 mm to 431 mm) (?)***

Public Health England

- What we are doing now

Public Health England

UK National Patient Dose Audits

NRPB

HPA

Conventional X-ray and Fluoroscopy

PHE

2019

1st X-ray survey

Review

Review

Review

Review

National Patient Dose Database (excl CT)

Key people retired within 3 years

1985 1990 1995 2000 2005 2010 2015

CT

CT

CT

CT

1st CT survey 1989

2nd CT survey 2003

3rd CT survey 2011 (Published Sept 1st 2014)

4th CT survey **2019**

Computed Tomography

Current UK National Patient Dose Audits

Public Health England






Endorsed CPD Now

UK Adult: plain X-ray; simple IR/fluoro surveys

Pilot

17th April 2019

Mid-2018 | 2019 | April | July | Sept | 2020

Pilot

20th March 2019

UK 4th CT survey (adult) pilot

UK 4th CT survey (adult)

Computed Tomography

6th June 2019

IPEM/PHE

UK 4th CT survey (paediatric)

Public Health England

Current National Dose Audits - 2019

		Modality		Launch	'Closing …'	
^	1	CT	Adult	20th March	End of Oct*	PHE
^	2	CT	Paediatric	6th June	End of Dec*	IPEM/PHE
	3	Planar X-Ray	Adult	17th April	End of Dec*	PHE
	4	IR and Fluoro	Adult	17th April	End of Dec*	PHE

^ CT priority
* Revised end dates

End dates flexible – as running a few surveys simultaneously

Public Health England

Dose Data Collection

WHERE FROM

- Modality, RIS, PACs
- Dose Management Systems:
  Internal, Commercial, Open Source

WHAT

- Sample data
- All data
- Mean/median

HOW

- Spreadsheet,
- Export from electronic systems




Public Health England

Dose Data Collection

WHERE FROM

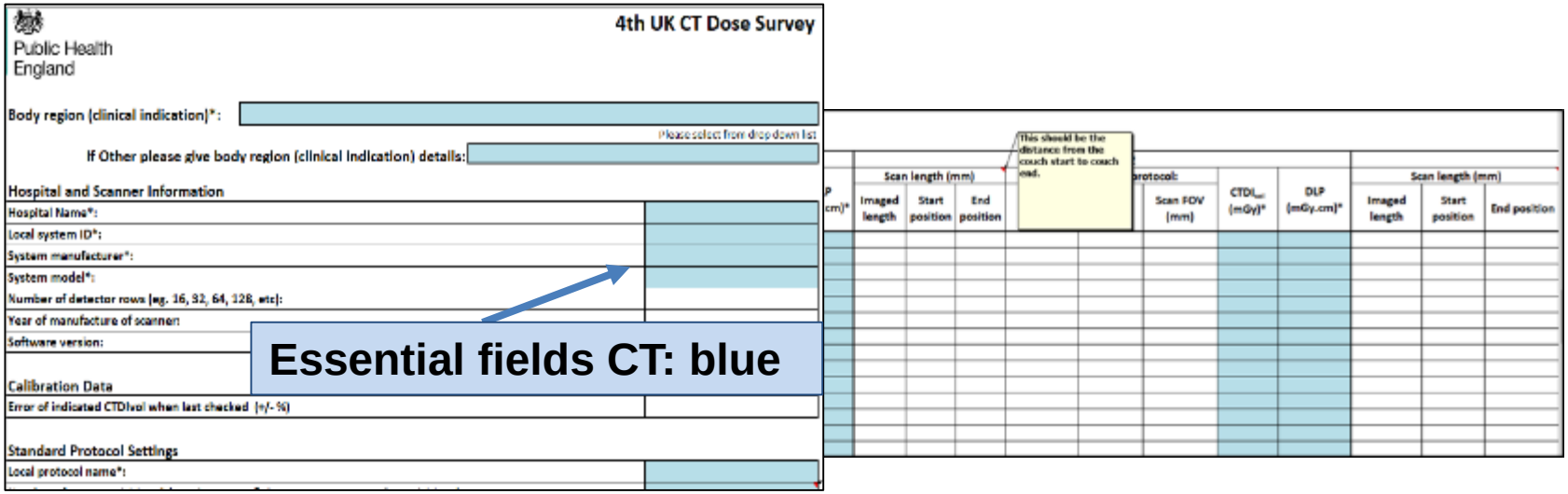
- Modality, RIS, PACs
- **Decided on spreadsheet submission – to allow any hospital, large or small, to submit data.**
- **Getting the data into the spreadsheet is a local decision (manually, electronically..)**
- Export from electronic systems

