Feidhmeannacht na Seirbhíse Sláinte
Health Service Executive

QUALITY ASSURANCE AND VERIFICATION DIVISION

Tús Áite do Shábháilteacht Othar
Patient Safety First

MEDICAL EXPOSURE RADIATION UNIT (MERU)

NATIONAL SURVEY ON POPULATION DOSE FROM COMPUTED TOMOGRAPHY 2017

Our Values
Care Compassion Trust Learning

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MERU National Survey on Population Dose from Computed Tomography, 2017

Executive Summary of Results

The National Radiation Safety Committee (NRSC), under Statutory Instrument (SI) 478 (2002), is required to collect and publish statistics on population dose exposure levels from the use of medical ionising radiation. To meet this obligation a national survey of Computed Tomography (CT) activity for 2016 was undertaken by the Medical Exposure Radiation Unit (MERU) of the Health Service Executive, on behalf of the National Population Dose and Optimisation Sub-committee. The aims of the survey were to determine the total collective dose of radiation to patients nationally from the use of CT and to enhance patient safety through promoting the principle of optimisation using a concept called Diagnostic Reference Levels. A diagnostic reference level can be used (a) to improve a regional, national or local distribution of observed results for a general medical imaging task, by reducing the frequency of unjustified high or low values; (b) to promote attainment of a narrower range of values that represent good practice for a more specific medical imaging task; and (c) to promote attainment of an optimum range of values for a specified medical imaging protocol (ICRP. 2017).

The objectives were to identify the median dose administered for the most frequently performed CT procedures in both paediatric and adult services, and to inform national diagnostic reference levels (DRLs) for the most common CT procedures. This survey aimed to generate age and gender based population dose and diagnostic reference level information included for in the European Basic Safety Standard Directive EU 59/13 which will become law in Ireland in 2018. A substantial section was devoted this time to surveying paediatric CT scanning. The availability of Dose Modulation and/or Iterative Reconstruction software was also surveyed. A novel approach to optimisation involving the generation of clinical indication based diagnostic reference levels has also been adopted by the survey. This moves toward the idea that there is an optimum dose for a clinical question to be answered rather than a body part. This approach, adopted by the International Commission on Radiation Protection (ICRP) is being developed by professional bodies in Europe such as the European Society of Radiology's (ESR) Eurosafe imaging program as a consequence of the International Atomic Energy Agency's Call for Action on radiation protection in medicine.

In total, 60 locations were issued the survey and 49 respondents representing 54 separate centres (90%) and 64 actual scanners nationally made appropriate electronic returns within the specified timeframe. This was considered a positive response and provided a good representation of current practice nationally in relation to CT activity.

Respondents indicated that the total number of CT scans performed on patients in 2016 for the specified examinations included in the survey was 361,132 patients. The number of scans absent from the returned data was estimated at 41,171 giving a total figure of 402,303. This is an increase of 190,608 on the total number of CT scans recorded in the previous Population Dose Report of 2010 which cited 211,728 for the categories surveyed. This broadly represents a 90% increase in activity but consideration must be given to the differences in categories between the two surveys.

The survey found there to be 64 scanners who returned data and a further 6 known scanners for a population of 4.76 million which equates to 14.7 scanners per million of the population. This is in line with previous estimates which had 65 scanners equating to 15 scanners per million of the population.

Diagnostic reference levels (DRLs) were updated for common Adult and Paediatric CT examinations.

The Collective Effective Dose was determined to be 1,388 Person Sievert after the inclusion of estimated data, which compares to the 1,368 Person Sievert of the 2010 report. This would indicate that the increase in number of examinations has been offset by improvements in dose software and scanning parameters in maintaining the Collective Effective Dose.

The Dose per Caput was found to be 0.32 mSv per head of the population before the inclusion of the estimated data. This is in line with the previously established Dose per Caput of the last Population Dose Survey which was 0.31 mSv per head of the population. Including the estimated data the Dose per Caput was found to be 0.38 mSv per head of the population.

Introduction

The National Radiation Safety Committee (NRSC), under Statutory Instrument (SI) 478 (2002), is required to collect and publish statistics on population dose exposure levels from the use of medical ionising radiation. To meet this obligation on an annual basis, the National Population Dose and Optimisation Subcommittee of the NRSC choose a different diagnostic modality each year and review the dose administered to the population from that procedure.

A national survey of Computed Tomography (CT) activity for 2016 was undertaken by the Medical Exposure Radiation Unit (MERU) of the Health Service Executive, on behalf of the National Population Dose and Optimisation Sub-committee. International studies in recent years have highlighted that medical exposure from CT is increasing with the development of new technology and the application of CT in a wider range of diagnostic interventions[1].

The aims of the survey were to determine the total collective dose of radiation to patients nationally from the use of CT and to enhance patient safety through promoting the principle of optimisation. The objectives were to identify the median dose administered for the most frequently performed CT procedures in both paediatric and adult services, and to inform national diagnostic reference levels (DRLs) for the most common CT procedures.

All data submitted was treated as confidential and individual locations were not identified.

Methodology

The survey was developed using the *Survey Monkey* platform and piloted across a small number of sites to ensure it was fit for purpose. Subsequent amendments to the tool were made and the survey was issued by MERU to all public and private radiological locations nationwide, with a one month return deadline. This deadline was later extended to two months due to technical difficulties experienced by healthcare locations nationwide as a consequence of the WannaCry virus which limited access to the internet. The link to *Survey Monkey* was uploaded to the MERU website and the MERU website link was circulated directly to each location to ensure that there were no access issues.

The survey was to be completed by the relevant personnel in the radiology department, such as the radiation safety officer, radiographic services manager or medical physics expert, and the data returned was to be verified and signed off by the practitioner in charge.

The survey consisted of two sections: completing Part One was mandatory and concerned Population Dose, whereas Part Two was optional and concerned DRLs. The information required to inform DRLs could be deduced from the figures detailed in Part One if people chose not to complete Part Two.

[1] Dose Data Med 2 Project Report on European Population Dose Estimation, 2010

As per European guidelines for analysis of CT doses, locations were requested to identify the median dose delivered by every scanning machine for each of the most common procedures performed in adult and paediatric services, as listed in the figure below:

Figure 1: Most common CT procedures performed in adult and paediatric services

Most common CT procedures performed in adult and paediatric services	
Adult CT procedures	Brain; Cervical Spine; High Resolution Thorax; CTPA; Thorax-Abdomen-Pelvis; Abdomen-Pelvis; Kidney-Urethra-Bladder; Other
Paediatric CT procedures	Brain: 0-3months, 3-12months, 1-6 years Thorax: <5kg or neonate, 5-15kg, 16-30Kg, 31-50Kg Abdomen-Pelvis: <5Kg or neonate, 5-15Kg, 16-30Kg, 31-50Kg Other

A guidance document entitled *'Answers to the most frequently asked questions when completing the survey'* was developed by the National Population Dose and Optimisation Subcommittee and circulated by MERU, together with an Excel spreadsheet to assist in the calculation of the median dose. The spreadsheet contained designated pages for each CT procedure and broke the information down further to male, female and paediatric categories. It also explained the rationale for the data collection, together with the acronyms associated with the survey and provided a step by step process to encourage a positive response.

In Part One, participants reviewed CT activity for 2016 and selected 60 procedures, divided into 30 male and 30 female. They listed the median dose delivered by each scanning machine for the selected type of procedure and ensured that the selection represented the routine procedures undertaken in the facility. In Part Two, data on clinical DRLs was requested based on clinical indications rather than anatomical area. Clinical DRLs took into account that the same imaging quality and dose was not required for all imaging of the same anatomical area. The figure below details the thirteen most common presenting complaints that require a CT imaging procedure and these were chosen for review of DRLs. The selection of these clinical indications was based on discussions of the Population Dose Committee with input from members of the European Society of Radiology radiation safety committee (J. Damalakis, Personal Communication).

Figure 2: Most common presenting complaints that require a CT imaging procedure

Most common presenting complaints that require a CT imaging procedure	
Chronic Sinusitis	Coronary Angiography Retrospective Gating
Acute Head Injury	Coronary Angiography Prospective Gating
Cervical Spine Trauma	Chest – Abdomen – Pelvis Oncologic Follow-up
Total body CT in Severe Trauma	Abdomino-pelvic CT for Liver and Abdominal Metastases in Colorectal Cancer
Pulmonary Embolus	Appendicitis
Pulmonary Metastases	Urinary Calculus
Diffuse Infiltrative lung Disease	

The following sections outline the findings from the survey, the analysis of the data and subsequent conclusions:

1. Survey Section One: Analysis of Respondents
2. Survey Section Two: Analysis of Population Dose Examinations
3. Survey Section Three: Analysis of Dose Reference Level Examinations
4. Survey Section Four: Analysis of Paediatric Population Dose Examinations
5. Survey Section Five: Analysis of Adult Dose Modulation and Iterative Reconstruction
6. Survey Section Six: Analysis of Paediatric Dose Modulation and Iterative Reconstruction
7. Survey Section Seven: Establishing Diagnostic Reference Levels
8. Survey Section Eight: Establishing Population Dose

Survey Section One: Analysis of Respondents

In total, 60 locations were issued the survey and 49 respondents representing 54 separate centres (90%) and 64 actual scanners nationally made appropriate electronic returns within the specified timeframe. This was considered a positive response and provided a good representation of current practice nationally in relation to CT activity. The data submitted was used to update the national DRLs for the common procedures listed previously in Figure 2.

The scanners types are shown in Table 1 below. Year of installation of scanner ranged from 2003 to 2016 with a median installation year of 2009 as shown in Table 2. The availability of Dose Modulation and/or Iterative Reconstruction software is depicted in Table 3.

Table 1: Scanner Type

Scanner Type	Quantity
Siemens	27
Toshiba	10
GE	11
Philips	14

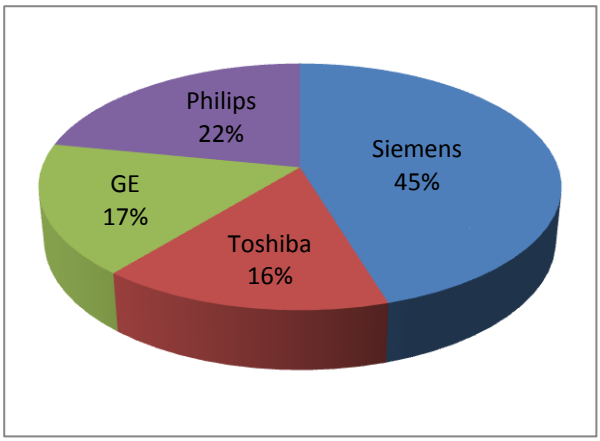
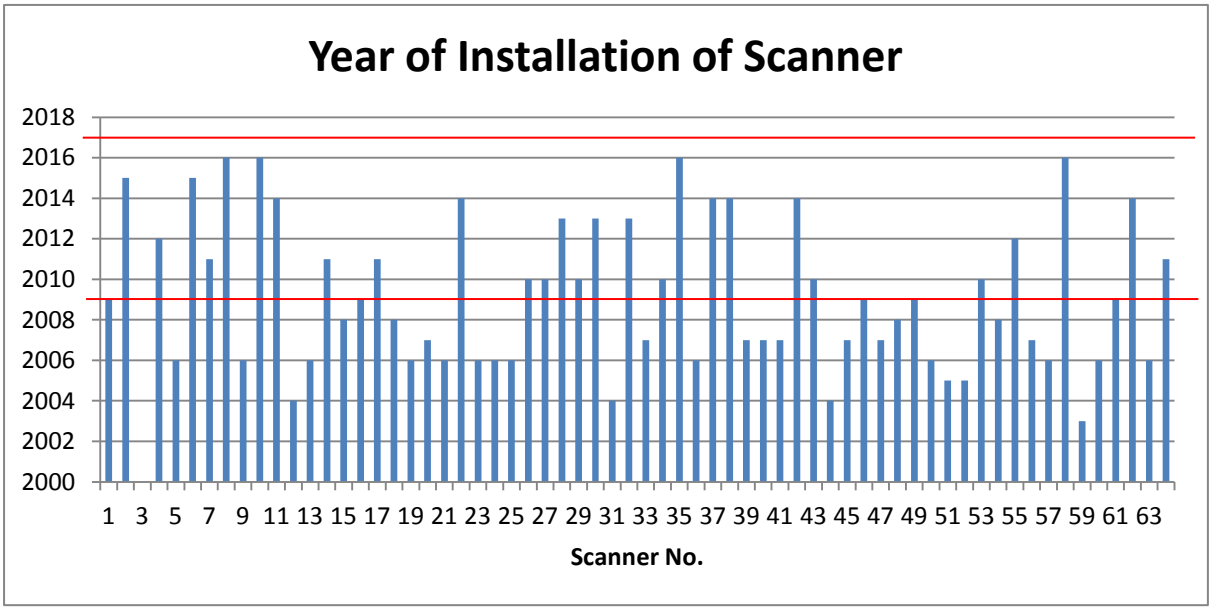


Table 2: Year of Installation of Scanner (red line denotes HSE recommendation of 8 year review)



Scanner	Installation
Min Value	2003
Max Value	2016
Median	2009
Average	2009
75% percentile	2012

Table 3: Availability of Dose Modulation and Iterative Reconstruction software

Dose Modulation	Iterative Reconstruction	Both
Yes	Yes	Yes
59	31	29
No	No	No
4	31	33
Blank	Blank	Blank
1	2	2

Patient Numbers and Gender Distribution

Respondents indicated that the total number of CT scans performed on patients in 2016 for the specified examinations included in the survey was 361,132 patients, the breakdown of which is outlined in the table below. Tables 18 and 19 in Survey Section Eight calculate the number of scans absent from the returned data at 41,171 giving a total figure of 402,303 CT scans performed on patients in 2016. This is an increase of 190,575 on the total number of CT scans recorded in the previous Population Dose Report of 2010 which cited 211,728 for the categories surveyed. This broadly represents a 90% increase in activity but consideration must be given to the differences in categories between the two surveys. A total figure of 402,303 examinations across a population of 4,761,865 (taken from Table 16, Survey Section Eight) gives a value of 84.48 examinations per thousand inhabitants which is slightly above the OECD UK figure of 79.