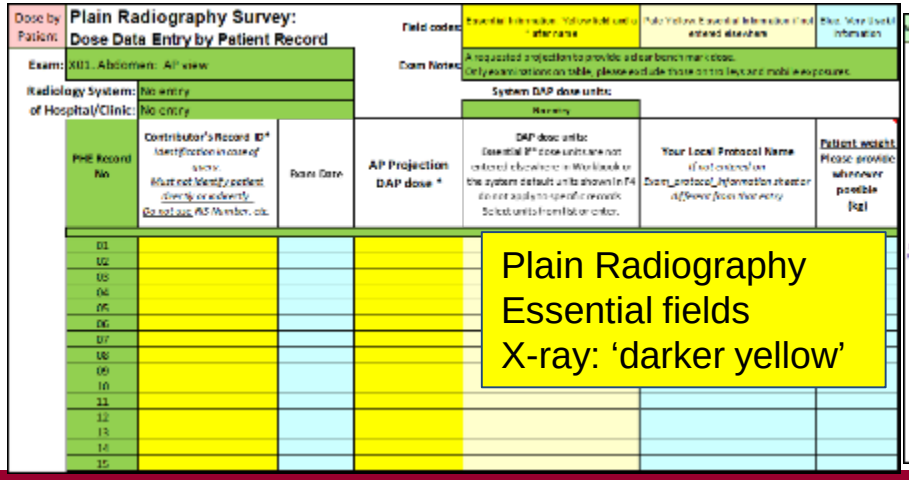
WHAT

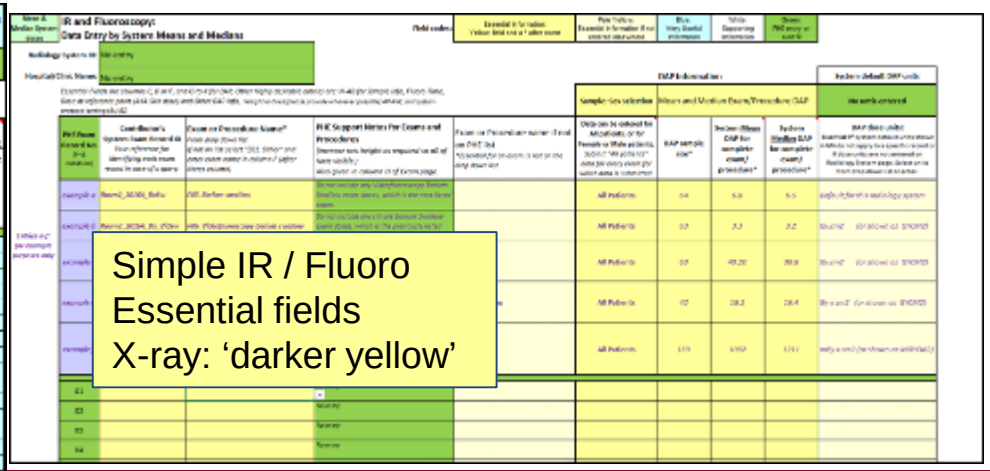



Public Health England

Workbooks: Colour coding

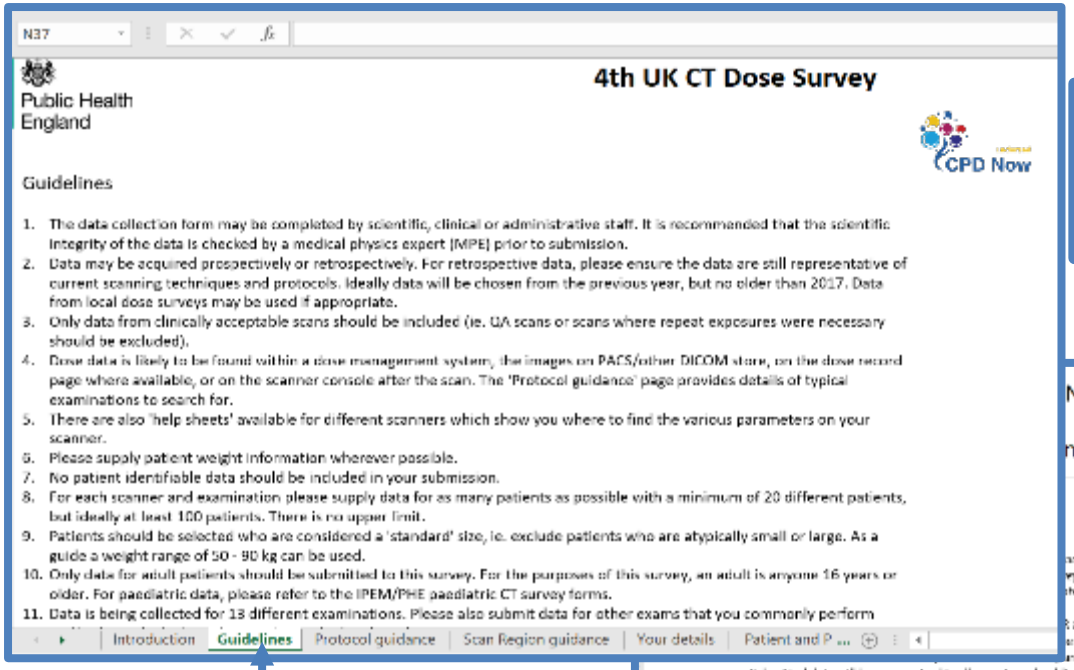




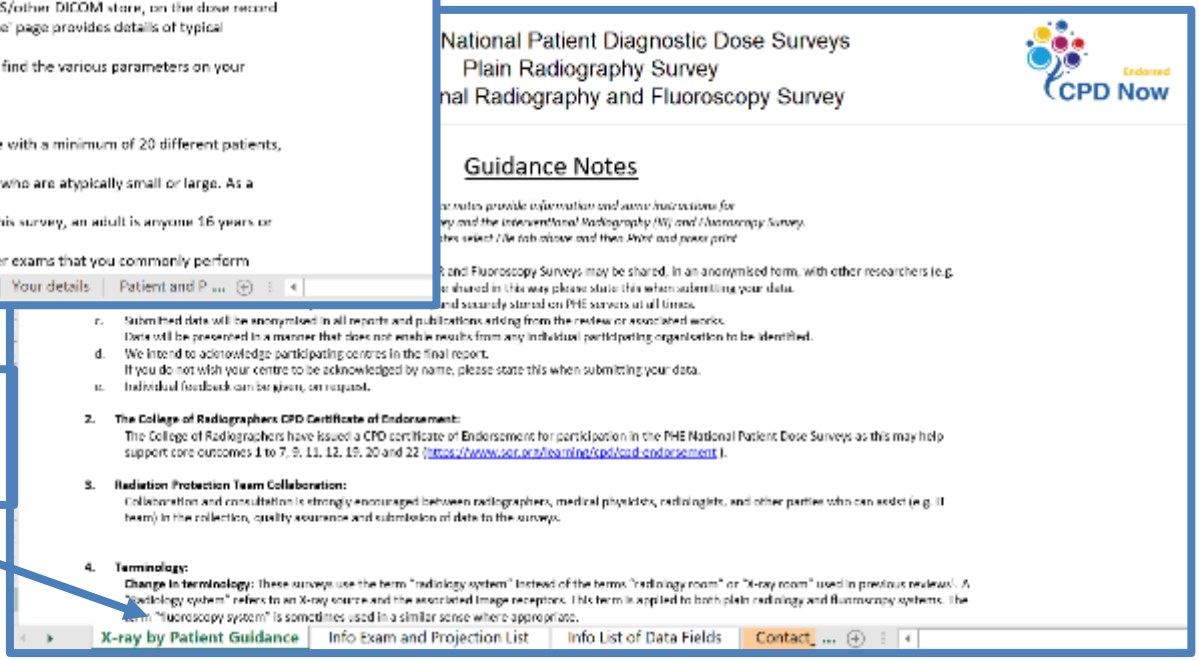


Public Health England

Guidance Notes



- Email with any questions
- We will answer as best we can
- FAQ



Guidance Notes - A tab in each Excel file

Public Health England

National Dose Audits – Future ?

For UK survey – need to have many ways of submitting data

- Small hospitals
- Large hospitals with dose management systems

Originally in 2013 a three level strategy was proposed:

- Spreadsheet (and paper) submissions as before
- Investigate a web based system
  - Not viable for us at the moment
- Establish, and make use of, suitable export files from commercial (and home grown) systems

Public Health England

Dose Management Systems

- We approached a number of suppliers to see whether they will be willing to assist by supplying an export of required fields
  - e.g. as csv file, or into spreadsheet format
- Main task is mapping of protocols to ‘PHE’ protocols
- Then add in some admin details and send to us

OpenREM

Radiation Exposure Monitoring for the physicist

Public Health England

Dose Management Systems

- We had a few suppliers looking into this (e.g. GE, Bayer)
  - They have since said they now had other priorities for this year
  - Timing doesn't work
- OpenRem however have worked on it, also Qaelum

OpenREM

Radiation Exposure Monitoring for the physicist

Public Health England

Dose Management Systems

- We had a few suppliers looking into this (e.g. GE, Bayer)
  - They h… …is year
  - Timing…
- OpenRe… …Qaelum

However it is not too hard to set up your own export of the required fields into Excel format

OpenREM

Radiation Exposure Monitoring for the physicist

Public Health England

Dose Management Systems – GE example

2. To import PHE DRLs values into DoseWatch

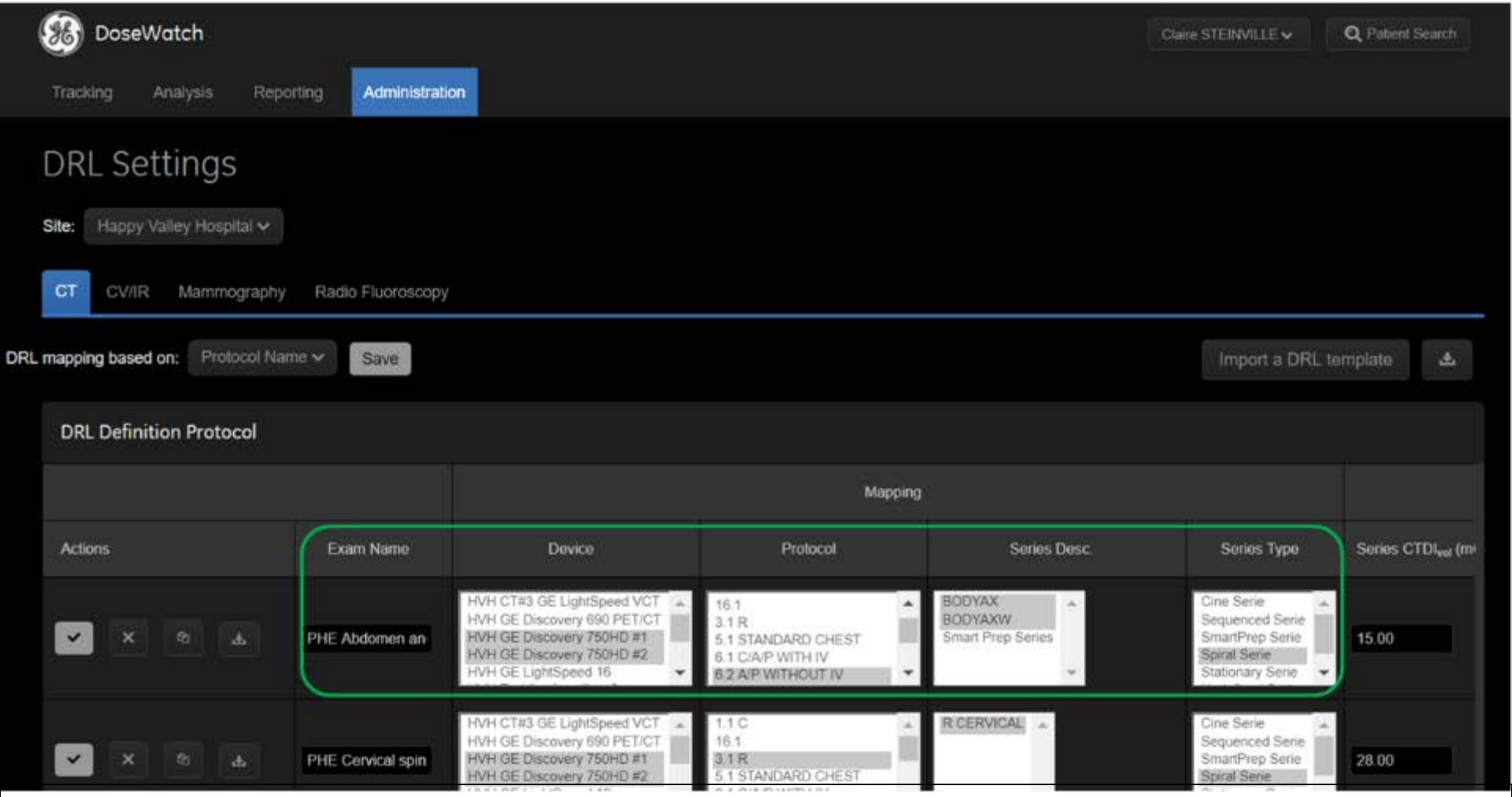
2. To import PHE template into DoseWatch

GE

Public Health

Dose Management Systems – GE example

3. To map PHE Protocol to local protocols into DoseWatch



3. To map PHE Protocol to local protocols into DoseWatch

OpenREM

Free and Open Source Radiation Exposure Monitoring for the physicist

What is OpenREM?

OpenREM is a free, open source application for patient dose monitoring. It features:

- Importing of CT, planar X-ray, fluoroscopy, and mammography data
- Displaying summary exposure data, with filtering and searching
- Charts to visualise and explore the data, including mean and median dose metrics, histograms, workload data and more
- Skin dose maps for fluoroscopy using a simple geometric phantom
- Export of data into spreadsheets, sorted and summarised

OpenREM therefore provides the tools a qualified medical physicist needs both to gather data for reference/representative dose reporting and — more importantly — for monitoring and optimising radiation exposures as part of an interdisciplinary dose and image quality radiology team.

By default, patient identifable data or protected health information are not retained. Specifically, name, date of birth, patient ID etc are not stored; however, patient age (decimal) and patient sex are as these are useful for population dose analysis. Alternatively patient name and ID can be retained, used in searches and exported based on permissions. These details can also be stored in a hashed format.

Display of data

OpenREM provides a web interface for display of the studies that have been imported into the database, allowing easy review of the latest data. It also has a filtering function to enable any subset of the studies to be reviewed.

Latest...

Current release: 0.10.0 Please review the instructions in the release notes.
Changes: OpenREM version history

Tweets by @_OpenREM

OpenREM
@_OpenREM

New release! 0.10 now available for install or upgrade! New export for UK fluoro/radiography users; more imports of faulty RDSRs, docs improvements and bug fixes.docs.openrem.orgdocs.openrem.org/en/0.10.0-docs…#pdms #DoseManagement #NHSOpenSource #MedPhys

Nov 8, 2019

A useful OpenSource Tool – ‘Google’ OpenRem

PHE National DRL Working Party

- Aim: To work collaboratively with radiology professionals in the areas of National Dose Surveys and National Diagnostic Reference Levels
- Formed in 2014
  - PHE and Department of Health
  - Meet formally once a year from March 2015 ….. May 2019 (5 meetings)

Multi-disciplinary working party

PHE NDRL Working Party - members

- Radiology Professional Bodies
  - IPEM, BIR, RCR, BSCI, CSoR, SRP
  - i.e. Medical physicists, radiographers and radiologists
- Representatives from national surveys underway
  - Cardiac CT (BSCI), CT in NM (IPEM), CT in RT (IPEM) …
- Specific Experts
  - Paediatrics
  - Automatic Dose Data Collection
  - IHE (integrating health enterprise)

- Primarily diagnostic imaging
  - Other areas where imaging is used (RT, NM, Mammography screening)

PHE NDRL Working Party - members

- Radiology Professional Bodies
  - IPEM, BIR, RCR, BSCI, CSoR, SRP
  - i.e. Medical physicists, radiograph
- Representatives fr rveys underway
  - Cardiac CT (BSCI) CT in RT (IPEM) …
- Specific
  - Pa
  - Au ata Collection
  - IHE (ing health enterprise)
- Primarily diagnostic imaging
  - Other areas where imaging is used (RT, NM, Mammography screening)

Many people working together

PHE/DH NDRL Working Party

- A key role is in the adoption and publication of National DRLs
  - DH (now Department of Health and Social Care) assigned responsibility in 2014 to PHE
  - Achieved through the PHE NDRL WP
- PHE undertakes national surveys as well as responsible for setting national DRLs?
  - so to separate out the functions…. Established a referee process through the WP

PHE/DH NDRL Working Party

- Draft Guidance 2016 – finalised 2019
  - For running a national survey (does not have to be PHE)
  - For results to be adopted as National DRLs.
- Proven and agreed process

PHE Working Party on National Patient Dose Surveys and DRLs

Process for adoption of National DRLs

Background

PHE does not have the resources to undertake National patient dose surveys to the same extent as in previous years (as undertaken by NRPB and HPA). With this limitation PHE staff can currently only focus on surveys to provide updated values of previous studies, and there is little scope to undertake national surveys in specialist or new areas.

There are already two national surveys underway, run by professional bodies, in the areas of cardiac CT and hybrid imaging (PET-CT and SPECT-CT). Both of these are drawing to a conclusion. It has been considered that both are of a suitable standard to enable to resultant data to be accepted as national DRLs, and both provide a model as to how we could progress for future studies.

The aim of this document is to provide an agreed procedure by which a national survey can be operated, and for the results to be adopted as DRLs.

Public Health England

National Survey and Adoption process for new NDRLs

- Professional Body run
- Multi-disciplinary (physics, radiography, radiology)
- Follow various specific detailed guidelines (ICRP/IAEA/PHE/IPEM/NRPB/HPA)
- Representative coverage
- ‘Clinical dose audit’ – body part and clinical question
- Pilot
- Various presentations
- Scientific publication
- NDRL proposals go to PHE NDRLWP; and agreed through a referee process

PHE national audits to follow same process

Public Health England

Coronary CT Angiography

J Cardiovasc Comput Tomogr. 2017 Jul - Aug;11(4):268-273. doi: 10.1016/j.jcct.2017.05.002. Epub 2017 May 8.

A prospective national survey of coronary CT angiography radiation doses in the United Kingdom.

Castellano IA[1], Nicol ED[2], Bull RK[3], Roobottom CA[4], Williams MC[5], Harden SP[6].

Author information

Abstract

BACKGROUND: Little real-world radiation dose data exist for the majority of cardiovascular CT. Some data have been published for coronary CT angiography (coronary CTA) specifically, but they invariably arise from high-volume centres with access to the most recent technology.

OBJECTIVE: The aim of this study was to document real-world radiation doses for coronary CTA in the United Kingdom, and to establish their relationship to clinical protocol selection, acquisition heart rate, and scanner technology.

METHODS: A dose survey questionnaire was distributed to members of the British Society of Cardiovascular Imaging and other UK cardiac CT units. All participating centres collected data for consecutive coronary CTA cases over one month. The survey captured information about the exam conducted, patient demographics, pre-scan details such as beta-blocker administration, acquisition heart rate and scan technique, and post-scan dose indicators - series volumetric CT dose index ($CTDI_{vol}$), series dose-length product (DLP), and exam DLP.

RESULTS: Fifty centres provided data on a total of 1341 coronary CTA exams. Twenty-nine centres (58%) performed at least 20 coronary CTA scans in the collection period. The median BMI, acquisition heart rate and exam DLP were 28 kg/m^2, 60 bpm and 209 mGycm respectively. The corresponding effective dose was estimated as 5.9 mSv using a conversion factor of 0.028 mSv/mGycm. There was no statistically significant difference in radiation dose between low and high-volume centres. Median exam DLP increased with the acquisition heart rate due to the selection of wider temporal windows. The highest exam DLPs were obtained on the older scanner technology.

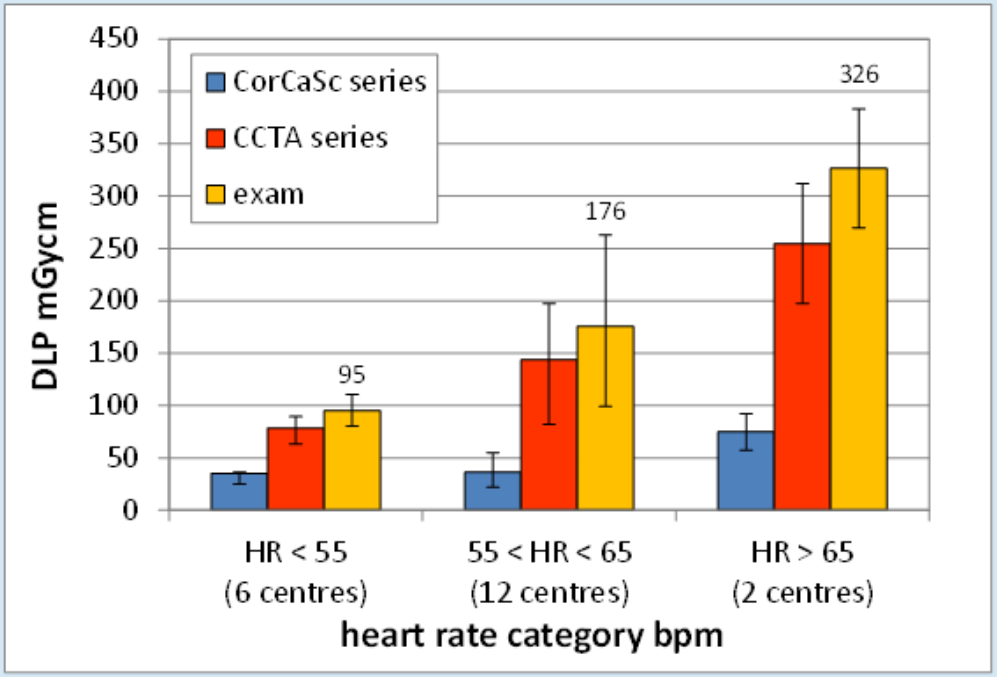
Public Health England

Coronary CT Angiography

Slide courtesy of Elly Castellano RMH London

Results

- coronary CTA data for standard-sized patients with BMI 25 - 31kg/m^2 filtered according to heart rate
  - 19 centres with at least 8 exams in one category included



CT in PET-CT and SPECT-CT

Original article

Nuclear Medicine Communications

A national survey of computed tomography doses in hybrid PET-CT and SPECT-CT examinations in the UK

Gareth R. Iball[a], Natalie A. Bebbington[b,c], Maria Burniston[d], Sue Edyvean[e], Louise Fraser[f], Peter Julyan[g], Nasreen Parkar[f] and Tim Wood[h,i]

Objectives The aim of this study was to conduct a nationwide survey of computed tomography (CT) doses for a wide range of PET-CT and single photon emission computed tomography-computed tomography (SPECT-CT) imaging procedures, with the aim of generating proposed UK national diagnostic reference levels (NDRLs).