Table 4: Total CT Examinations and gender distribution of patients

CT Patients for 2016				
Total CT Examinations:	Male:	Female:	Other*	Unspecified**
361,132	153,699	158,378	539	48,516
	42.56%	43.86%	0.15%	13.43%

*Other refers to patients who fall outside the categories listed, for example, transgender patients.
** Unspecified refers to where a respondent gave information regarding examination numbers and / or dose information but did not give gender information.

Adult and Paediatric Patient Distribution

Of the 64 scanners surveyed only 2 are dedicated paediatric scanners. 30 scanners accept paediatric patients with 28 of these scanning both adults and paediatrics. This is depicted in Table 5.

Table 5: Adult and Paediatric Patient Distribution

Adults Patients	Paediatric Patients	Both
Yes	Yes	Yes
62	30	28
No	No	No
2	34	36

Archiving of Dose Information to PACS

50 scanners automatically send dose information to PACS, 7 scanners do not and 7 scanners did not supply this information. This is shown in Table 6.

Table 6: Archiving of Dose Information to PACS

Archiving of Dose Information to PACS		
Yes	No	Blank
50	7	7

Sign Off on Submission of Data

The majority of respondents provided the Environmental Protection Agency licence number and details of each CT scanner. Of the 49 respondents, 44 provided some information (name and/or contact details) on who completed the submission, 41 provided some information (name and/or contact details) on the Medical Physics Expert (MPE) involved, and 43 provided some information (name and/or contact details) on the Medical Practitioner involved.

Regarding sign off on the submission of data, 34 indicated that the data was read and approved by the MPE, 2 said that the MPE had not read and approved the data and 13 left the field blank; 39 indicated that the data was read and approved by the Medical Practitioner, 3 said that the Medical Practitioner had not read and approved the data and 7 left the field blank. This is shown in Table 7.

Table 7: Sign Off on Submission of Data

Survey Completed by (Named Person)	Reviewed and approved by the MPE	Reviewed and approved by the Medical Practitioner
Yes	Yes	Yes
44	34	39
No	No	No
0	2	3
Blank	Blank	Blank
5	13	7

Survey Section Two: Analysis of Population Dose Examinations

Each category was analysed and the information arranged to produce three tables. The first table shows the following information separately for male and female patients for each specified exam:

1. The minimum and maximum number of that specific examination performed across the 64 scanners, together with the Median, the Average and the 75th percentile.
2. The minimum and maximum Median $CTDI_{vol}$ in mGy employed for that specific examination across the 64 scanners, together with the Median, the Average and the 75th percentile.
3. The minimum and maximum Median DLP in mGycm employed for that specific examination across the 64 scanners, together with the Median, the Average and the 75th percentile.
4. The total number of exams performed across the 64 scanners for that category.

The second table looks at scanner activity and patient volumes and shows the following information separately for male and female patients for each specified exam:

1. The minimum and maximum summed DLP in mGycm in that category performed across the 64 scanners, together with the Median, the Average and the 75th percentile.
2. The total summed DLP in mGycm for each category of examination.

The third table shows the following information separately for male and female patients for each specified exam:

1. The minimum and maximum % of exams in that category performed across the 64 scanners, together with the Median, the Average and the 75th percentile.

CT Cervical Spine

CT Cervical Spine: Scanner Activities

	Cervical Spine					
	Female Adults			Male Adults		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	1	5	130	3	6	145
Max Value	276	71	834	301	75	788
Median	30	15	305	30	18	369
Average	47	18	323	61	21	379
75% percentile	61	23	354	85	26	490
Total	1,643	N/A	N/A	2,186	N/A	N/A

CT Cervical Spine: Summed DLP (mGycm) per Scanner

	Cervical Spine	
	Female	Male
	Sum DLP (mGycm)	Sum DLP (mGycm)
Min Value	300	1,479
Max Value	92,315	120,664
Median	9,510	12,100
Average	16,589	25,354
75% percentile	18,400	33,099
Total	547,422	836,666

CT Cervical Spine: Scanner Gender Distributions

	Cervical Spine	
	Female	Male
	% of Exams	% of Exams
Min Value	0.0%	0.1%
Max Value	16.8%	13.8%
Median	1.8%	1.4%
Average	2.8%	2.8%
75% percentile	3.5%	3.9%
Total	100.0%	100.0%

CT Brain

CT Brain: Scanner Activities

	Brain					
	Female Adults			Male Adults		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	10	15	238	9	16	264
Max Value	5,629	138	1,100	5,629	139	1,163
Median	374	46	725	335	49	769
Average	822	51	724	805	53	778
75% percentile	1,380	56	845	1,444	57	927
Total	46,864	N/A	N/A	44,258	N/A	N/A

CT Brain: Summed DLP (mGycm) per Scanner

	Brain	
	Female	Male
	Sum DLP (mGycm)	Sum DLP (mGycm)
Min Value	6,984	7,691
Max Value	2,764,571	3,000,865
Median	240,092	233,112
Average	567,854	606,206
75% percentile	885,778	1,234,358
Total	32,367,706	33,341,318

CT Brain: Scanner Gender Distributions

	Brain	
	Female	Male
	% of Exams	% of Exams
Min Value	0.0%	0.0%
Max Value	12.0%	12.7%
Median	0.5%	0.4%
Average	1.7%	1.7%
75% percentile	2.8%	3.0%
Total	100.0%	100.0%

CT Sinuses

CT Sinuses: Scanner Activities

	Sinuses					
	Female Adults			Male Adults		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	79	9	111	78	9	116
Max Value	343	102	235	289	21	228
Median	106	21	137	98	17	147
Average	153	33	148	135	16	161
75% percentile	245	62	190	209	21	211
Total	764	N/A	N/A	674	N/A	N/A

CT Sinuses: Summed DLP (mGycm) per Scanner

	Sinuses	
	Female	Male
	Sum DLP (mGycm)	Sum DLP (mGycm)
Min Value	8,748	9,078
Max Value	39,068	34,189
Median	21,090	19,041
Average	21,236	20,699
75% percentile	32,007	31,809
Total	106,182	103,497

CT Sinuses: Scanner Gender Distributions

	Sinuses	
	Female	Male
	% of Exams	% of Exams
Min Value	10.3%	11.6%
Max Value	44.9%	42.9%
Median	13.9%	14.5%
Average	20.0%	20.0%
75% percentile	32.0%	31.0%
Total	100.0%	100.0%

CT Hi-Res Thorax

CT Hi-Res Thorax: Scanner Activities

	Hi-Res Thorax					
	Female Adults			Male Adults		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	3	1	23	1	1	31
Max Value	692	39	410	705	44	575
Median	34	7	205	38	7	293
Average	84	7	219	80	9	281
75% percentile	76	9	313	89	11	374
Total	4,175	N/A	N/A	3,991	N/A	N/A

CT Hi-Res Thorax: Summed DLP (mGycm) per Scanner

	Hi-Res Thorax	
	Female	Male
	Sum DLP (mGycm)	Sum DLP (mGycm)
Min Value	866	402
Max Value	99,302	149,108
Median	8,012	8,325
Average	13,390	16,805
75% percentile	16,475	23,842
Total	656,100	823,422

CT Hi-Res Thorax: Scanner Gender Distributions

	Hi-Res Thorax	
	Female	Male
	% of Exams	% of Exams
Min Value	0.00%	0.00%
Max Value	17.02%	18.19%
Median	0.74%	0.77%
Average	1.96%	1.96%
75% percentile	1.77%	1.96%
Total	100.00%	100.00%

CT Thorax

CT Thorax: Scanner Activities

	Thorax					
	Female Adults			Male Adults		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	21	4	93	27	5	136
Max Value	647	19	575	765	24	695
Median	147	7	265	134	7	280
Average	166	7	250	170	9	311
75% percentile	217	8	280	243	10	377
Total	2,496	N/A	N/A	2,550	N/A	N/A

CT Thorax: Summed DLP (mGycm) per Scanner

	Thorax	
	Female	Male
	Sum DLP (mGycm)	Sum DLP (mGycm)
Min Value	4,695	4,904
Max Value	170,161	216,097
Median	36,431	19,648
Average	47,982	62,176
75% percentile	60,324	80,919
Total	719,734	932,642

CT Thorax: Scanner Gender Distributions

	Thorax	
	Female	Male
	% of Exams	% of Exams
Min Value	0.84%	1.06%
Max Value	25.92%	30.00%
Median	5.89%	5.25%
Average	6.67%	6.67%
75% percentile	8.69%	9.53%
Total	100.00%	100.00%

CTPA

CTPA: Scanner Activities

	CTPA					
	Female Adults			Male Adults		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	2	2	99	2	3	99
Max Value	1,009	104	667	1,009	143	761
Median	125	10	223	90	11	271
Average	169	16	251	134	21	304
75% percentile	278	21	310	191	24	379
Total	8,624	N/A	N/A	6,697	N/A	N/A

CTPA: Summed DLP (mGycm) per Scanner

	CTPA	
	Female	Male
	Sum DLP (mGycm)	Sum DLP (mGycm)
Min Value	315	372
Max Value	296,691	327,804
Median	22,876	21,584
Average	39,292	38,925
75% percentile	59,923	54,397
Total	1,964,600	1,868,380

CTPA: Scanner Gender Distributions

	CTPA	
	Female	Male
	% of Exams	% of Exams
Min Value	0.00%	0.00%
Max Value	11.7%	15.07%
Median	1.18%	1.16%
Average	1.89%	1.89%
75% percentile	3.08%	2.78%
Total	100.00%	100.00%

CT Thorax – Abdomen – Pelvis

CT Thorax – Abdomen - Pelvis: Scanner Activities

	Thorax - Abdomen - Pelvis					
	Female Adults			Male Adults		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	5	3	215	3	4	258
Max Value	2,792	35	1,413	2,792	42	1,929
Median	274	10	554	229	12	721
Average	390	12	580	378	14	709
75% percentile	581	14	661	553	18	830
Total	21,470	N/A	N/A	20,416	N/A	N/A

CT Thorax – Abdomen - Pelvis: Summed DLP (mGycm) per Scanner

	Thorax - Abdomen - Pelvis	
	Female	Male
	Sum DLP (mGycm)	Sum DLP (mGycm)
Min Value	3,829	5,647
Max Value	1,867,694	2,122,389
Median	137,395	144,949
Average	225,090	261,728
75% percentile	311,938	378,728
Total	12,379,971	14,133,299

CT Thorax – Abdomen - Pelvis: Scanner Gender Distributions

	Thorax-Abdomen-Pelvis	
	Female	Male
	% of Exams	% of Exams
Min Value	0.00%	0.00%
Max Value	13.00%	13.68%
Median	0.90%	0.94%
Average	1.69%	1.69%
75% percentile	2.61%	2.51%
Total	100.00%	100.00%

CT Abdomen – Pelvis

CT Abdomen - Pelvis: Scanner Activities

	Abdomen - Pelvis					
	Female Adults			Male Adults		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	10	4	211	6	6	284
Max Value	2,601	16	790	2,601	21	862
Median	263	9	424	199	10	499
Average	403	9	429	370	10	503
75% percentile	709	11	533	550	12	592
Total	22,555	N/A	N/A	20,351	N/A	N/A

CT Abdomen - Pelvis: Summed DLP (mGycm) per Scanner

	Abdomen - Pelvis	
	Female	Male
	Sum DLP (mGycm)	Sum DLP (mGycm)
Min Value	2,105	3,250
Max Value	1,344,660	1,574,978
Median	104,887	98,685
Average	177,129	195,613
75% percentile	261,627	286,104
Total	9,919,218	10,758,692

CT Abdomen - Pelvis: Scanner Gender Distributions

	Abdomen - Pelvis	
	Female	Male
	% of Exams	% of Exams
Min Value	0.00%	0.00%
Max Value	11.53%	12.78%
Median	1.08%	0.73%
Average	1.69%	1.69%
75% percentile	3.07%	2.67%
Total	100.00%	100.00%

CT KUB

CT KUB: Scanner Activities

	CT KUB					
	Female Adults			Male Adults		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	8	2	91	2	3	100
Max Value	2,100	21	563	1,954	23	776
Median	54	5	219	65	6	260
Average	150	6	247	149	7	300
75% percentile	146	7	288	148	8	381
Total	5,854	N/A	N/A	5,967	N/A	N/A

CT KUB: Summed DLP (mGycm) per Scanner

	CT KUB	
	Female	Male
	Sum DLP (mGycm)	Sum DLP (mGycm)
Min Value	1,215	1,410
Max Value	1,182,090	989,896
Median	14,518	17,835
Average	53,769	53,322
75% percentile	37,071	48,008
Total	1,935,691	1,972,907

CT KUB: Scanner Gender Distributions

	CT KUB	
	Female	Male
	% of Exams	% of Exams
Min Value	0.00%	0.03%
Max Value	35.87%	32.75%
Median	0.89%	1.08%
Average	2.50%	2.50%
75% percentile	2.44%	2.47%
Total	100.00%	100.00%

Survey Section Three: Analysis of Dose Reference Level Examinations

Completion of this section was optional and an average of 7 out of 49 respondents provided information for each of the categories. Information was sought on Median $CTDI_{vol}$ in mGy and Median DLP in mGycm for each category but information was not sought on total number of examinations for each scanner.

Each category was analysed and the information arranged to produce a table. The table shows the following information separately for male and female patients for each specified clinical presentation and is presented directly below the corresponding main category from Section 2 of the survey:

1. The minimum and maximum Median $CTDI_{vol}$ in mGy employed for that specific clinical presentation across the scanners who provided information; together with the Median, the Average and the 75^{th} percentile.

2. The minimum and maximum Median DLP in mGycm employed for that specific clinical presentation across the scanners who provided information; together with the Median, the Average and the 75^{th} percentile.

This allows a comparison to be made of the Median $CTDI_{vol}$ in mGy and the Median DLP in mGycm between the main category in Section 2 and the specific clinical presentation in Section 3, to ascertain whether specific clinical presentations result in a modified CT examination.

CT for Cervical Spine Trauma

	Cervical Spine					
	Female Adults			Male Adults		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	1	5	130	3	6	145
Max Value	276	71	834	301	75	788
Median	30	15	305	30	18	369
Average	47	18	323	61	21	379
75% percentile	61	23	354	85	26	490

	Cervical Spine Trauma			
	Female		Male	
	Median CTDIvol (mGy)	Median DLP (mGycm)	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	9	261	9	233
Max Value	31	563	7	605
Median	17	376	19	437
Average	18	392	22	419
75% percentile	26	469	31	477

CT for Head Trauma

	Brain					
	Female Adults			Male Adults		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	10	15	238	9	16	264
Max Value	5,629	138	1,100	5,629	139	1,163
Median	374	46	725	335	49	769
Average	822	51	724	805	53	778
75% percentile	1,380	56	845	1,444	57	927

	Head Trauma			
	Female		Male	
	Median CTDIvol (mGy)	Median DLP (mGycm)	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	29	459	46	476
Max Value	68	943	68	971
Median	52	834	50	820
Average	52	762	54	774
75% percentile	62	918	64	927

CT for Sinusitis

	Sinuses					
	Female Adults			Male Adults		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	79	9	111	78	9	116
Max Value	343	102	235	289	21	228
Median	106	21	137	98	17	147
Average	153	33	148	135	16	161
75% percentile	245	62	190	209	21	211

	Sinusitis			
	Female		Male	
	Median CTDIvol (mGy)	Median DLP (mGycm)	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	2	40	2	49
Max Value	21	263	49	691
Median	9	100	10	125
Average	11	126	15	175
75% percentile	21	183	21	210

CT for Diffuse Infiltrate Lung Disease

	Hi-Res Thorax					
	Female Adults			Male Adults		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	3	1	23	1	1	31
Max Value	692	39	410	705	44	575
Median	34	7	205	38	7	293
Average	84	7	219	80	9	281
75% percentile	76	9	313	89	11	374

	Diffuse Infiltrate Lung Disease			
	Female		Male	
	Median CTDIvol (mGy)	Median DLP (mGycm)	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	1	31	1	34
Max Value	8	270	10	308
Median	4	98	4	125
Average	4	128	4	151
75% percentile	7	210	7	249

CT for Pulmonary Metastases

	Thorax					
	Female Adults			Male Adults		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	21	4	93	27	5	136
Max Value	647	19	575	765	24	695
Median	147	7	265	134	7	280
Average	166	7	250	170	9	311
75% percentile	217	8	280	243	10	377
Total	2,496	N/A	N/A	2,550	N/A	N/A

	Pulmonary Metastases			
	Female		Male	
	Median CTDIvol (mGy)	Median DLP (mGycm)	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	1	47	2	57
Max Value	9	256	9	365
Median	5	210	6	242
Average	5	185	6	228
75% percentile	7	241	7	272

CT for Pulmonary Embolus

	CTPA					
	Female Adults			Male Adults		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	2	2	99	2	3	99
Max Value	1,009	104	667	1,009	143	761
Median	125	10	223	90	11	271
Average	169	16	251	134	21	304
75% percentile	278	21	310	191	24	379

	Pulmonary Embolus			
	Female		Male	
	Median CTDIvol (mGy)	Median DLP (mGycm)	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	3	99	3	99
Max Value	11	248	38	400
Median	7	214	8	216
Average	7	181	11	234
75% percentile	9	234	12	278

CT Chest – Abdomen - Pelvis oncologic follow-up (single phase)

	Thorax - Abdomen - Pelvis					
	Female Adults			Male Adults		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	5	3	215	3	4	258
Max Value	2,792	35	1,413	2,792	42	1,929
Median	274	10	554	229	12	721
Average	390	12	580	378	14	709
75% percentile	581	14	661	553	18	830

	Chest-abdomen-pelvis oncologic follow-up (single phase)			
	Female		Male	
	Median CTDIvol (mGy)	Median DLP (mGycm)	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	4	256	4	283
Max Value	8	672	8	703
Median	7	517	7	510
Average	6	487	7	502
75% percentile	8	605	8	643

CT for Appendicitis and CT for liver and abdominal metastases in colorectal cancer

	Abdomen - Pelvis					
	Female Adults			Male Adults		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	10	4	211	6	6	284
Max Value	2,601	16	790	2,601	21	862
Median	263	9	424	199	10	499
Average	403	9	429	370	10	503
75% percentile	709	11	533	550	12	592

	Appendicitis			
	Female		Male	
	Median CTDIvol (mGy)	Median DLP (mGycm)	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	3	277	4	247
Max Value	10	537	10	707
Median	8	370	8	411
Average	7	388	7	418
75% percentile	9	439	10	490

	Liver and abdominal metastases in colorectal cancer			
	Female		Male	
	Median CTDIvol (mGy)	Median DLP (mGycm)	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	4	277	4	279
Max Value	13	566	13	693
Median	8	472	8	451
Average	8	448	8	452
75% percentile	9	554	10	515

CT for Urinary Calculus

	CT KUB					
	Female Adults			Male Adults		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	8	2	91	2	3	100
Max Value	2,100	21	563	1,954	23	776
Median	54	5	219	65	6	260
Average	150	6	247	149	7	300
75% percentile	146	7	288	148	8	381

	Urinary calculus			
	Female		Male	
	Median CTDIvol (mGy)	Median DLP (mGycm)	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	2	91	3	108
Max Value	7	255	16	369
Median	4	216	5	239
Average	4	201	6	235
75% percentile	6	254	8	291

Survey Section Four: Analysis of Paediatric Population Dose Examinations

Each category was analysed and the information arranged to produce three tables. The first table shows the following information for each specified exam:

1. The minimum and maximum number of that specific examination performed across the 30 paediatric scanners, together with the Median, the Average and the 75th percentile.
2. The minimum and maximum Median $CTDI_{vol}$ in mGy employed for that specific examination across the 30 paediatric scanners, together with the Median, the Average and the 75th percentile.
3. The minimum and maximum Median DLP in mGycm employed for that specific examination across the 30 paediatric scanners, together with the Median, the Average and the 75th percentile.
4. The total number of exams performed across the 30 paediatric scanners where relevant for that category.

The second table looks at scanner activity and patient volumes and shows the following information for each specified exam:

1. The minimum and maximum summed DLP in mGycm in that category performed across the 30 paediatric scanners, together with the Median, the Average and the 75th percentile.
2. The total summed DLP in mGycm for each category of examination.

The third table shows the following information separately for each specified exam:

1. The minimum and maximum % of exams in that category performed across the 30 paediatric scanners where relevant, together with the Median, the Average and the 75th percentile.

Paediatric CT Brain (0 < 3 months)

Paediatrics: CT Brain (0 < 3 months): Scanner Activities

	Paediatrics: CT Brain 0 < 3 months		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	1	7	86
Max Value	14	18	288
Median	4	13	150
Average	6	13	176
75% percentile	11	15	239
Total	53	N/A	N/A

Paediatrics: CT Brain (0 < 3 months): Summed DLP (mGycm) per Scanner

	Paediatrics: CT Brain 0 < 3 months
	Sum DLP (mGycm)
Min Value	86
Max Value	2,653
Median	670
Average	1,059
75% percentile	1,940
Total	9,530

Paediatrics: CT Brain (0 < 3 months): Scanner % distribution of activity for specified examinations

	Paediatrics: CT Brain 0 < 3 months
	% of Exams
Min Value	1.89%
Max Value	26.42%
Median	7.55%
Average	11.11%
75% percentile	19.81%
Total	100.00%

Paediatric CT Brain (3 months < 1 year)

Paediatrics: CT Brain 3 months < 1 year: Scanner Activities

	Paediatrics: CT Brain 3 months < 1 year		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	1	7	113
Max Value	74	35	599
Median	11	19	293
Average	16	18	297
75% percentile	21	23	376
Total	253	N/A	N/A

Paediatrics: CT Brain 3 months < 1 year: Summed DLP (mGycm) per Scanner

	Paediatrics: CT Brain 3 months < 1 year
	Sum DLP (mGycm)
Min Value	133
Max Value	17,316
Median	2,890
Average	4,390
75% percentile	5,416
Total	70,234

Paediatrics: CT Brain 3 months < 1 year: Scanner % distribution of activity for specified examinations

	Paediatrics: CT Brain 3 months < 1 year
	% of Exams
Min Value	0.40%
Max Value	29.25%
Median	4.35%
Average	6.25%
75% percentile	8.20%
Total	100.00%

Paediatric CT Brain (1 < 6 years)

Paediatrics: CT Brain 1 < 6 years: Scanner Activities

	Paediatrics: CT Brain 1 < 6 years		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	11	8	130
Max Value	306	40	680
Median	27	21	388
Average	48	25	398
75% percentile	51	34	536
Total	813	N/A	N/A

Paediatrics: CT Brain 1 < 6 years: Summed DLP (mGycm) per Scanner

	Paediatrics: CT Brain 1 < 6 years
	Sum DLP (mGycm)
Min Value	2,388
Max Value	116,280
Median	11,130
Average	19,280
75% percentile	21,709
Total	327,756

Paediatrics: CT Brain 1 < 6 years: Scanner % distribution of activity for specified examinations

	Paediatrics: CT Brain 1 < 6 years
	% of Exams
Min Value	1.35%
Max Value	37.64%
Median	3.32%
Average	5.88%
75% percentile	6.21%
Total	100.00%

Paediatric CT Brain (>6 years inclusive)

Paediatrics: CT Brain > 6 years (inclusive): Scanner Activities

	Paediatrics: Brain > 6 years (inclusive)		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	20	12	64
Max Value	481	53	910
Median	52	39	633
Average	88	37	563
75% percentile	114	44	742
Total	1,766	N/A	N/A

Paediatrics: CT Brain > 6 years (inclusive): Summed DLP (mGycm) per Scanner

	Paediatrics: Brain > 6 years (inclusive)
	Sum DLP (mGycm)
Min Value	5,835
Max Value	359,307
Median	19,078
Average	54,555
75% percentile	60,872
Total	1,091,103