Methods CT protocol and dosimetry data for three PET-CT and seven SPECT-CT examinations were gathered from centres across the UK. Data were divided according to CT purpose (attenuation correction, localization or diagnostic) and third quartile values of scanner average dose metrics were used to generate suggested NDRLs for a range of examination and CT purpose combinations. Achievable doses were also established from the median of the dose observed. The survey highlighted the need for targeted optimization work in many centres.

Conclusion Suggested UK NDRLs and achievable doses for six common PET-CT and SPECT-CT examinations have been established as a result of this study. *Nucl Med Commun* 00:000–000

Nuclear Medicine Communications 2017, 00:000–000

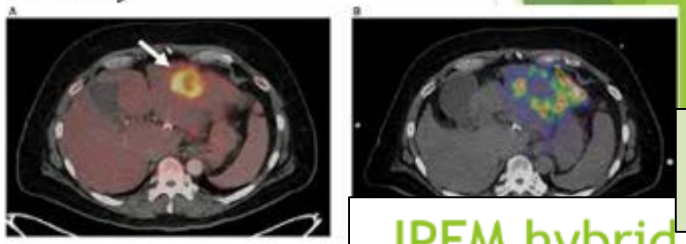
Keywords: computed tomography, diagnostic reference levels dosimetry, positron emission tomography, single photon emission computed tomography

[a]Leeds Teaching Hospitals NHS Trust, Medical Physics Department, Old Medical School, Leeds General Infirmary, Leeds, LS1 3EX, [b]University Hospitals Birmingham NHS Foundation Trust, Queen Elizabeth Hospital Birmingham, Mindelsohn Way, Edgbaston, Birmingham, B15 2GW, [c]Siemens Healthineers

CT in PET-CT and SPECT-CT

Working party methodology

- Drew up list of 10 common indications
  - 3 PET, 7 SPECT
    - PET- whole/half body
    - PET- brain
    - PET- cardiac
    - Bone
    - Parathyroid
    - MIBG
    - Octreotide
    - Sentinel node
    - Post I131 therapy ablation
    - Cardiac SPECT



Appropriate Indications for Nuclear Medicine

Slides courtesy of Gareth Iball, Maria Burniston

IPEM hybrid DRL working group

- DR
  - Chair Gareth Iball, Leeds
  - Tim Wood, Hull
- NM
  - Maria Burniston, Royal Free London
  - Natalie Bebbington, Denmark
  - Peter Julyan, Manchester
- National bodies
  - PHE Sue Edyvean
  - ARSAC Louise Fraser, Nasreen Parker

Public Health England

Administration of Radioactive Substances Advisory Committee

Nuclear Medicine and diagnostic physicists

CT Planning scans in Radiotherapy

Physics in Medicine & Biology

IPEM Institute of Physics and Engineering in Medicine

CrossMark

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18 April 2018

REVISED
12 June 2018

ACCEPTED FOR PUBLICATION
14 June 2018

PUBLISHED
10 September 2018

PAPER

IPEM topical report: the first UK survey of dose indices from radiotherapy treatment planning computed tomography scans for adult patients

Tim J Wood[1,2,3], Anne T Davis[1,4,5], James Earley[1,6], Sue Edyvean[7], Una Findlay[8], Rebecca Lindsay[1,9], Andrew Nisbet[1,5,6], Antony L Palmer[1,4,5], Rosaleen Plaistow[1,10] and Matthew Williams[1,11]

[1] Radiotherapy and Diagnostic Radiology Special Interest Groups, Institute of Physics and Engineering in Medicine, Doses to patients from x-ray imaging in radiotherapy working party York, United Kingdom
[2] Radiation Physics Department, Queen's Centre for Oncology and Haematology, Castle Hill Hospital, Hull & East Yorkshire Hospitals NHS Trust, Castle Road, Hull, HU16 5JQ, United Kingdom
[3] Faculty of Science, University of Hull, Cottingham Road, Hull, HU6 7RX, United Kingdom
[4] Medical Physics Department, Portsmouth Hospitals NHS Trust, Portsmouth, PO6 3LY, United Kingdom
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[9] Medical Physics Department, St James's Institute for Oncology, Leeds, LS9 7TF, United Kingdom
[10] Medical Physics Department, Cambridge University Hospitals NHS Foundation Trust, Cambridge CB2 0QX, United Kingdom
[11] Medical Physics, Velindre NHS Trust, Velindre Road, Whitchurch, Cardiff, CF14 2TL, United Kingdom

E-mail: tim.wood@hey.nhs.uk

CT Planning scans in Radiotherapy




IPEM Institute of Physics and Engineering in Medicine

The first UK survey of doses from radiotherapy treatment planning CT scans for adult patients

Tim Wood, Anne Davis, James Earley, Sue Edyvean, Una Findlay, Rebecca Lindsay, Rosy Plaistow, Andrew Nisbet, Antony Palmer, Matt Williams

Working party of Radiotherapy & Diagnostic Radiology Special Interest Groups

Radiotherapy and diagnostic physicists

- **Clinical examination**
- **Reference values not strictly DRLs**

→ National Reference Values

CT Planning scans – Reference Values

(3rd quartile)

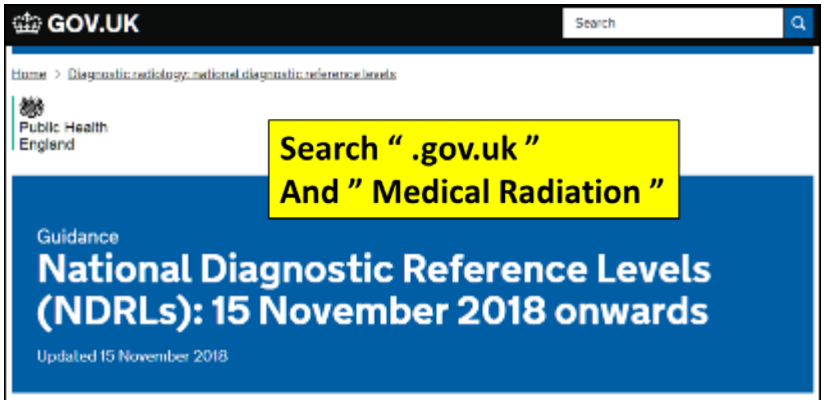
Examination	Phantom diameter (cm)	$CTDI_{vol}$ (mGy)	DLP (mGy.cm)	Scan length (mm)
Breast	32	10	390	360
Gynaecological	32	16	610	400
Lung 3D	32	14	550	390
Lung 4D	32	63	1750	340
Prostate	32	16	570	340
Brain	16	50	1500	290
Head and neck	16	49	2150	420

www.ipem.ac.uk

IPEM Institute of Physics and Engineering in Medicine

Public Health England

NDRLs – published November 2018



- CT cervical spine (update)(PHE)
- **CT coronary angiography CT (BSCI)**
- **CT in NM PET-CT, SPECT-CT (IPEM)**
- **CT in RT planning (IPEM)**
- **Mammography Screening (NCCPM, National BSQA Physics)**

- ***Acknowledgements and thanks:***
  - *Holroyd and Edyvean British Journal of Radiology. 2018;91:20170834*
  - ***Castellano et al Journal of Cardiovascular Computed Tomography. 2017;11:268 to 273***
  - ***Iball et al: Nuclear Medicine Communications. 2017;38(6):459 to 470***
  - ***Wood et al. Physics in Medicine and Biology 2018;63:185008***
  - ***Oduko and Young: Breast Imaging, 13th International Workshop, IWDM 2016 Malmö, Sweden, June 2016, Proceedings / Young and Oduko British Journal of Radiology 2016; 89***

2c. Adult CT examinations as part of PET-CT and SPECT-CT examinations

Examination	Clinical indication	Scan region / technique	CTDIvol per sequence (mGy)	DLP per complete examination (mGy cm)
PET half body	attenuation correction and localisation of the nuclear medicine signal	All sequences	4.3	400
SPECT bone scan	attenuation correction and localisation of the nuclear medicine signal	All sequences	4.9	150
SPECT parathyroid	attenuation correction and localisation of the nuclear medicine signal	All sequences	5.6	170
SPECT post-thyroid ablation	attenuation correction and localisation of the nuclear medicine signal	All sequences	5.9	210
SPECT mIBG/octreotide	attenuation correction and localisation of the nuclear medicine signal	All sequences	5.5	240
SPECT cardiac	attenuation correction	All sequences	2.1	36

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

Values taken from Iball, G.R. and others. A national survey of computed tomography doses in hybrid PET-CT and SPECT-CT examinations in the UK. Nuclear Medicine

Radiotherapy Planning CT Scans

Radiotherapy planning CT scans are not considered diagnostic scans, and therefore the use of the term Diagnostic Reference Levels is not appropriate. However, the use of dose reference levels is a useful method of demonstrating dose optimisation has taken place. The following table provides dose index values, which can be taken to be equivalent to formal NDRLs.

Examination	CTDIvol per sequence (mGy)	DLP per complete examination (mGy cm)	Scan length (mm)
Breast	10	390	360
Gynaecological	16	610	400
Lung 3D	14	550	390
Lung 4D	63	1750	340
Prostate	16	570	340
Brain	50	1500	290
Head and Neck	49	2150	420

Doses for the brain and 'head and neck' examinations only refer to measurements in the 16cm standard CT dosimetry phantom. All other doses refer to measurements in the 32cm standard CT dosimetry phantom.

Values taken from Wood T.J. and others. IPEM topical report: the first UK survey of dose indices from radiotherapy treatment planning computed tomography scans for adult patients. Physics in Medicine and Biology 2018;63:185008.

Public Health England

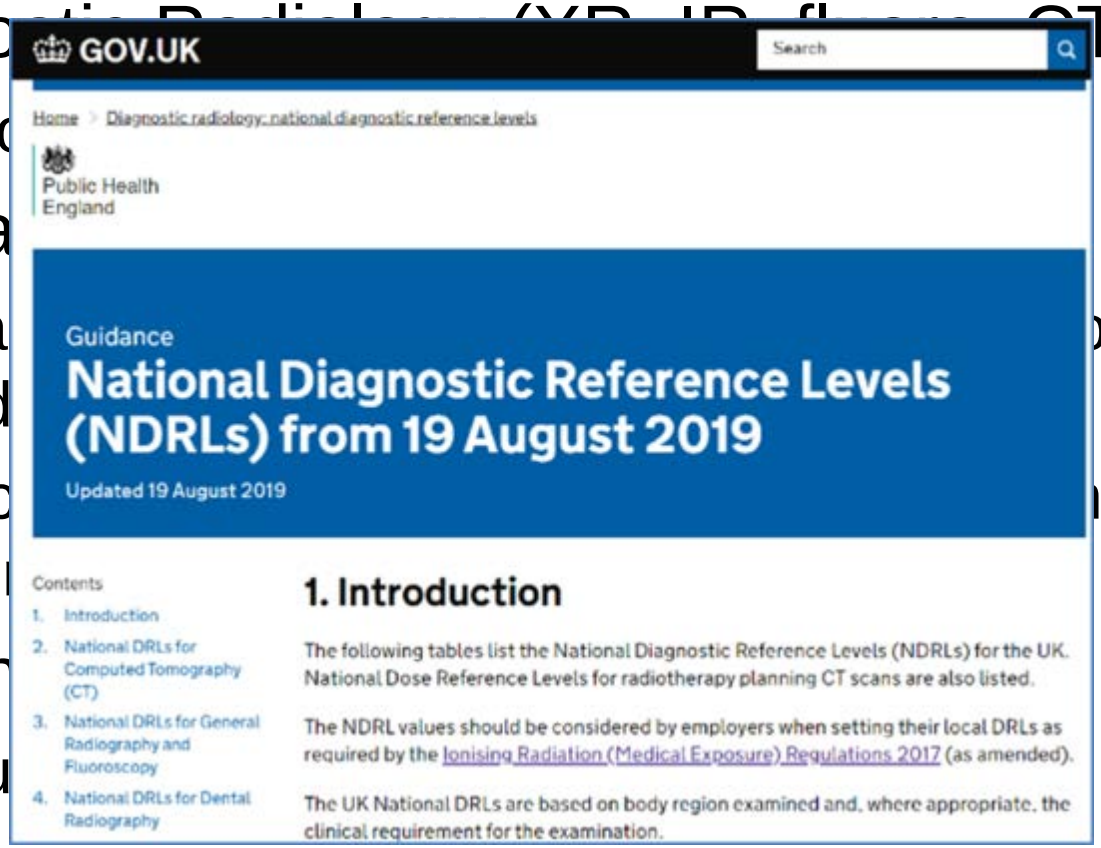
National DRLs across modalities established by different approaches:

- Diagnostic Radiology (XR, IR, fluoro, CT, dental)
  - From national dose audits – third quartile
- Nuclear Medicine injected radioactivity
  - Values set by clinical experts, ARSAC Government Advisory group (secretariat PHE)
  - local adaptation to weight allowed and implemented by some centres
- Screening Mammography
  - Survey based, maximum value assigned

Public Health England

NDRLs across modalities established by different approaches:

- Diagnostic Radiology (XR, IR, fluoro, CT, dental)
  - Fr
- Nuclea
  - Va … overnment Ad
  - loc … mplemented by so
- Screen
  - Su


GOV.UK

Search

Home > Diagnostic radiology: national diagnostic reference levels

Public Health England

Guidance

National Diagnostic Reference Levels (NDRLs) from 19 August 2019

Updated 19 August 2019

Contents

1. Introduction
2. National DRLs for Computed Tomography (CT)
3. National DRLs for General Radiography and Fluoroscopy
4. National DRLs for Dental Radiography

1. Introduction

The following tables list the National Diagnostic Reference Levels (NDRLs) for the UK. National Dose Reference Levels for radiotherapy planning CT scans are also listed.

The NDRL values should be considered by employers when setting their local DRLs as required by the Ionising Radiation (Medical Exposure) Regulations 2017 (as amended).

The UK National DRLs are based on body region examined and, where appropriate, the clinical requirement for the examination.

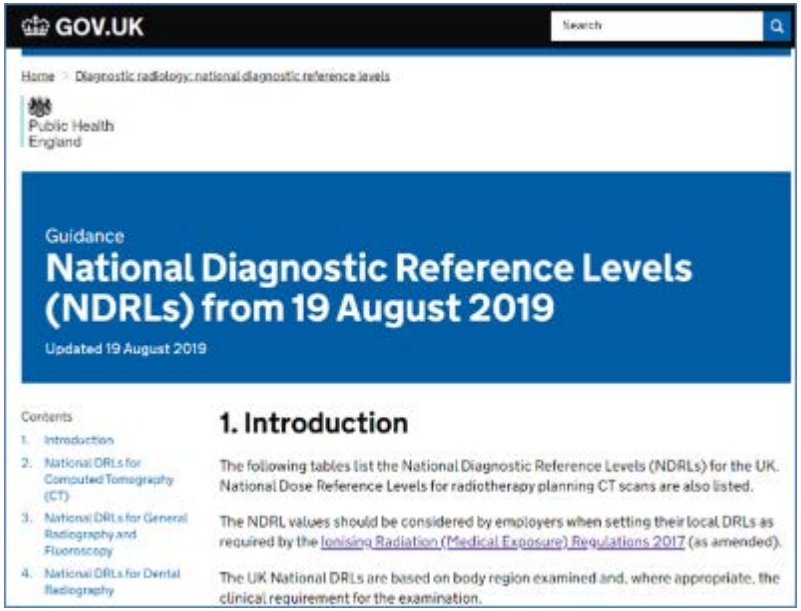
Search " .gov.uk "
And " Medical Radiation "

NDRLs – published August 2019

- Dental (PHE survey)
  - new values added for cephalometric and CBCT imaging
  - Intra-oral and panoramic values have decreased

The report detailing the new values published at **https://www.gov.uk/government/publications/dental-radiographic-x-ray-imaging-dose-to-patients**

X-ray type	Patient size (clinical indication)	Proposed NDRL
Intra oral	Adult mandibular molar	1.2 mGy
	Child mandibular molar	0.7 mGy
Panoramic	Adult full jaw	81 mGy.cm^2
	Child full jaw	60 mGy.cm^2
Cephalometric	Adult lateral	35 mGy.cm^2
	Child lateral	24 mGy.cm^2
Dental CBCT	Adult (imaging prior to placement of a maxillary molar implant)	265 mGy.cm^2
	Child (imaging of an impacted maxillary canine of a 12 year old child)	170 mGy.cm^2



Public Health England

Current National Dose Audits - 2019

		Modality		Launch	'Closing …'	
^	1	CT	Adult	20th March	End of Oct*	PHE
^	2	CT	Paediatric	6th June	End of Dec*	IPEM/PHE
	3	Planar X-Ray	Adult	17th April	End of Dec*	PHE
	4	IR and F			*	PHE

Cone beam CT (CBCT) in RT (IPEM) – just launched

CT priority
Revised end dates

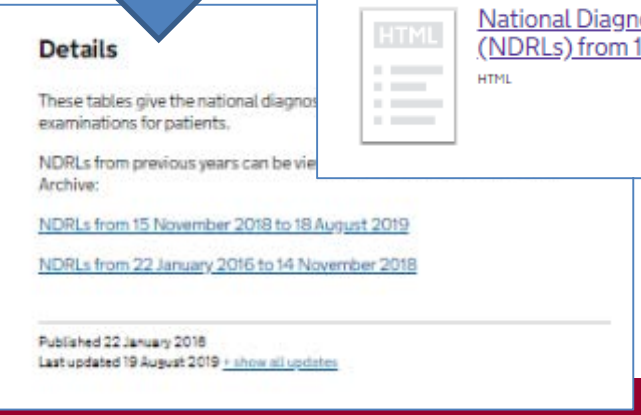
- Contacts:
  - PHE :
    - medicalradiationdoses@phe.gov.uk (Jenny Smith, John Holroyd, Sue Edyvean)
  - IPEM Paediatric survey (IPEM/PHE):
    - To submit data, email ipem.paed.optimisation@gmail.com.
    - For any queries, email markworrall@nhs.net.