Paediatrics: CT Brain > 6 years (inclusive): Scanner % distribution of activity for specified examinations

	Paediatrics: Brain > 6 years (inclusive)
	% of Exams
Min Value	1.13%
Max Value	27.24%
Median	2.92%
Average	5.00%
75% percentile	6.44%
Total	100.00%

Paediatric CT Thorax (< 5kg or neonates)

Paediatrics: CT Thorax < 5kg or neonates: Scanner Activities

	Paediatrics: Thorax < 5kg or neonates		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	2	1	20
Max Value	9	2	38
Median	6	1	29
Average	6	1	29
75% percentile	N/A	N/A	N/A
Total	11	N/A	N/A

Paediatrics: CT Thorax < 5kg or neonates: Summed DLP (mGycm) per Scanner

	Paediatrics: Thorax < 5kg or neonates
	Sum DLP (mGycm)
Min Value	75
Max Value	183
Median	129
Average	129
75% percentile	N/A
Total	258

Paediatrics: CT Thorax < 5kg or neonates: Scanner % distribution of activity for specified examinations

	Paediatrics: Thorax < 5kg or neonates
	% of Exams
Min Value	18.18%
Max Value	81.82%
Median	50.00%
Average	50.00%
75% percentile	N/A
Total	100.00%

Paediatric CT Thorax (5 < 15kg)

Paediatrics: CT Thorax 5 < 15kg: Scanner Activities

	Paediatrics: Thorax 5 < 15kg		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	1	1	15
Max Value	25	3	121
Median	2	2	32
Average	9	2	50
75% percentile	21	3	81
Total	51	N/A	N/A

Paediatrics: CT Thorax 5 < 15kg: Summed DLP (mGycm) per Scanner

	Paediatrics: Thorax 5 < 15kg
	Sum DLP (mGycm)
Min Value	33
Max Value	626
Median	128
Average	223
75% percentile	428
Total	1,339

Paediatrics: CT Thorax 5 < 15kg: Scanner % distribution of activity for specified examinations

	Paediatrics: Thorax 5 < 15kg
	% of Exams
Min Value	1.96%
Max Value	49.02%
Median	3.92%
Average	16.67%
75% percentile	41.67%
Total	100.00%

Paediatric CT Thorax 16 < 30 kg (inclusive)

Paediatrics: CT Thorax 16 < 30 kg (inclusive): Scanner Activities

	Paediatrics: Thorax 16 < 30 kg (inclusive)		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	1	1	42
Max Value	25	7	110
Median	6	3	83
Average	10	3	78
75% percentile	20	5	99
Total	79	N/A	N/A

Paediatrics: CT Thorax 16 < 30 kg (inclusive): Summed DLP (mGycm) per Scanner

	Paediatrics: Thorax 16 < 30 kg (inclusive)
	Sum DLP (mGycm)
Min Value	54
Max Value	1,755
Median	584
Average	665
75% percentile	1,090
Total	5,317

Paediatrics: CT Thorax 16 < 30 kg (inclusive): Scanner % distribution of activity for specified examinations

	Paediatrics: Thorax 16 < 30 kg (inclusive)
	% of Exams
Min Value	1.27%
Max Value	31.65%
Median	6.96%
Average	12.50%
75% percentile	25.32%
Total	100.00%

Paediatric CT Thorax 31 <50 kg (inclusive)

Paediatrics: CT Thorax 31 < 50kg (inclusive): Scanner Activities

	Paediatrics: Thorax 31 < 50 kg (inclusive)		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	1	2	77
Max Value	30	9	201
Median	3	3	88
Average	7	4	114
75% percentile	14	6	166
Total	59	N/A	N/A

Paediatrics: CT Thorax 31 < 50kg (inclusive): Summed DLP (mGycm) per Scanner

	Paediatrics: Thorax 31 < 50 kg (inclusive)
	Sum DLP (mGycm)
Min Value	80
Max Value	2,460
Median	286
Average	662
75% percentile	1,133
Total	5,297

Paediatrics: CT Thorax 31 < 50kg (inclusive): Scanner % distribution of activity for specified examinations

	Paediatrics: Thorax 31 < 50 kg (inclusive)
	% of Exams
Min Value	1.69%
Max Value	50.85%
Median	4.24%
Average	12.50%
75% percentile	23.31%
Total	100.00%

Paediatric CT Thorax 51 < 80 kg (inclusive)

Paediatrics: CT Thorax 51 < 80kg (inclusive): Scanner Activities

	Paediatrics: Thorax 51 < 80 kg (inclusive)		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	1	3	97
Max Value	24	6	192
Median	4	4	117
Average	7	4	125
75% percentile	7	4	131
Total	46	N/A	N/A

Paediatrics: CT Thorax 51 < 80kg (inclusive): Summed DLP (mGycm) per Scanner

	Paediatrics: Thorax 51 < 80 kg (inclusive)
	Sum DLP (mGycm)
Min Value	192
Max Value	2,496
Median	413
Average	728
75% percentile	917
Total	5,098

Paediatrics: CT Thorax 51 < 80kg (inclusive): Scanner % distribution of activity for specified examinations

	Paediatrics: Thorax 51 < 80 kg (inclusive)
	% of Exams
Min Value	2.17%
Max Value	52.17%
Median	8.70%
Average	14.29%
75% percentile	15.22%
Total	100.00%

Paediatric CT Abdomen - Pelvis 16 < 30 kg (inclusive)

Paediatrics: CT Abdomen - Pelvis 16 < 30kg (inclusive): Scanner Activities

	Paediatrics: Abdomen - Pelvis 16 < 30 kg (inclusive)		
	Number of Exams	MedianCTDIvol (mGy)	Median DLP (mGycm)
Min Value	1	1	22
Max Value	17	6	280
Median	2	3	113
Average	5	3	119
75% percentile	6	6	168
Total	51	N/A	N/A

Paediatrics: CT Abdomen - Pelvis 16 < 30kg (inclusive): Summed DLP (mGycm) per Scanner

	Paediatrics: Abdomen - Pelvis 16 < 30 kg (inclusive)
	Sum DLP (mGycm)
Min Value	29
Max Value	1,357
Median	276
Average	411
75% percentile	672
Total	4,522

Paediatrics: CT Abdomen - Pelvis 16 < 30kg (inclusive): Scanner % distribution of activity for specified examinations

	Paediatrics: Abdomen - Pelvis 16 < 30 kg (inclusive)
	% of Exams
Min Value	1.96%
Max Value	33.33%
Median	3.92%
Average	9.09%
75% percentile	11.76%
Total	100.00%

Paediatric CT Abdomen - Pelvis 51 < 80 kg (inclusive) (Limited Data)

Paediatrics: CT Abdomen - Pelvis 51 < 80kg (inclusive): Scanner Activities

	Paediatrics: Abdomen - Pelvis 51 < 80 kg (inclusive)		
	Number of Exams	MedianCTDIvol (mGy)	Median DLP (mGycm)
Min Value	2	3	124
Max Value	23	14	549
Median	10	7	290
Average	12	7	313
75% percentile	23	7	397
Total	35	N/A	N/A

Paediatrics: CT Abdomen - Pelvis 51 < 80kg (inclusive): Summed DLP (mGycm) per Scanner

	Paediatrics: Abdomen - Pelvis 51 < 80 kg (inclusive)
	Sum DLP (mGycm)
Min Value	0
Max Value	9,678
Median	N/A
Average	1,208
75% percentile	563
Total	13,285

Paediatrics: CT Abdomen - Pelvis 51 < 80kg (inclusive): Scanner % distribution of activity for specified examinations

	Paediatrics: Abdomen - Pelvis 51 < 80 kg (inclusive)
	% of Exams
Min Value	0.00%
Max Value	65.71%
Median	0.00%
Average	9.09%
75% percentile	5.71%
Total	100.00%

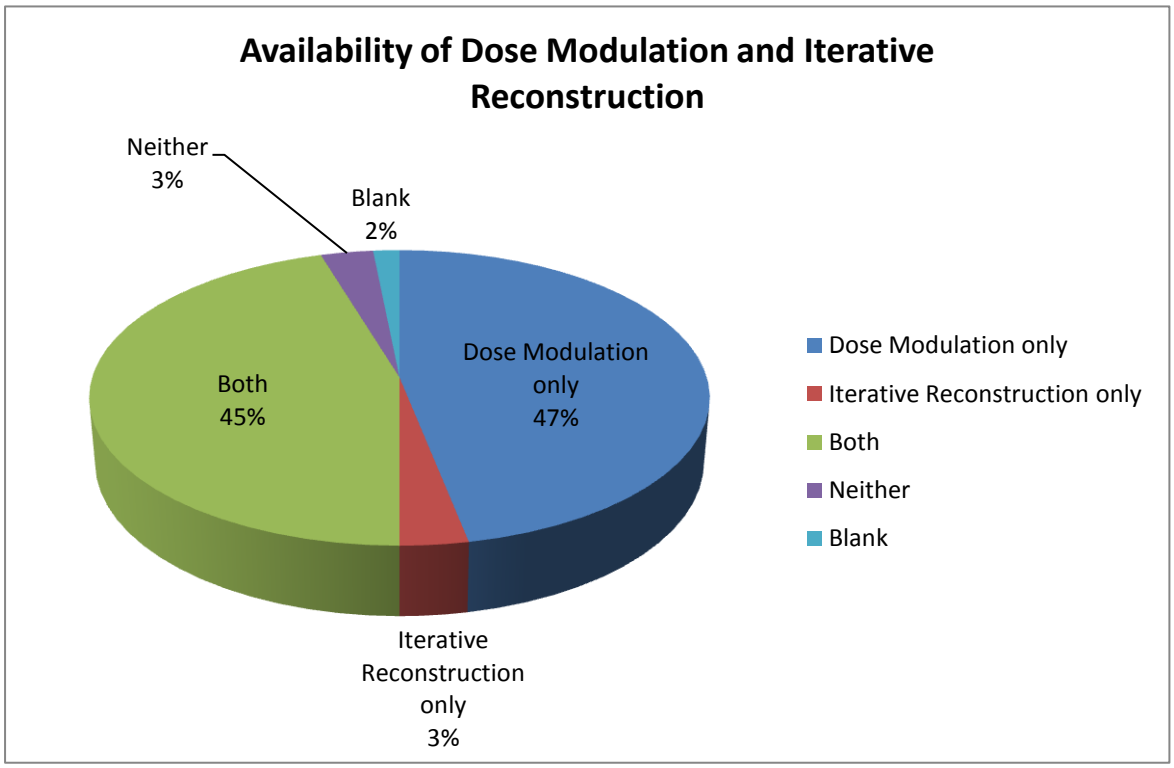
Survey Section Five: Analysis of Adult Dose Modulation and Iterative Reconstruction

Information on the availability of Dose Modulation and/or Iterative Reconstruction software was requested of respondents and the information provided regarding the 64 scanners is depicted in Table 3 reproduced from page 8.

Table 3: Availability of Dose Modulation and Iterative Reconstruction software

Dose Modulation	Iterative Reconstruction	Both
Yes	Yes	Yes
59	31	29
No	No	No
4	31	33
Blank	Blank	Blank
1	2	2

From this information it has been possible to extract dose information for several examination categories to allow comparison of those scanners utilising dose modulation, iterative reconstruction or both. This information is presented in the sections below.



CT Hi-Res Thorax:

Summary of Scanner Activities based on Dose Modulation (DM) and Iterative Reconstruction (IR)

General Data	Hi-Res Thorax					
	Female Adults			Male Adults		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	3	1	23	1	1	31
Max Value	692	39	410	705	44	575
Median	34	7	205	38	7	293
Average	84	7	219	80	9	281
75% percentile	76	9	313	89	11	374
Total	4,175	N/A	N/A	3,991	N/A	N/A

Dose Modulation only	Hi-Res Thorax					
	Female Adults			Male Adults		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	8	1	23	4	1	31
Max Value	511	39	410	392	44	575
Median	30	8	273	30	10	336
Average	75	9	254	70	11	324
75% percentile	72	10	332	71	12	428
Total	1,788	N/A	N/A	1,668	N/A	N/A

Dose Modulation and Iterative Reconstruction	Hi-Res Thorax					
	Female Adults			Male Adults		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	3	3	89	1	3	110
Max Value	430	29	376	355	28	462
Median	50	5	194	36	6	258
Average	63	7	208	59	8	269
75% percentile	78	7	286	79	8	351
Total	1,323	N/A	N/A	1,296	N/A	N/A

Summary of Summed DLP (mGycm) per Scanner based on DM and IR

	General Data		DM only		DM and IR	
	Hi-Res Thorax		Hi-Res Thorax		Hi-Res Thorax	
	Female	Male	Female	Male	Female	Male
	Sum DLP (mGycm)	Sum DLP (mGycm)	Sum DLP (mGycm)	Sum DLP (mGycm)	Sum DLP (mGycm)	Sum DLP (mGycm)
Min Value	866	402	1,426	1,440	866	402
Max Value	99,302	149,108	70,211	66,830	46,440	49,523
Median	8,012	8,325	7,902	9,413	9,084	8,325
Average	13,390	16,805	13,100	15,469	11,248	13,738
75% percentile	16,475	23,842	17,767	25,163	15,830	21,178
Total	656,100	823,422	314,406	371,256	224,961	288,505

Summary of Scanner Gender Distributions based on DM and IR

	General Data		DM only		DM and IR	
	Hi-Res Thorax		Hi-Res Thorax		Hi-Res Thorax	
	Female	Male	Female	Male	Female	Male
	% of Exams	% of Exams	% of Exams	% of Exams	% of Exams	% of Exams
Min Value	0.00%	0.00%	0.4%	0.2%	0.0%	0.0%
Max Value	16.57%	17.66%	28.6%	23.5%	32.5%	27.4%
Median	0.72%	0.75%	1.7%	1.8%	2.3%	2.3%
Average	1.89%	1.89%	4.2%	4.2%	4.3%	4.3%
75% percentile	1.74%	2.04%	4.0%	4.2%	5.4%	5.9%
Total	100.00%	100.00%	100.0%	100.0%	100.0%	100.0%

CT Thorax

Summary of Scanner Activities based on Dose Modulation (DM) and Iterative Reconstruction (IR)

General Data	Thorax					
	Female Adults			Male Adults		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	21	4	93	27	5	136
Max Value	647	19	575	765	24	695
Median	147	7	265	134	7	280
Average	166	7	250	170	9	311
75% percentile	217	8	280	243	10	377
Total	2,496	N/A	N/A	2,550	N/A	N/A

Dose Modulation only	Thorax					
	Female Adults			Male Adults		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	21	5	172	27	6	163
Max Value	647	19	575	765	24	695
Median	142	7	267	94	8	282
Average	171	8	274	179	9	331
75% percentile	208	9	296	256	12	392
Total	1,706	N/A	N/A	1,793	N/A	N/A

Dose Modulation and Iterative Reconstruction	Thorax					
	Female Adults			Male Adults		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	30	4	93	30	5	136
Max Value	366	7	280	319	11	475
Median	147	4	177	145	5	230
Average	158	5	197	151	7	268
75% percentile	292	7	279	276	9	394
Total	790	N/A	N/A	757	N/A	N/A

Summary of Summed DLP (mGycm) per Scanner based on DM and IR

	General Data		DM only		DM and IR	
	Thorax		Thorax		Thorax	
	Female	Male	Female	Male	Female	Male
	Sum DLP (mGycm)	Sum DLP (mGycm)	Sum DLP (mGycm)	Sum DLP (mGycm)	Sum DLP (mGycm)	Sum DLP (mGycm)
Min Value	4,695	4,904	5,526	4,904	4,695	5,564
Max Value	170,161	216,097	170,161	216,097	102,480	151,621
Median	36,431	19,648	43,867	37,940	13,671	19,648
Average	47,982	62,176	53,325	67,590	37,296	51,349
75% percentile	60,324	80,919	75,098	112,149	81,402	112,324
Total	719,734	932,642	533,254	675,899	186,480	256,744

Summary of Scanner Gender Distributions based on DM and IR

	General Data		DM only		DM and IR	
	Thorax		Thorax		Thorax	
	Female	Male	Female	Male	Female	Male
	% of Exams	% of Exams	% of Exams	% of Exams	% of Exams	% of Exams
Min Value	0.8%	1.1%	1.2%	1.5%	3.8%	4.0%
Max Value	25.9%	30.0%	37.9%	42.7%	46.3%	42.1%
Median	5.9%	5.3%	8.3%	5.2%	18.6%	19.2%
Average	6.7%	6.7%	10.0%	10.0%	20.0%	20.0%
75% percentile	8.7%	9.5%	12.2%	14.3%	36.9%	36.5%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

CT Thorax – Abdomen – Pelvis (TAP)

Summary of Scanner Activities based on Dose Modulation (DM) and Iterative Reconstruction (IR)

General Data	Thorax - Abdomen – Pelvis (TAP)					
	Female Adults			Male Adults		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	5	3	215	3	4	258
Max Value	2,792	35	1,413	2,792	42	1,929
Median	274	10	554	229	12	721
Average	390	12	580	378	14	709
75% percentile	581	14	661	553	18	830
Total	21,470	N/A	N/A	20,416	N/A	N/A

Dose Modulation only	Thorax - Abdomen – Pelvis (TAP)					
	Female Adults			Male Adults		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	5	6	388	3	7	505
Max Value	2,792	35	1,413	2,792	38	1,929
Median	174	12	618	173	14	780
Average	360	13	650	359	15	800
75% percentile	503	15	710	499	18	851
Total	10,070	N/A	N/A	9,683	N/A	N/A

Dose Modulation and Iterative Reconstruction	Thorax - Abdomen – Pelvis (TAP)					
	Female Adults			Male Adults		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	10	3	215	10	4	258
Max Value	1,655	21	812	1,314	24	966
Median	326	8	511	310	9	600
Average	435	9	501	408	10	603
75% percentile	637	9	572	658	12	741
Total	10,877	N/A	N/A	10,204	N/A	N/A

Summary of Summed DLP (mGycm) per Scanner based on DM and IR

	General Data		DM only		DM and IR	
	TAP		TAP		TAP	
	Female	Male	Female	Male	Female	Male
	Sum DLP (mGycm)	Sum DLP (mGycm)	Sum DLP (mGycm)	Sum DLP (mGycm)	Sum DLP (mGycm)	Sum DLP (mGycm)
Min Value	3,829	5,647	7,064	5,787	3,829	5,647
Max Value	1,867,694	2,122,389	1,867,694	2,122,389	920,180	1,254,213
Median	137,395	144,949	95,560	120,839	174,472	165,873
Average	225,090	261,728	227,433	268,588	227,315	260,063
75% percentile	311,938	378,728	321,403	368,256	326,558	440,921
Total	12,379,971	14,133,299	6,368,112	7,251,874	5,682,871	6,501,573

Summary of Scanner Gender Distributions based on DM and IR

	General Data		DM only		DM and IR	
	TAP		TAP		TAP	
	Female	Male	Female	Male	Female	Male
	% of Exams	% of Exams	% of Exams	% of Exams	% of Exams	% of Exams
Min Value	0.00%	0.00%	0.05%	0.00%	0.00%	0.00%
Max Value	13.00%	13.68%	27.73%	28.83%	15.22%	12.88%
Median	0.90%	0.94%	1.72%	1.66%	2.87%	2.92%
Average	1.69%	1.69%	3.57%	3.57%	3.85%	3.85%
75% percentile	2.61%	2.51%	5.00%	5.10%	5.80%	5.98%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

CT Abdomen - Pelvis

Summary of Scanner Activities based on Dose Modulation (DM) and Iterative Reconstruction (IR)

General Data	Abdomen - Pelvis					
	Female Adults			Male Adults		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	10	4	211	6	6	284
Max Value	2,601	16	790	2,601	21	862
Median	263	9	424	199	10	499
Average	403	9	429	370	10	503
75% percentile	709	11	533	550	12	592
Total	22,555	N/A	N/A	20,351	N/A	N/A

Dose Modulation only	Abdomen - Pelvis					
	Female Adults			Male Adults		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	10	7	302	6	8	336
Max Value	2,601	16	647	2,601	21	862
Median	146	10	437	117	11	514
Average	370	10	446	329	11	528
75% percentile	712	11	534	538	12	602
Total	10,346	N/A	N/A	9,211	N/A	N/A

Dose Modulation and Iterative Reconstruction	Abdomen - Pelvis					
	Female Adults			Male Adults		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	10	4	211	10	6	284
Max Value	2,100	14	790	1,954	15	740
Median	339	7	375	290	9	446
Average	429	8	404	408	9	468
75% percentile	703	10	475	557	11	559
Total	10,733	N/A	N/A	10,204	N/A	N/A

Summary of Summed DLP (mGycm) per Scanner based on DM and IR

	General Data		DM only		DM and IR	
	Abdomen - Pelvis		Abdomen - Pelvis		Abdomen - Pelvis	
	Female	Male	Female	Male	Female	Male
	Sum DLP (mGycm)	Sum DLP (mGycm)	Sum DLP (mGycm)	Sum DLP (mGycm)	Sum DLP (mGycm)	Sum DLP (mGycm)
Min Value	2,105	3,250	4,380	3,872	2,105	3,250
Max Value	1,344,660	1,574,978	1,344,660	1,574,978	1,182,090	1,351,240
Median	104,887	98,685	57,696	45,229	120,450	142,535
Average	177,129	195,613	165,510	175,582	188,291	212,792
75% percentile	261,627	286,104	239,518	280,681	270,748	254,840
Total	9,919,218	10,758,692	4,634,287	4,916,303	4,707,264	5,319,796

Summary of Scanner Gender Distributions based on DM and IR

	General Data		DM only		DM and IR	
	Abdomen - Pelvis		Abdomen - Pelvis		Abdomen - Pelvis	
	Female	Male	Female	Male	Female	Male
	% of Exams	% of Exams	% of Exams	% of Exams	% of Exams	% of Exams
Min Value	0.00%	0.00%	0.10%	0.07%	0.00%	0.00%
Max Value	11.53%	12.78%	25.14%	28.24%	19.57%	19.15%
Median	1.08%	0.73%	1.41%	1.26%	2.96%	2.79%
Average	1.69%	1.69%	3.57%	3.57%	3.85%	3.85%
75% percentile	3.07%	2.67%	6.88%	5.84%	6.50%	5.42%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Survey Section Six: Analysis of Paediatric Dose Modulation and Iterative Reconstruction

Due to the relatively lower number of respondents and the low number of examinations performed in most of the paediatric categories it was not possible to perform analysis on most of the body categories where dose modulation and iterative reconstruction would most benefit dose reduction. Table 8 shows the breakdown of respondents and the numbers of examinations per category.

Table 8: Breakdown of Respondents and Number of Examinations per Category

Examination Category	Respondents	Number of Examinations
Brain: 0 – 3 months	9	53
Brain: 3 months – 1 year	16	253
Brain: 1 -6 years	17	813
Brain: > 6 years	20	1766
Thorax: < 5kg or neonates	2	11
Thorax: 5 < 15kg	6	51
Thorax: 16 < 30 kg (inclusive)	8	79
Thorax: 31 <50 kg (inclusive)	8	59
Abdomen - Pelvis: < 5kg or neonates	1	2
Abdomen - Pelvis: 5 < 15kg	2	7
Abdomen - Pelvis: 16 < 30 kg	10	51
Abdomen - Pelvis: 31 < 50 kg	1	4
Abdomen - Pelvis: 51 < 80 kg	11	35

Two categories provided sufficient data to allow analysis of Dose Modulation and Iterative Reconstruction. They were:

1. **Abdomen - Pelvis: 16 < 30 kg**
2. **Abdomen - Pelvis: 51 < 80 kg**

Paediatric CT Abdomen – Pelvis 16 < 30 kg (inclusive)

Summary of Scanner Activities based on Dose Modulation (DM) and Iterative Reconstruction (IR)

General Data	ABDOMEN / PELVIS: 16 < 30 kg (inclusive)		
	Paediatrics		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	1	1	22
Max Value	17	6	280
Median	2	3	113
Average	5	3	119
75% percentile	5	6	153
Total	51	N/A	N/A

Dose Modulation only	ABDOMEN / PELVIS: 16 < 30 kg (inclusive)		
	Paediatrics		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	1	2	75
Max Value	4	6	280
Median	2	6	138
Average	2	5	164
75% percentile	3	6	247
Total	10	N/A	N/A

Dose Modulation and Iterative Reconstruction	ABDOMEN / PELVIS: 16 < 30 kg (inclusive)		
	Paediatrics		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	1	1	22
Max Value	17	6	168
Median	6	1	44
Average	8	2	75
75% percentile	15	4	141
Total	40	N/A	N/A

Summary of Summed DLP (mGycm) per Scanner based on DM and IR

	ABDOMEN / PELVIS: 16 < 30 kg (inclusive)		
	General Data	DM only	DM and IR
	Sum DLP (mGycm)	Sum DLP (mGycm)	Sum DLP (mGycm)
Min Value	29	112	29
Max Value	1,357	560	1,357
Median	276	276	672
Average	411	292	589
75% percentile	616	430	1,056
Total	4,522	1,462	2,946