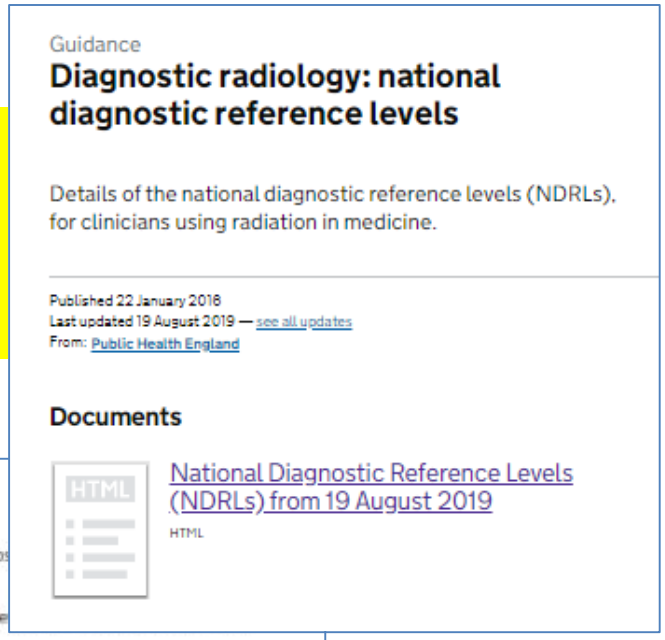
Endorsed CPD Now

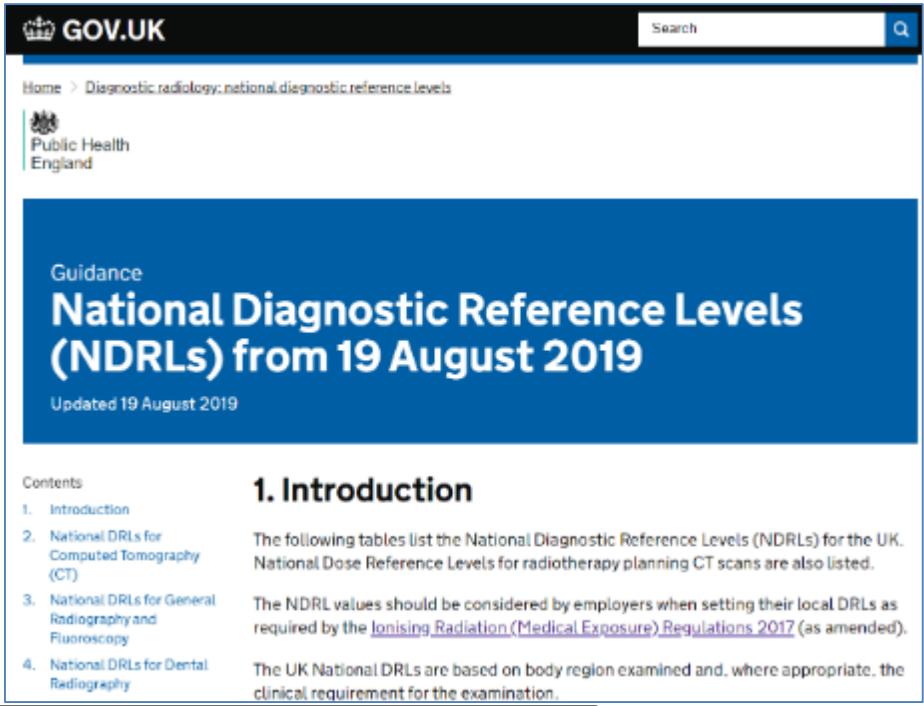
NDRLS – where to find them

- Go to " .gov.uk" and search for medical radiation doses or NDRLs
- **https://www.gov.uk/government/publications/diagnostic-radiology-national-diagnostic-reference-levels-ndrls**

Previous dated pages







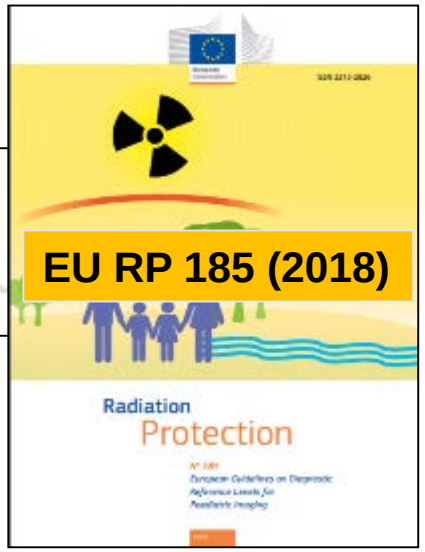
Search " .gov.uk "
And " Medical Radiation " **or "NDRLS"**

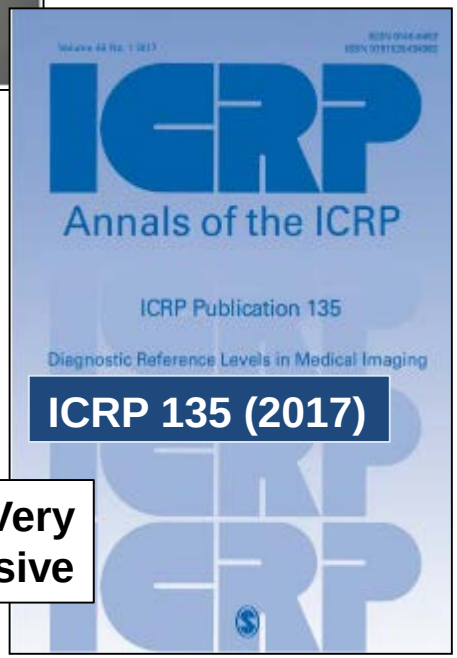
Public Health England

Sources of Information

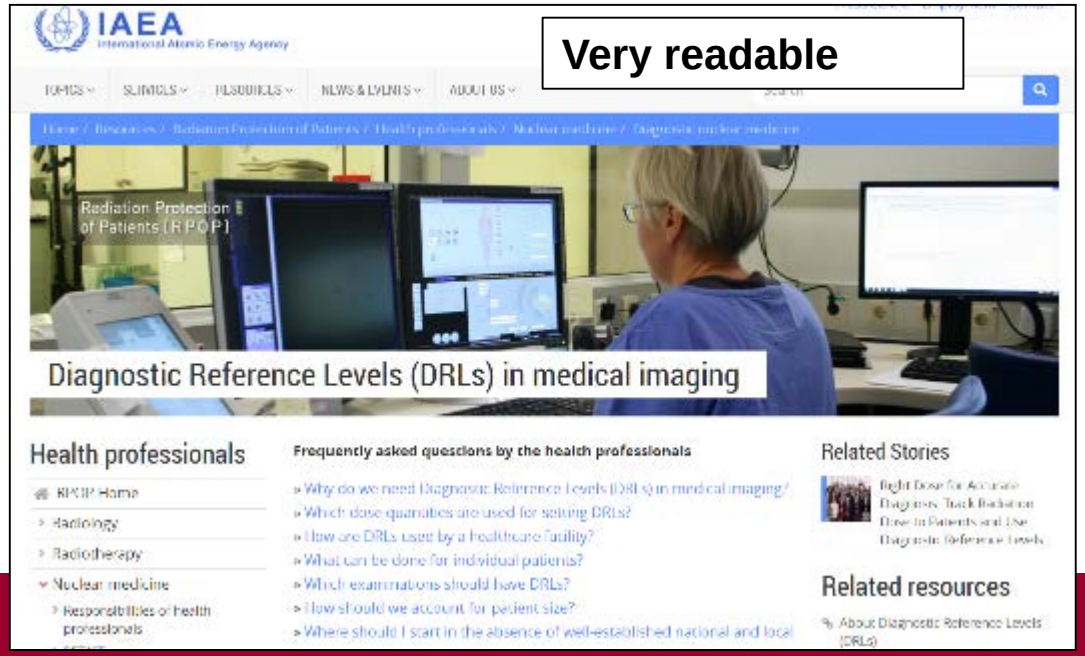
Very detailed, thorough and practical – *currently being updated*

Paediatrics





Very comprehensive



Very readable

Public Health England

IAEA International Atomic Energy Agency

DRLs in Action – UK Experience

ICTP-IAEA Workshop on Establishment and Utilization of Diagnostic Reference Levels in Medical Imaging Imaging (smr3333):
18-22 November 2019 **Trieste, Italy**

Sue Edyvean

Senior Scientific Group Leader
Medical radiation Dosimetry, CRCE
Public Health England
Didcot, Oxon. OX11 0RQ, UK

Public Health England

Approaches by Other Countries

Public Health England

Australian Government
Australian Radiation Protection and Nuclear Safety Agency

Welcome to the

National Diagnostic Reference Level Database

The aim of the National Diagnostic Reference Level Database (NDRLD) project is to work with the medical and paramedical professions to ensure the most effective use of ionizing radiation in diagnostic imaging by undertaking surveys of patient exposures to assist in establishing Australian Diagnostic Reference Levels.

This portal will be used as a means of undertaking these surveys, initially starting with multidetector computed tomography (MDCT).

This portal has been developed by, and is operated and maintained by, the Australian Radiation Protection And Nuclear Safety Agency (ARPANSA).

Please refer to the following information before you register for the NDRLD.

Before you Register

Please login to the NDRLD website

Username

Password

Login

Forgotten Username and/or Password?

If this is your first time to this site then please register to obtain your username and password

Register

Courtesy: A. Wallace ARPANSA

Australian Government
Australian Radiation Protection and Nuclear Safety Agency

Survey Structure

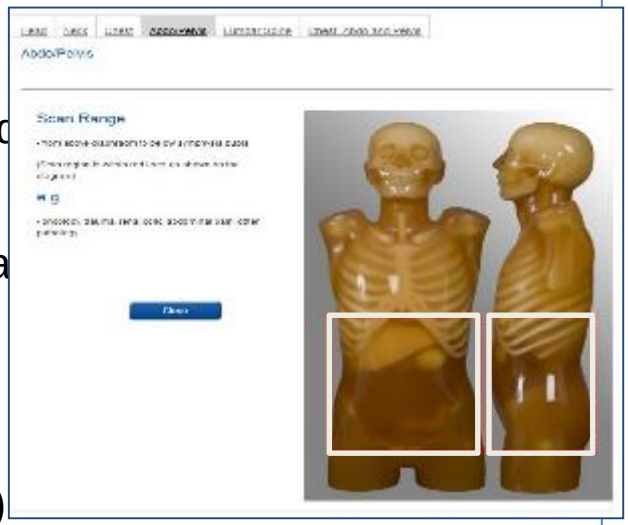
Registration

LSPN (Location Specific Practice Number)

- Public or Private or combination (4)

Contacts (3)

- Radiologist
- Manager/Rad
- Data entry
  - CT pla



Survey

Age cohort (3)

Body habitus (6)

Protocol

Platform

20 patients

- $CTDI_{vol}$, DLP, Weight, Age, Sex

Practice report

Australian National Diagnostic Reference Level Survey

Practice Name Healthcare Imaging Knox

Protocol	Abdo/Pelvis	Age Group	Adult
Machine	Siemens SOMATOM Definition AS+	Start Date	April 1st 2011
	Radiology CT	End Date	April 20th 2011

kVp	140	Rotation Time	0.8	Helical/Axial	Axial
mAs	100	Dose Modulation	YES	Reconstruction Slice Width	2
Pitch	1	No. of Phases	1		
Contrast	NO	Scan Field of View	25	Noise Index	2.2
Beam Shaping Filter		Reconstruction Algorithm/Kernel		Detector Configuration	
Nil		Standard		16 X	0.6

Comments
This is a non contrast abdopelvis done according to protocol one blah blah blah

Patient	DLP	CTDIvol	Patient Weight	Patient Age	Patient Sex
1	410	7	60	35	M
2	252	6	77	42	M
3	556	11	52	61	F
4	1431	27	75	22	F
5	1328	25	86	41	F
6	587	12	68	45	M
7	1346	25	63	58	F
8	1188	22	67	84	F
9	1487	26	83	80	F
10	1898	33	95	75	M
11	362	7	78	65	M
12	345	7	72	39	F
13	292	6	70	61	M
14	549	11	69	62	M
15	926	15	70	62	M
16	440	8	67	69	F
17	423	8	50	32	F
18	467	7	49	80	M
19	490	9	70	74	M
20	510	10	70	36	F

DRL Practice Report Pages

Australian Government

Australian Radiation Protection and Nuclear Safety Agency

Australian National Diagnostic Reference Level Survey

Diagnostic Imaging & Nuclear Medicine Section, 619 Lower Plenty Road, Yallambie, 3085.

Report For: Healthcare Imaging Services Knox

Protocol: Abdo/Pelvis — Age Group: Adult

Machine: Siemens SOMATOM Definition AS+ Radiology CT — Start Date: April 1st 2011 — End Date: April 20th 2011

Survey Outcome

Dose Metric	PRL	Australian Adult DRL	Comment
DLP	526	700	Your practice falls within the Australian Adult DRL.
$CTDI_{vol}$	21	15	Your PRL is greater than the Australian Adult DRL. Unless clinically justified the implementation of an optimisation process is recommended. Information on optimisation can be found on the ARPANSA website www.arpansa.b'a.b'a.b'a

Australian Adult MDCT DRLs

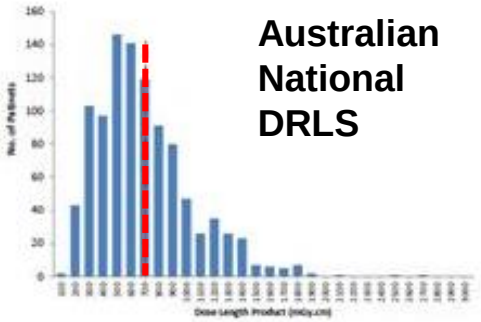
Protocol	DLP (mGy.cm)	$CTDI_{vol}$ (mGy)
Head	1000	60
Neck	600	30
Chest	450	15
AbdoPelvis	700	15
ChestAbdoPelvis	1200	30
Lumbar Spine	900	40

PO Box 655 MIRANDA NSW 1490 Phone +61 2 9541 8333 — E-mail: ndrls@arpansa.gov.au Free call: 1800 something (a free call from fixed phones in Australia) Web: www.arpansa.gov.au — 619 Lower Plenty Road YALLAMBIE VIC 3085 Phone +613 9433 2211

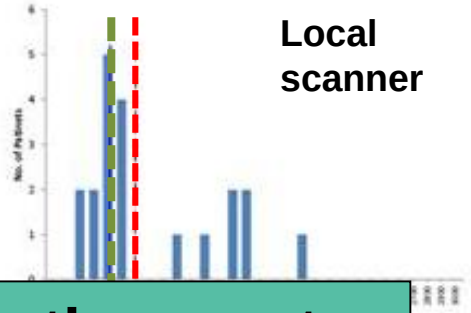
Australian National Diagnostic Reference Level Survey

Australian National Diagnostic Reference Level Survey

Dose Length Product (DLP)



Australian National DRLS



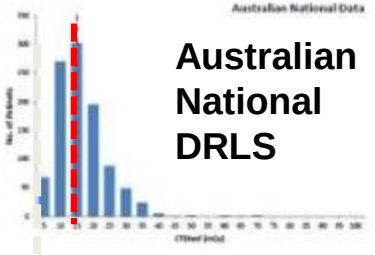
Local scanner

Page 2 of 4

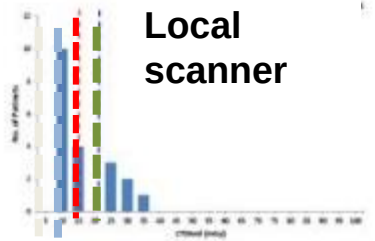
Australian National Diagnostic Reference Level Survey

Computed Tomography Dose Index $_{Volume}$ ($CTDI_{vol}$)

Australian National Data



Australian National DRLS



Local scanner

Carl-Magnus Larsson
CEO
ARPANSA

If you have any enquiries about this report please contact the Diagnostic Imaging and Nuclear Medicine Section at ARPANSA.
Email: ndrls@arpansa.gov.au
Phone: 1800 033 672