Scanner % distribution of activity based on DM and IR

	ABDOMEN / PELVIS: 16 < 30 kg (inclusive)		
	General Data	DM only	DM and IR
	% of Exams	% of Exams	% of Exams
Min Value	2%	10.0%	2.5%
Max Value	33%	40.0%	42.5%
Median	4%	20.0%	15.0%
Average	9%	20.0%	20.0%
75% percentile	10%	30.0%	36.3%
Total	100%	100.0%	100.0%

Paediatric CT Abdomen – Pelvis 51 < 80 kg (inclusive)

General Data	ABDOMEN / PELVIS: 51 < 80 kg (inclusive)		
	Paediatrics		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	2	3	124
Max Value	23	14	549
Median	10	7	290
Average	12	7	313
75% percentile	N/A	7	397
Total	35	N/A	N/A

Dose Modulation only	ABDOMEN / PELVIS: 51 < 80 kg (inclusive)		
	Paediatrics		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	N/A	5	209
Max Value	N/A	8	397
Median	N/A	6	285
Average	N/A	6	294
75% percentile	N/A	7	369
Total	N/A	N/A	N/A

Dose Modulation and Iterative Reconstruction	ABDOMEN / PELVIS: 51 < 80 kg (inclusive)		
	Paediatrics		
	Number of Exams	Median CTDIvol (mGy)	Median DLP (mGycm)
Min Value	10	3	124
Max Value	23	14	549
Median	17	7	304
Average	17	7	338
75% percentile	N/A	11	485
Total	33	N/A	N/A

Summary of Summed DLP (mGycm) per Scanner based on DM and IR

	ABDOMEN / PELVIS: 51 < 80 kg (inclusive)		
	General Data	DM only	DM and IR
	Sum DLP (mGycm)	Sum DLP (mGycm)	Sum DLP (mGycm)
Min Value	0	No Data	0
Max Value	9,678	No Data	9,678
Median	0	No Data	0
Average	1,208	No Data	2,544
75% percentile	281	No Data	6,361
Total	13,285	No Data	12,722

Scanner % distribution of activity based on DM and IR

	ABDOMEN / PELVIS: 51 < 80 kg (inclusive)		
	General Data	DM only	DM and IR
	% of Exams	% of Exams	% of Exams
Min Value	0.00%	No Data	0.0%
Max Value	65.71%	No Data	69.7%
Median	0.00%	No Data	0.0%
Average	9.09%	No Data	20.0%
75% percentile	2.86%	No Data	50.0%
Total	100.00%	No Data	100.0%

Survey Section Seven: Establishing Diagnostic Reference Levels

Diagnostic Reference Levels

One of the aims of the survey was to build upon the diagnostic reference levels (DRLs) for common CT examinations that were established in the 2010 Report and on the DRLs published in the HSE, MERU Patient Radiation Manual, 2013 for Adults; and in the HSE, MERU Patient Radiation Manual, 2013 and in the PiDRL Guidelines, 2016 for Paediatrics. Diagnostic reference levels are defined in these reports as dose levels in medical radio-diagnostic practices or in the case of radio-pharmaceuticals, levels of activity, for typical examinations for groups of standard sized patients or standard phantoms for broadly defined types of equipment. These levels are expected not to be exceeded for standard procedures when good and normal practice regarding diagnostic and technical performance is applied.

The Dose Length Product (mGycm) was chosen as the parameter for National DRL in CT. The DRL is for specific procedures and should only be applied to those procedures, e.g.: CT Thorax is not a suitable DRL for CT Thorax & Liver. Not all categories established in the previous surveys were re-examined in this survey so direct comparison is only possible in certain categories.

Adult Diagnostic Reference Levels

Table 9: National Survey on Population Dose from Computed Tomography, 2017: Gender Specific and Conflated Adult Diagnostic Reference Levels

National Survey on Population Dose from Computed Tomography, 2017 Adult Examinations	Female DRL	Male DRL	Conflated DRL
	DLP (mGycm)	DLP (mGycm)	DLP (mGycm)
Cervical Spine	354	490	474
Cervical Spine Trauma	469	477	473
Brain	845	927	908
Head Trauma	918	927	909
Sinuses	190	211	203
Sinusitis	183	210	184
Thorax	280	377	310
Hi-Res Thorax	313	374	337
Diffuse Infiltrate Lung Disease	210	249	218
CTPA	310	379	346
Pulmonary Embolus	234	278	250
Pulmonary Metastases	241	272	258
Thorax - Abdomen – Pelvis (TAP)	661	830	770
TAP oncologic follow-up (single phase)	605	643	635
Abdomen - Pelvis	533	592	556
Appendicitis	439	490	486
Liver and abdominal metastases in colorectal cancer	554	536	554
CT KUB	288	381	330
Urinary calculus	254	291	263

The original MERU categories for Adults are shown in Table 10.

Table 10: MERU, 2013 Patient Radiation Manual: Adult Diagnostic Reference Levels

Examination	MERU, 2013
	National DRL - DLP (mGycm)
Cervical Spine	600
Brain	990
Thorax	390
Thorax and Liver	460
Thorax and Abdomen	660
Hi-Res Thorax	350
CTPA	430
TAP	850
Pelvis	570
Abdomen - Pelvis	660
KUB	370

Comparison with the categories included in this survey can be seen in the table below. The National Survey on Population Dose from Computed Tomography, 2017 sought information on male and female patients so the DRLs are gender specific.

Table 11: DRL Comparisons for Population Dose Survey 2017 and MERU, 2013

Examination	National Survey on Population Dose from Computed Tomography, 2017			MERU, 2013
	Female	Male	Conflated	
	DRL DLP (mGycm)	DRL DLP (mGycm)	DRL DLP (mGycm)	NDRL DLP (mGycm)
Cervical Spine	354	490	474	600
Brain	845	927	908	990
Thorax	280	377	310	390
Hi-Res Thorax	313	374	337	350
CTPA	310	379	346	430
TAP	661	830	770	850
Abdomen - Pelvis	533	592	556	660
KUB	288	381	330	370

Paediatric Diagnostic Reference Levels

Table 12: National Survey on Population Dose from Computed Tomography, 2017: Paediatric Diagnostic Reference Levels

National Survey on Population Dose from Computed Tomography, 2017	Paediatric DRL DLP (mGycm)
Examination: CT Head	
Age	
0 - < 3 months	239
3 months - 1 year	376
1 - 6 years	536
> 6 years	742
Examination: CT Thorax	
Weight	
< 5 kg	No Data
5 < 15 kg	81
15 < 30 kg	99
30 < 50 kg	166
50 < 80 kg	131
Examination: CT Abdomen	
Weight	
< 5 kg	No Data
5 < 15 kg	No Data
15 < 30 kg	168
30 < 50 kg	No Data
50 < 80 kg	397

Existing work on establishing Paediatric Diagnostic Reference Levels is shown in the tables below. It can be seen that a variety of methods have been used previously including weight and age based surveys. None of these previous surveys is an exact fit for comparison so comparisons have only been made in certain categories of the current survey where possible.

Table 13: MERU Patient Radiation Manual: Paediatric Diagnostic Reference Levels

Examination	MERU, 2013
	National DRL - DLP (mGycm)
Examination: CT Brain	
Age	
Newborn	340
1-4 years	470
5-9 years	620
10-15 years	850
Adult	950
Examination: CT Abdomen Pelvis	
Age	
Newborn	130
1-4 years	160
5-9 years	230
10-15 years	400
Adult	640

Table 14: European Paediatric CT DRLs, PiDRL Guidelines, 2016

Examination	European DRL - DLP (mGycm)	
	CTDIvol mGy	DLP mGycm
Examination: CT Head		
Age	24	300
0 - < 3 months	28	385
3 months - 1 year	40	505
1 - 6 years	50	650
> 6 years		
Examination: CT Thorax		
Weight		
< 5 kg	1.4	35
5 < 15 kg	1.8	50
15 < 30 kg	2.7	70
30 < 50 kg	3.7	115
50 < 80 kg	5.4	200
Examination: CT Abdomen		
Weight		
< 5 kg		45
5 < 15 kg	3.5	120
15 < 30 kg	5.4	150
30 < 50 kg	7.3	210
50 < 80 kg	13	480

Comparison with the categories included in the above surveys can be seen in the table below.

Table 15: DRL Comparisons for Paediatric Population Dose Survey 2017, MERU, 2013 and PiDRL Guidelines, 2016

	National Survey on Population Dose from Computed Tomography, 2017	PiDRL,2016 DLP (mGycm)	MERU, 2013 DLP (mGycm)
		European	National
Examination: CT Head			**Approximation based on age**
Age			
0 - < 3 months	239	300	340
3 months - 1 year	376	385	
1 - 6 years	536	505	470
> 6 years	742	650	620 - 850
Examination: CT Thorax			
Weight			
< 5 kg	No Data	35	
5 < 15 kg	81	50	
15 < 30 kg	99	70	
30 < 50 kg	166	115	
50 < 80 kg	131	200	
Examination: CT Abdomen			
Weight			
< 5 kg	No Data	45	130
5 < 15 kg	No Data	120	
15 < 30 kg	168	150	160
30 < 50 kg	No Data	210	230
50 < 80 kg	397	480	400

Survey Section Eight: Establishing Population Dose

Irish National Population Demographics

Census 2016 results show that Ireland's population increased by 173,613 persons over the five years since April 2011, to reach 4,761,865 persons in April 2016. This represents a total increase of 3.8 per cent over the 5 years. The population aged over 65 has increased by 19.1 per cent since 2011. This is especially evident in the male population which rose by 53,523 (22%) to 296,837 compared with an increase of 48,651 (16.7%) to 340,730 for females. For the population aged over 85, the male population increased by 24.8 per cent to 23,062 while the female population increased by 11.4 per cent to 44,493. This has implications for referral patterns for CT scanning which should be considered when comparing with the previous CT Population Dose Survey, 2010.

Table 16: Demographics of the Irish National Population based on Census, 2016

Gender	Number
Male adults	1,777,183
Female Adults	1,855,498
Male Paediatric (under 16 years)	577,245
Female Paediatric (under 16 years)	551,939
Total Paediatric	1,129,184
Total Male	2,354,428
Total Female	2,407,437
Total Adults	3,632,681
Total Population	4,761,865

Scanners per Million of the Population

This survey found there to be 64 scanners for a population of 4.76 million which equates to 13.4 scanners per million of the population. This is a slight decrease on the 2009 survey which had 65 scanners equating to 15 scanners per million of the population. There are several centres however who failed to return data and an estimated six additional scanners may be assumed from known centres with CT scanners. This would yield a value of 14.7 scanners per million of the population which would be in line with previous estimates. However the number of scanners returned was less than that listed in the 2015 OECD scanner density for Ireland at 17.8 CT scanners per 1,000,000 population (85 in total). (https://data.oecd.org/healthcare/computed-tomography-ct-scanners.htm). Lack of available data from all sites will require extrapolation of data from similar sites with known returns for population dose purposes.

Adult Population Dose

Population dose is reported as the annual Collective Effective Dose Person Sievert and Dose per Caput as recommended by RP-154. Practical dosimetry quantities for CT examinations included in the survey are Computed Tomography Dose Index (CTDI) and Dose – Length Product (DLP). Research has led to the publication of coefficients for converting these dose quantities into Effective Dose.

Effective Dose determination was made with reference to research published by Huda et al, 2011 which used established weighting factors commonly adopted to convert DLP (mGycm) into Effective Dose (µSv). The table below shows these conversion factors for the body specific examinations that were included in the survey. These conversion factors were replicated from the previous Population Dose Survey in CT, 2010 to allow comparisons to be made with the earlier data.

Examination	Female	Huda et al		Female	
	Average DLP (mGycm)	Conversion Factor	Effective Dose mSv / mGycm	No of Exams	Person mSv
Cervical Spine	323	0.0054	1.744	1,643	2,866
Brain	724	0.0022	1.593	46,864	74,645
Sinuses	148	0.0022	0.326	764	249
Thorax	250	0.017	4.250	2,496	10,608
Hi-Res Thorax	219	0.017	3.723	4,175	15,544
CTPA	251	0.017	4.267	8,624	36,799
TAP	580	0.019	11.020	21,470	236,599
Abdomen - Pelvis	429	0.016	6.864	22,555	154,818
KUB	247	0.016	3.952	5,854	23,135
			Total Person mSv		555,262

Examination	Male	Huda et al		Male	
	Average DLP (mGycm)	Conversion Factor	Effective Dose mSv / mGycm	No of Exams	Person mSv
Cervical Spine	379	0.0054	2.047	2,186	4,474
Brain	778	0.0022	1.712	44,258	75,752
Sinuses	161	0.0022	0.354	674	239
Thorax	311	0.017	5.287	2,550	13,482
Hi-Res Thorax	281	0.017	4.777	3,991	19,065
CTPA	304	0.017	5.168	6,697	34,610
TAP	709	0.019	13.471	20,416	275,024
Abdomen - Pelvis	503	0.016	8.048	20,351	163,785
KUB	300	0.016	4.800	5,967	28,642
			Total Person mSv		615,072

Adult Population Dose

The Collective Effective Dose is defined as the sum of the average effective dose for each examination times the frequency of each examination. Combining the Total Person mSv for both male and female patients and converting from mSv to Sieverts (Sv) gives the following result for Adult Population Dose:

Table 17: Total Adult Population Dose based on submitted data

Total Adult Population Dose		
	Person mSv	Person Sievert
Female	555,262	555
Male	615,072	615
Total	1,170,334	1,170

A calculation was then performed to estimate the number and type of scans from known CT scanners at centres who had not submitted electronic data. This is known to be six scanners. A calculation was also performed to estimate the number and type of scans from centres who had returned incomplete data regarding numbers of exams or gender specific numbers. Average examination numbers for each category were applied to the relevant centres and a total of 41,204 scans were estimated to be absent from the data. Gender specific tables are shown below.