Page 3 of 4

Automatic report – as soon as 20 patients entered

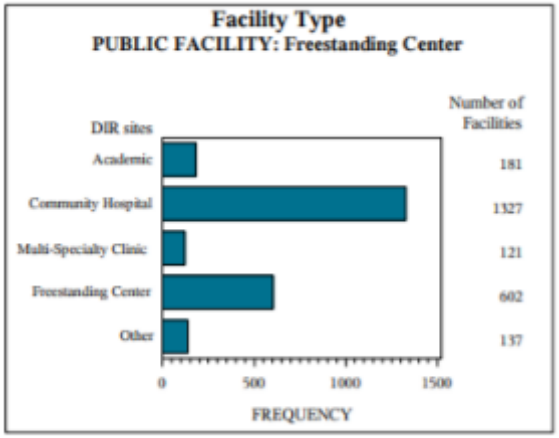
Public Health England

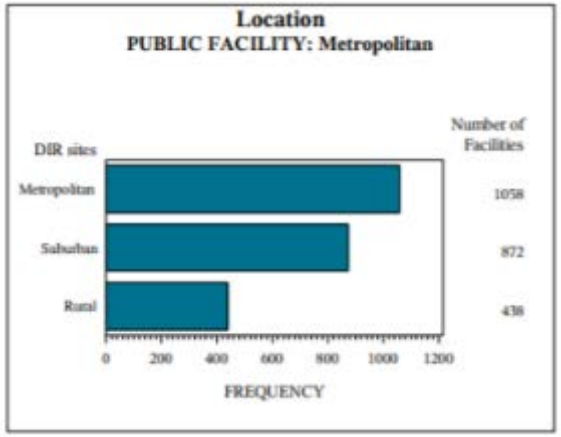
ACR Dose Registry

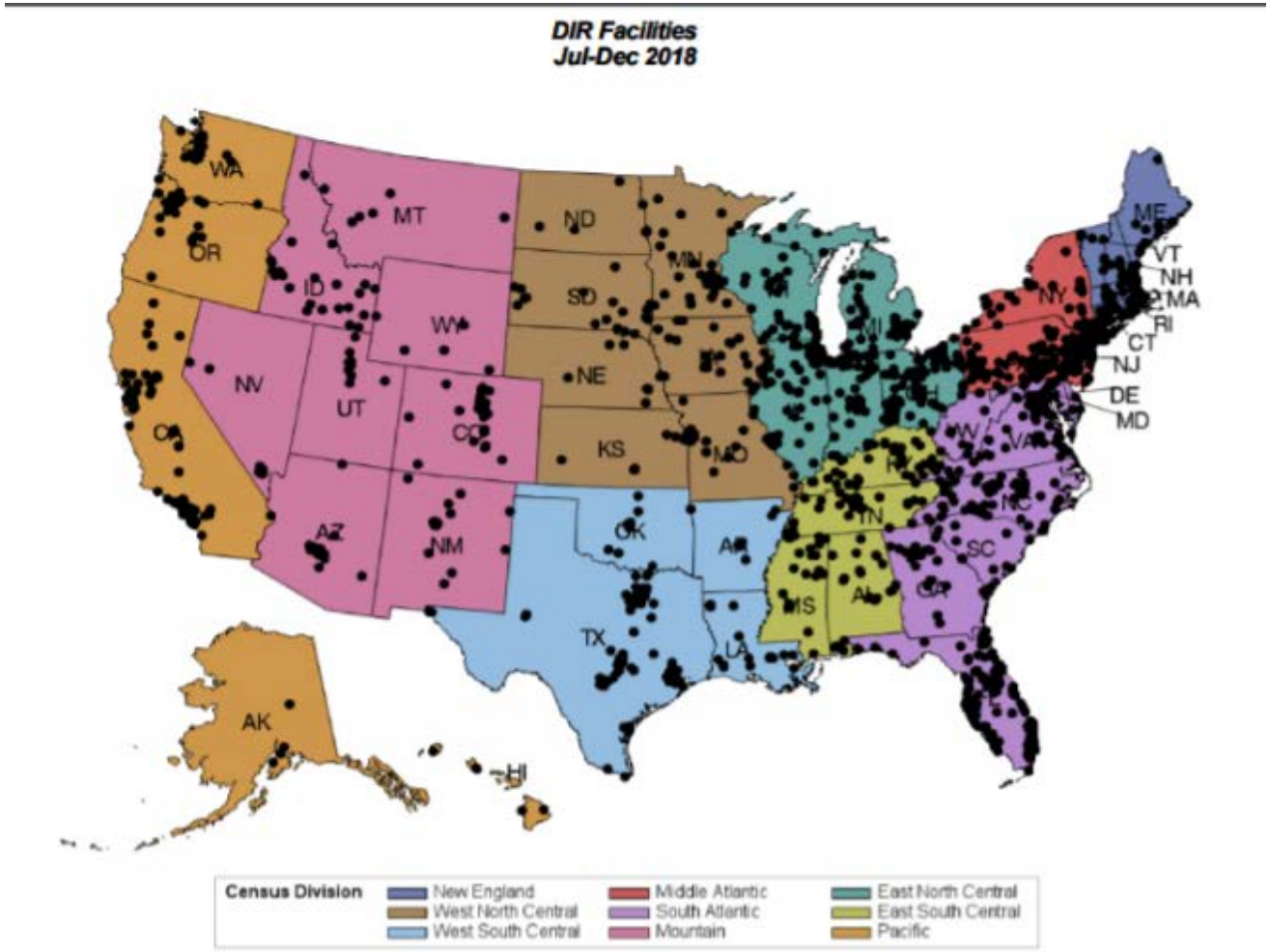
- **Pay to join**
- **Some software installed on a PC**
- **All patient data sent to PC – anonymised**
- **All patient data sent to registry**

Public Health England

ACR National Radiology Data Registry

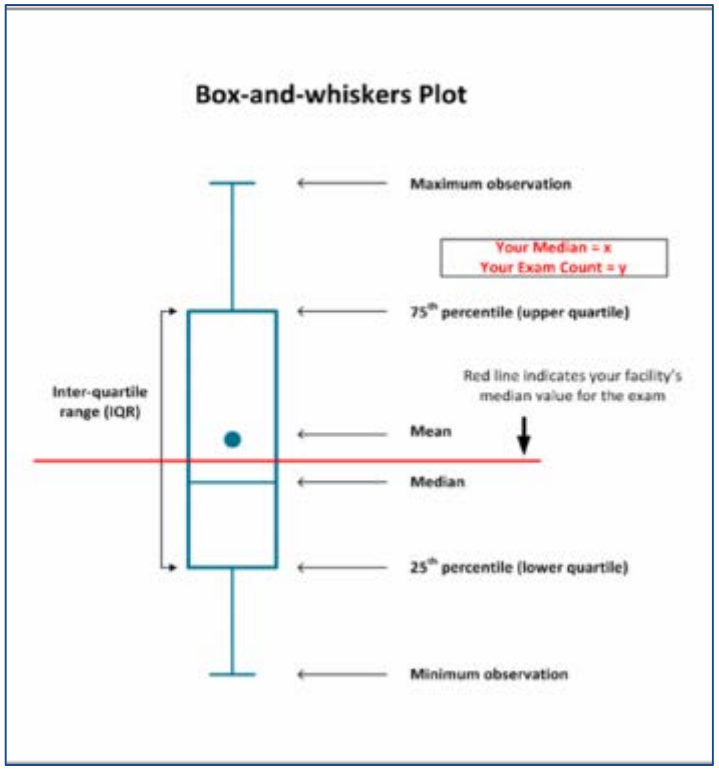


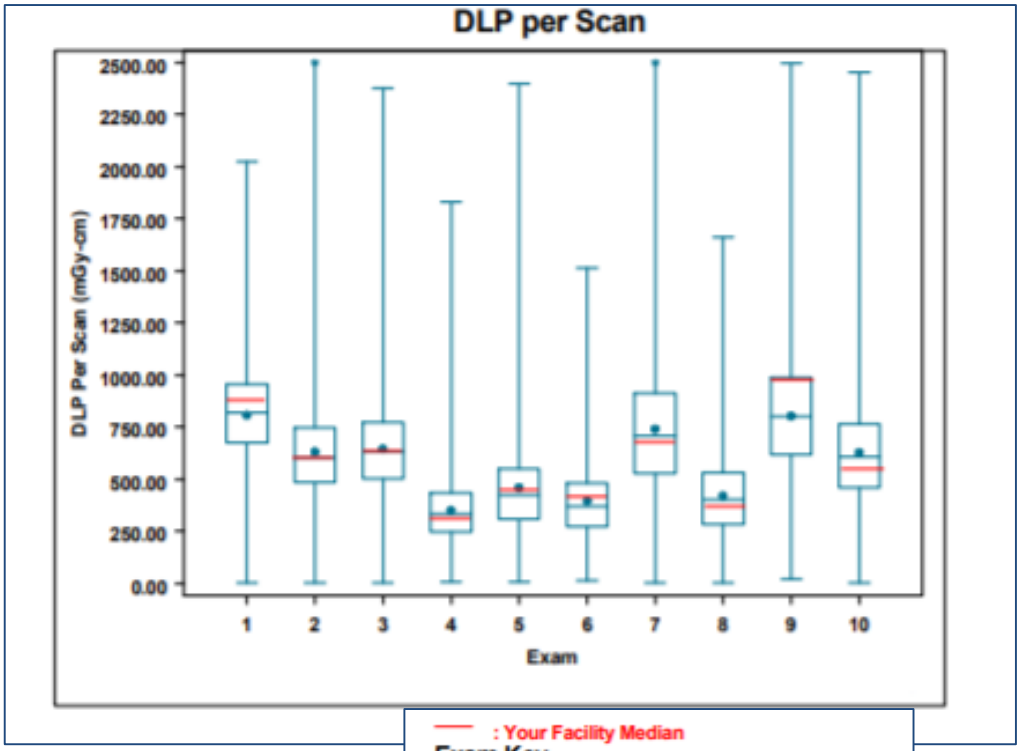




Public Health England

Your Facility's Performance on the 10 High Volume DIR Exams (Adult)





: Your Facility Median

Exam Key

1 = CT HEAD BRAIN WO IVCON
2 = CT ABDOMEN PELVIS W IVCON
3 = CT ABDOMEN PELVIS WO IVCON
4 = CT CHEST WO IVCON
5 = CT C SPINE WO IVCON
6 = CT CHEST W IVCON
7 = CT CHEST ABDOMEN PELVIS W IVCON
8 = CT CHEST PULMONARY ARTERIES W IVCON
9 = CT HEAD
10 = CT ABDOMEN PELVIS KIDNEY WO IVCON

Visual result incorporating all the examinations

*Extreme outliers were excluded for this exam for optimal presentation.