Table 18: Estimated Absent Examinations Contribution to Population Dose (Female)

Estimated Absent Examinations Contribution to Population Dose	Female	Huda et al		Female	
	Average DLP (mGycm)	Conversion Factor	Effective Dose mSv / mGycm	Estimated No of Absent Exams	Person mSv
Cervical Spine	323	0.0054	1.744	282	492
Brain	724	0.0022	1.593	7,398	11,784
Sinuses	148	0.0022	0.326	918	299
Thorax	250	0.017	4.250	1,162	4,939
Hi-Res Thorax	219	0.017	3.723	672	2,502
CTPA	251	0.017	4.267	1,352	5,769
TAP	580	0.019	11.020	3,900	42,978
Abdomen - Pelvis	429	0.016	6.864	3,627	24,896
KUB	247	0.016	3.952	900	3,557
				Total mSv	97,214

Table 19: Estimated Absent Examinations Contribution to Population Dose (Male)

Estimated Absent Examinations Contribution to Population Dose	Male	Huda et al		Male	
	Average DLP (mGycm)	Conversion Factor	Effective Dose mSv / mGycm	Estimated No of Absent Exams	Person mSv
Cervical Spine	379	0.0054	2.047	366	749
Brain	778	0.0022	1.712	8,050	13,778
Sinuses	161	0.0022	0.354	810	287
Thorax	311	0.017	5.287	1,190	6,292
Hi-Res Thorax	281	0.017	4.777	720	3,439
CTPA	304	0.017	5.168	1,072	5,540
TAP	709	0.019	13.471	4,158	56,012
Abdomen - Pelvis	503	0.016	8.048	3,700	29,778
KUB	300	0.016	4.800	894	4,291
				Total mSv	120,167

Table 20: Estimate of Additional Adult Population Dose not included in data

Additional Total Adult Population Dose		
	Person mSv	Person Sievert
Female	97,214	97.21
Male	120,167	120.17
Total	217,381	217

Table 21: Total Adult Population Dose based on submitted data and estimate of absent data

Total Adult Population Dose		
	Person mSv	Person Sievert
Female	652,476	652.48
Male	735,239	735.24
Total	1,387,715	1,388

Adult Dose per Caput

The Dose per Caput is defined as the collective dose average over the whole population. Table 16 shows the Adult population to be 3,632,681. Excluding the low collective dose attributed to the paediatric population the Dose per Caput was found to be 0.32 mSv per head of the adult population before the inclusion of the estimated data. This is in line with the previously established Dose per Caput of the last Population Dose Survey which was 0.31 mSv per head of the population. Including the estimated data from Table 20 the Dose per Caput was found to be 0.38 mSv per head of the adult population.

Table 22 shows the breakdown of the percentage contribution each category makes to the total number of exams performed, separated by gender. Table 23 shows the breakdown of the percentage contribution each category makes to the total male and female population dose. This must be considered an underestimate as only certain categories were included in the survey. Categories including Brain, C-spine, Hi-Res Thorax, TAP and Abdomen – Pelvis remain broadly the same as in 2010. The 9 mandatory categories account for a total of 221,535 exams (61.34 %) of the survey total of 361,132 returned exams.

Table 22: Breakdown of the percentage contribution by gender each category makes to the total number of exams performed (including "unspecified" and "other" returns) across all surveyed categories

Examination	Adult Female	%	Adult Male	%
	No of Exams		No of Exams	
Cervical Spine	1,643	1.44%	2,186	2.04%
Brain	46,864	40.95%	44258	41.33%
Sinuses	764	0.67%	674	0.63%
Thorax*	2,496	2.18%	2,550	2.38%
Hi-Res Thorax	4,175	3.65%	3,991	3.73%
CTPA	8,624	7.54%	6,697	6.25%
TAP	21,470	18.76%	20,416	19.06%
Abdomen - Pelvis	22,555	19.71%	20,351	19.00%
KUB	5,854	5.12%	5,967	5.57%
Total	114,445	100.00%	107,090	100.00%

Worked Examples: Of the 114,445 female examinations performed in the mandatory categories, 40.95% were Female Brain exams; while of the 107,090 male examinations performed in the mandatory categories, 41.33% were Male Brain exams

*** Thorax was not a mandatory category and had limited data returns by respondents**

Table 23: Breakdown of the percentage contribution by gender each category makes across surveyed categories to the total male and female population dose

CT Examination	Female	%	Male	%
	Person mSv		Person mSv	
Cervical Spine	2,866	0.52%	4,474	0.73%
Brain	74,645	13.44%	75,752	12.32%
Sinuses	249	0.04%	239	0.04%
Thorax*	10,608	1.91%	13,482	2.19%
Hi-Res Thorax	15,544	2.80%	19,065	3.10%
CTPA	36,799	6.63%	34,610	5.63%
TAP	236,599	42.61%	275,024	44.71%
Abdomen - Pelvis	154,818	27.88%	163,785	26.63%
KUB	23,135	4.17%	28,642	4.66%
Total	555,262	100.00%	615,072	100.00%

Worked Examples: Of the 555,262 Person mSv accruing from female examinations performed in the mandatory categories, 13.44% was from Female Brain exams while of the 615,072 Person mSv accruing from male examinations performed in the mandatory categories, 12.32% was from Male Brain exams

*** Thorax was not a mandatory category and had limited data returns by respondents**

Paediatric Population Dose

Effective dose determination was made with reference to research published by Alesso, 2010 which established paediatric weighting factors to convert DLP (mGycm) into Effective dose (µSv). The table below shows these conversion factors for the body specific examinations that were included in the survey. These conversion factors were replicated from the previous Population Dose Survey in CT, 2010 to allow comparisons to be made with the earlier data.

Table 24: Total Paediatric Population Dose based on submitted data

Paediatric Examination	Average DLP (mGycm)	Alesso et al Conversion Factor	Effective Dose mSv / mGycm	No of Exams	Person mSv	Person Sv
CT Brain						
0 < 3 months	176	0.013	2.29	53	121	0.12
3 months < 1 year	297	0.013	3.86	253	977	0.98
1 < 6 years	398	0.008	3.18	813	2,589	2.59
>6 years inclusive	563	0.005	2.82	1766	4,971	4.97
CT Thorax						
< 5kg or neonates	29	0.057	1.65	11	18	0.02
5 < 15kg	50	0.038	1.90	51	97	0.10
16 < 30 kg (inclusive)	78	0.026	2.03	79	160	0.16
31 <50 kg (inclusive)	114	0.019	2.17	59	128	0.13
51 < 80 kg (inclusive)	125	0.019	2.38	46	109	0.11
CT Abdomen/Pelvis						
16 < 30 kg (inclusive)	119	0.021	2.50	51	127	0.13
51 < 80 kg (inclusive)	313	0.015	4.70	35	164	0.16
					Total	9.46

Paediatric Population Dose: Collective Effective Dose

The Collective Effective Dose is defined as the sum of the average effective dose for each examination times the frequency of each examination. Combining the Total Person mSv for paediatric patients and converting from mSv to Sieverts (Sv) gives the following result for Paediatric Population Dose:

Table 25: Total Paediatric Population Dose

Total Paediatric Population Dose	
Person mSv	Person Sieverts
9,462	9.46

Due to the varied nature of the paediatric data returned from each centre it was not possible to extrapolate for missing data. In addition, as only certain selected categories were included in the survey the Paediatric Population Dose should be considered to be a conservative estimate.

Paediatric Dose per Caput

The Dose per Caput is defined as the collective dose average over the whole population. Table 16 shows the Paediatric population to be 1,129,184. The Paediatric Dose per Caput was found to be 0.008 mSv per head of the paediatric population. This is in line with the previously established Paediatric Dose per Caput of the last Population Dose Survey which was 0.01 mSv per head of the paediatric population.

Table 26 shows the breakdown of the percentage contribution each category makes to the total number of exams performed. Table 27 shows the breakdown of the percentage contribution each category makes to the total paediatric population dose. This must also be considered an underestimate as only certain categories were included in the survey.

Table 26: Breakdown of the percentage contribution each category makes across surveyed categories to the total number of exams performed

Paediatric Examination	No of Exams	%
Brain		
0 < 3 months	53	1.65%
3 months < 1 year	253	7.86%
1 < 6 years	813	25.27%
>6 years inclusive	1,766	54.9%
Thorax		
< 5kg or neonates	11	0.34%
5 < 15kg	51	1.59%
16 < 30 kg (inclusive)	79	2.46%
31 <50 kg (inclusive)	59	1.83%
51 < 80 kg (inclusive)	46	1.43%
Abdomen/Pelvis		
16 < 30 kg (inclusive)	51	1.59%
51 < 80 kg (inclusive)	35	1.09%
Total	3,217	100.00%

Worked Example: Of the 3,217 paediatric examinations performed in the mandatory categories, 54.9% were Brain exams in the > 6 year category

Table 27: Breakdown of the percentage contribution each category makes across surveyed categories to the total paediatric population dose

Paediatric Examination	Person mSv	%
Brain		
0 < 3 months	121	1.28%
3 months < 1 year	977	10.32%
1 < 6 years	2,589	27.37%
>6 years inclusive	4,971	52.54%
Thorax		
< 5kg or neonates	18	0.19%
5 < 15kg	97	1.02%
16 < 30 kg (inclusive)	160	1.69%
31 <50 kg (inclusive)	128	1.35%
51 < 80 kg (inclusive)	109	1.15%
Abdomen/Pelvis		
16 < 30 kg (inclusive)	127	1.34%
51 < 80 kg (inclusive)	164	1.73%
Total	9,461	100.00%

Worked Example: Of the 9,461 Person mSv accruing from paediatric examinations performed in the mandatory categories, 52.54% was from Brain exams in the > 6 year category

Discussion Points

Survey Format

There was a lot of duplication in the submitted data where a second Respondent ID was assigned when a centre resubmitted additional data or clarified previous data. This occurred for nine separate centres, one Respondent ID was blank and at least one centre data was omitted because they submitted in paper format. This required a lot of work to extricate the data across all fields. Future surveys should allow a respondent re-entry to a submission via a password.

Several centres failed to provide information on important demographic sections including details of the person completing the survey, the Medical Physics expert and the Medical Practitioner. A crucial section concerning patient numbers was left blank by several centres which detracts from overall Population Dose calculations. Future surveys should make these fields mandatory, whereby they cannot be left blank. It is also apparent that several centres did not submit any data at all as known CT scanner centres do not appear in the data.

A section of the survey allowed respondents to furnish information on other examinations common in their centre. Due to the disparate nature of these examinations it is not possible to perform any analysis of national significance on the data returned. It does however indicate that there are several protocols involving the CT Thorax with specific parameters in common usage in centres which could form the basis of future research.

Comments from some respondents cited an inability to separate out scanner type and male / female patients retrospectively due to technical issues and time constraints. There were also comments that the survey spreadsheet differed slightly from the on-line Survey Monkey template, particularly with regard to the paediatric weight ranges.

Insufficient data to allow analysis was returned for the following examinations:

1. Total body CT in severe trauma
2. Coronary angiography retrospective gating
3. Coronary angiography prospective gating
4. Paediatrics: (Other)
5. Paediatrics: ABDOMEN / PELVIS: < 5kg or neonates
6. Paediatrics: ABDOMEN / PELVIS: 5 < 15kg
7. Paediatrics: ABDOMEN / PELVIS: 5 < 15kg

One large referral centre submitted combined data across two scanners; for the purposes of analysis these examinations were divided equally across both scanners.

Adult Examination Categories

Significant deviation from the National Median CTDIvol (mGy) or the National Median DLP (mGycm) and where centres are outside the 75th percentile should prompt clarification of the local practice. Ideally the Population Dose Committee with access to the complete data sheets could initiate this clarification by contacting the relevant centres. Additionally where a centre performs a high volume of a particular examination and performs well in relation to National DRLs it might benefit to contact the centre and ask for clarification of their local scanning parameters which could be disseminated to centres who perform the examinations less frequently to allow them to compare parameters and possibly implement positive change.

Worked Example: Cervical Spine

There is a range of 5 – 71 (Female) and 6 – 75 (Male) Median CTDIvol (mGy) with a National Median value of 15 and 18 respectively. There is a range of 130 – 844 (Female) and 145 – 788 (Male) Median DLP (mGycm) with a National Median value of 305 and 369 respectively.

These ranges are evident in several of the examined categories and clarification should be sought where evidenced.

Dose Reference Levels

It would have been useful to have asked for the number of examinations performed in each of the Dose Reference Level categories as it would have allowed estimation of the percentage subset of the main category. This would provide some information on referral patterns. Examples of relevant categories include CT for Sinusitis, CT for Cervical Spine Trauma and CT for Head Injury, which are subsets of CT Sinuses, CT Cervical Spine and CT Brain respectively.

Paediatric Examination Categories

The most immediate finding of the survey was the referral patterns of paediatric patients for Brain imaging were markedly different from expected with the three main paediatric centres scanning a relatively low percentage of paediatric patients in many age categories. Several centres performed up to sixteen times the volume of the dedicated paediatric centres in certain categories, particularly the 1 – 6 year and the > 6 year Brain examinations.

For Paediatric Thoracic scanning this finding reverted to the three dedicated paediatric centres performing the overwhelming majority of the scans.

For Paediatric Abdominal and Pelvis scanning very little data was returned and many centres omitted patient numbers making it impossible to ascertain accurate referral patterns. From what data was available it would appear to be consistent with the data for Thoracic scanning in that the dedicated paediatric centres performed the majority of the scans.

This report is based on data supplied by respondents to the MEDICAL EXPOSURE RADIATION UNIT (MERU) NATIONAL SURVEY ON POPULATION DOSE FROM COMPUTED TOMOGRAPHY 2017, and is therefore subject to verification and validation. Where uncertainty surrounding supplied data existed further clarification was sought from the relevant respondent. Conclusions drawn from the data and calculations of dose reference levels, population dose and dose per caput are based on this data and resultant estimates, and care must be taken when extrapolating beyond the data supplied.

Synopsis

What these findings mean with regard to current radiation protection in Ireland

Two key indices of effective national radiation protection practices are Collective Effective Dose and Dose per Caput. Collective Effective Dose sums the average dose for each examination and multiplies it by the frequency of each examination. This is measured in Sieverts (Sv) and in this report allowed us to estimate how much radiation was delivered nationally to CT patients in 2016. The Collective Effective Dose was determined to be 1,388 Person Sievert after the inclusion of estimated data, which compares to the 1,368 Person Sievert of the 2010 report.

Dose per Caput is the collective dose average over the whole population. The Dose per Caput was found to be 0.38 mSv per head of the population after the inclusion of estimated data. This is in line with the previously established Dose per Caput of the last Population Dose Survey which was 0.31 mSv per head of the population.

Although consideration must be given to the differences in examination categories between the two surveys the latest survey broadly shows a 90% increase in CT examination activity since the 2010 survey. It would appear from the report that the increase in number of examinations has been greatly offset by improvements in dose software and scanning parameters in maintaining the Collective Effective Dose and Dose per Caput. The continued education and training of key CT staff and the availability of dedicated Radiation Safety Officers, Clinical Specialist radiographers, medical physics experts and radiologists who monitor clinical radiation protection has also been crucial to keeping patient dose optimised. The role of radiation protection structures within hospitals and of national advisory bodies such as the National Radiation Safety Committee of the HSE, MERU, and EPA has strengthened since the last survey. The efforts by MERU to establish incident reporting, the patient safety manual and clinical audits have been particularly beneficial in developing both educational tools and points of contact with those involved in patient radiation safety.

This strengthening of radiation safety culture has been underpinned by the increasing educational and research output from academic and training bodies, radiography schools, faculty of radiology and medical physics expert training programs, with post graduate courses in CT, radiation safety officers training, research projects, and scientific meetings and papers. Ireland is well represented as part of the Europe wide contribution to radiation protection in terms of voluntary initiatives such as Eurosafe, and regulatory development through the Heads of the European Radiological Protection Competent Authorities (HERCA), International Atomic Energy Agency (IAEA), Euratom and membership of European professional societies such as the European Society of Radiology, European Federation of Medical Physicists and the European Federations of Radiographers' Societies.

For the patient, this National Survey on Population Dose from CT enables radiology departments to compare the doses delivered by their scanners for particular examinations against those delivered by both other scanners in the same department and against those delivered by other scanners throughout the country. This allows CT departments to constantly strive to optimise their examinations with regard to dose and to prioritise more radiation sensitive patients such as paediatrics and females of reproductive capacity on scanners where options for lower dose examinations exist. The National Diagnostic Reference Levels established by this report will help ensure that doses for patient examinations in each CT department are compared against a national standard for similar examinations to identify, and rectify upward dose trends with due regard for clinical performance .

Patient Safety and Radiation Protection in CT

One of the aims of the survey was to build upon the Diagnostic Reference Levels (DRLs) for common CT examinations that were established in the 2010 Report and on the DRLs published in the HSE, MERU Patient Radiation Manual, 2013 for Adults; and in the PiDRL Guidelines, 2016 for Paediatrics. As a result of this survey these Diagnostic Reference Levels (DRLs) have been updated for common Adult and Paediatric CT examinations. It is important that these updated DRL tables are incorporated into CT departments, particularly with regard to the gender specific values published in the report.

Sections Two and Three of the report produced tables for common Adult CT examinations showing information concerning Median CTDIvol (mGy), Median DLP (mGycm) and 75th percentile values for these examinations. Centres that perform these examinations should closely examine these tables in light of the information they submitted for the audit. Significant deviation from the National Median CTDIvol (mGy) or the National Median DLP (mGycm) and where centres are outside the 75th percentile should prompt clarification of the local practice.

Section Four of the report produced tables for common Paediatric CT examinations showing information concerning Median CTDIvol (mGy), Median DLP (mGycm) and 75th percentile values for these examinations. Centres that perform Paediatric CT examinations should closely examine these tables in light of the information they submitted for the audit. Significant deviation from the National Median CTDIvol (mGy) or the National Median DLP (mGycm) and where centres are outside the 75th percentile should prompt clarification of the local practice.

The most immediate finding of the paediatric part of the survey was the referral patterns of paediatric patients for brain imaging were markedly different from that expected with the three main paediatric centres scanning a relatively low percentage of paediatric patients in many age categories. Several centres performed up to sixteen times the volume of the dedicated paediatric centres in certain categories, particularly the 1 – 6 year and the > 6 year brain examinations. Of the sixty four scanners surveyed only two are dedicated paediatric scanners although a further twenty eight accept paediatric patients, with these centres scanning both adults and paediatrics. It is very important that centres that are not dedicated paediatric scanners are aware of and incorporate the newly published Paediatric DRLs contained in this report.

Information on the availability of Dose Modulation and/or Iterative Reconstruction software was requested of respondents. From this information it has been possible to extract dose information for several examination categories to allow comparison of those scanners utilising dose modulation, iterative reconstruction or both. Significant increase in patient dose was observed where Dose Modulation and/or Iterative Reconstruction were not available. Centres should be aware of this finding and should where possible ensure that more radiation sensitive patients such as paediatrics and women of reproductive capacity are examined using scanners where these features are available.

Data collection in CT going forward

It would be beneficial if the difficulties encountered in the analysis of collected data in this audit report could help structure how future data is collected locally. The format of the next audit process should be decided upon by the Population Dose Committee at an early stage and circulated to all centres so that they can begin to prepare for effective electronic capture of relevant data. In particular it should be stressed that future DRLs will deal separately with male and female patients.

A National Dose Watch system should be decided upon and utilised by all CT departments which would allow for greater standardisation of collected dose information and examination parameters and for easier and ideally computerised analysis of audit data. This would greatly assist in the production of the next report.

CT forums in Ireland should be approached by the Population Dose Committee with a view to encouraging communication of best practice from centres that performed well in the audit for particular examinations to centres that performed less well. The Population Dose Committee should initiate this clarification by contacting the relevant centres. Additionally where a centre performs a high volume of a particular examination and performs well in relation to national DRLs it might be beneficial to contact the centre and ask for clarification of their local scanning parameters which could be disseminated to centres who perform the examinations less frequently to allow them to compare parameters and possibly implement positive change.

There are several centres that appear to have failed to engage with or return data for the survey. There are an estimated six additional scanners which can be adduced from centres with known CT departments. These should be followed up with and clarification sought. Ideally these centres should now be asked again to submit their data for comparison against the National Survey on Population Dose from CT.

Conclusion

In conclusion, the value of undertaking a National Survey on Population Dose from CT is evident from the information returned. This national survey used an approach based on current radiation protection thinking and regulatory demands around patient demographics and clinical indications. We now have better information on the numbers and types of CT scanners in use and the dose reduction software enabled on these scanners which in turn can be correlated with patient dose. This should help form a business case and rationale for future updating of CT scanners. We also have good gender specific statistical information regarding types and frequencies of CT examination performed across Ireland and the doses associated with these examinations. A set of age and gender based diagnostic reference levels have been produced for CT examinations for anatomical areas and for some clinical indications. These diagnostic reference levels can be used (a) to improve a regional, national or local distribution of observed results for a general medical imaging task, by reducing the frequency of unjustified high or low values (b) to promote attainment of a narrower range of values that represent good practice for a more specific medical imaging task and (c) to promote attainment of an optimum range of values for a specified medical imaging protocol with due regard for image quality.

The data presented in this survey should help centres to ensure that their local CT examination parameters conform with best practice nationally and ultimately Europe wide. In order for patients to get the best value from this data and to improve future surveys, the following is recommended as actions for MERU, the National Radiation Safety Committee, professional training and research bodies and those charged with looking after patient radiation safety under the new regulations:

1. Increase awareness of the report and diagnostic reference levels by presentation at national and international meeting, publishing scientific papers and distribution to stake holders via the HSE website.

2. Inform procurement processes, professional, educational, audit, regulatory and training bodies regarding the effect of dose recording, audit and modern CT technology on improvement of patient safety.

3. Progress the management of patient dose tracking application software and recruitment of appropriate personnel in particular for the Irish Hospitals involved in the NIMIS project.

4. Participate in further Irish and European studies on the optimisation of dose and image quality for specific clinical questions.

5. Continue to monitor the effect of increased diagnostic radiology utilisation on the Irish population dose burden on a more frequent basis.

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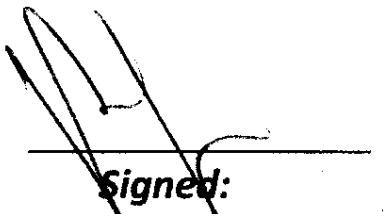
Appendix 1: Adult Diagnostic Reference Levels

National Survey on Population Dose from Computed Tomography, 2017 Adult Examinations	Female DRL DLP (mGycm)	Male DRL DLP (mGycm)
Cervical Spine	354	490
Cervical Spine Trauma	469	477
Brain	845	927
Head Trauma	918	927
Sinuses	190	211
Sinusitis	183	210
Thorax	280	377
Hi-Res Thorax	313	374
Diffuse Infiltrate Lung Disease	210	249
CTPA	310	379
Pulmonary Embolus	234	278
Pulmonary Metastases	241	272
Thorax - Abdomen – Pelvis (TAP)	661	830
TAP oncologic follow-up (single phase)	605	643
Abdomen - Pelvis	533	592
Appendicitis	439	490
Liver and abdominal metastases in colorectal cancer	554	536
CT KUB	288	381
Urinary calculus	254	291

Appendix 2: Paediatric Diagnostic Reference Levels

National Survey on Population Dose from Computed Tomography, 2017	Paediatric DRL DLP (mGycm)
Examination: CT Head	
Age	
0 - < 3 months	239
3 months - 1 year	376
1 - 6 years	536
> 6 years	742
Examination: CT Thorax	
Weight	
< 5 kg	No Data
5 < 15 kg	81
15 < 30 kg	99
30 < 50 kg	166
50 < 80 kg	131
Examination: CT Abdomen	
Weight	
< 5 kg	No Data
5 < 15 kg	No Data
15 < 30 kg	168
30 < 50 kg	No Data
50 < 80 kg	397

MERU wish to acknowledge the co-operation and goodwill afforded to them by the management and staff at all radiological facilities who participated in the survey.

Chair of the National Population Dose and Optimisation Committee: Mr. Paddy Gilligan	
Date:	13 September 2018

Acknowledgements

Development of survey questions	Brendan McCoubrey, Lee O'Hora, Mandy Lewis, Mike Rowan, Paddy Gilligan, and Rose Lindsay
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