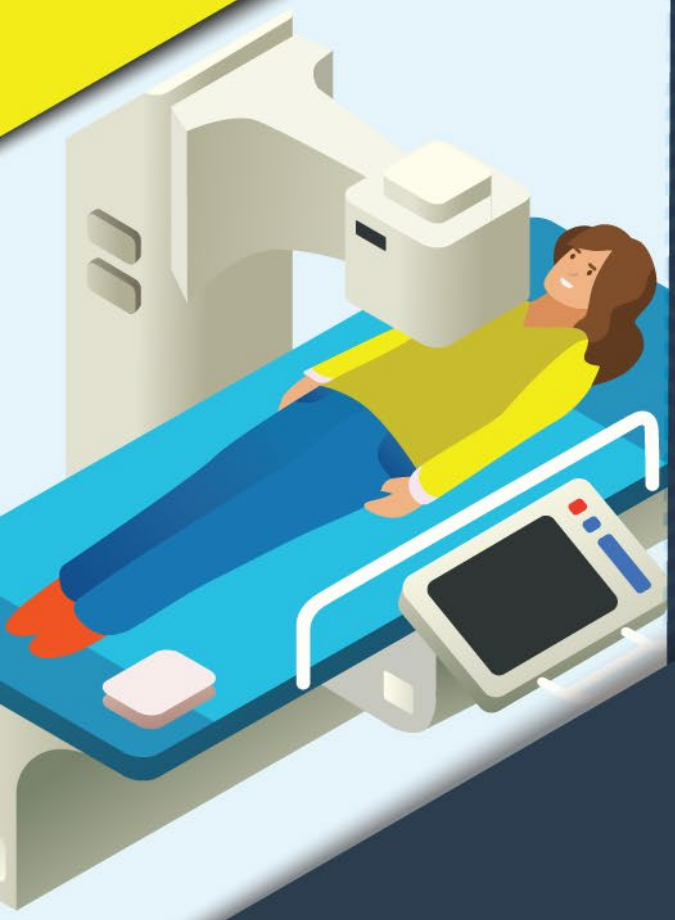
JULY 2021

Medical exposure to ionising radiation

National diagnostic reference levels (DRLs) for general radiography, mammography and DXA scanning



Regulation of health and social care services

Health Information and Quality Authority

An tÚdarás Um Fhaisnéis agus Cáilíocht Sláinte

About the Health Information and Quality Authority (HIQA)

The Health Information and Quality Authority (HIQA) is an independent statutory authority established to promote safety and quality in the provision of health and social care services for the benefit of the health and welfare of the public.

HIQA's mandate to date extends across a wide range of public, private and voluntary sector services. Reporting to the Minister for Health and engaging with the Minister for Children, Equality, Disability, Integration and Youth, HIQA has responsibility for the following:

- **Setting standards for health and social care services** — Developing person-centred standards and guidance, based on evidence and international best practice, for health and social care services in Ireland.
- **Regulating social care services** — The Chief Inspector within HIQA is responsible for registering and inspecting residential services for older people and people with a disability, and children's special care units.
- **Regulating health services** — Regulating medical exposure to ionising radiation.
- **Monitoring services** — Monitoring the safety and quality of health services and children's social services, and investigating as necessary serious concerns about the health and welfare of people who use these services.
- **Health technology assessment** — Evaluating the clinical and cost-effectiveness of health programmes, policies, medicines, medical equipment, diagnostic and surgical techniques, health promotion and protection activities, and providing advice to enable the best use of resources and the best outcomes for people who use our health service.
- **Health information** — Advising on the efficient and secure collection and sharing of health information, setting standards, evaluating information resources and publishing information on the delivery and performance of Ireland's health and social care services.
- **National Care Experience Programme** — Carrying out national service-user experience surveys across a range of health services, in conjunction with the Department of Health and the HSE.

Contents

Executive summary

In Ireland, the Health Information and Quality Authority (HIQA) is designated as the competent authority for regulating medical exposure to ionising radiation. This includes creating and reviewing national diagnostic reference levels (DRLs) for medical procedures using radiation. National DRL values are typical radiation dose levels set for common medical imaging procedures and clinical tasks, such as X-rays. DRLs help support medical facilities to compare local facility patient dose to a national standard, and allows them to use this as a benchmark to optimise patient radiation dose.

In November 2020, HIQA issued a DRL survey to 137 service providers in Ireland that provide either general radiography or X-rays, mammography, or dual-energy X-ray absorptiometry (DXA) service, or a combination of these services. Approximately 93%* of service providers responded and the data was compiled and reviewed.

Updated national DRLs for general radiography and mammography were determined and national DXA DRLs were produced for the first time in Ireland. National DRLs are set as the 75th percentile of the distribution of median values obtained. This means that out of all values surveyed 25% of Irish doses lie above this national DRL value and 75% of national doses are below this figure. A national median, or 50th percentile dose of median values obtained was also established. This means that out of all values surveyed, 50% of doses will be above, and 50% will be below this average figure. This new national data allows service providers to continue to compare representative service user doses to national DRL figures, identify medical radiological procedures that require review and put corrective actions in place where needed.

When comparing new national DRL data for general radiography and mammography to the previous study conducted in 2010 by the Health Service Executive (HSE), this survey found reductions in reference doses ranging from 2-27% for all medical imaging procedures reviewed. This new national DRL data compares positively with recently published European DRLs, as the vast majority of Irish DRLs, for both adult and paediatric radiography, are below that referenced in guidance issued by the European Commission.

The total number of general X-rays conducted in Ireland has remained relatively consistent since the last such survey in 2010, although increases have been seen in BreastCheck screening services, which may be due to the expansion of the service over the last 10 years.

* As part of regulatory requirements, each undertaking must provide HIQA with any information or statistics needed in order to determine the level of compliance by the undertaking with these regulations. The remaining service providers were followed up as part of standard regulatory process.

In Ireland, it was found that there is newer equipment used in mammography, followed by paediatric radiography, where dedicated equipment was used, followed by adult general radiography and DXA. It was found that 46.9% of DXA equipment, 43.9% of general radiography equipment, 31% of dedicated paediatric radiography equipment and 9.8% of mammography equipment were 10 years or older. Although older equipment may continue to operate within acceptable limits, undertakings should incorporate a rolling equipment replacement strategy, particularly noting the potential for rapidly changing technologies in diagnostic imaging equipment.

In addition to the age profile of equipment being determined, the survey also asked about the types of equipment used by facilities. HIQA found that the majority of undertakings are providing general radiography services using direct radiography (DR) and providing DXA services using fan beam equipment.

The survey results suggest that people using services are now typically receiving reduced radiation doses nationally in general radiography and mammography. This is of benefit to people receiving these types of X-rays, as the risk associated with exposure to ionising radiation is reduced while maintaining the diagnostic integrity of the images produced.

1. Introduction

The European Union (Basic Safety Standards for Protection Against Dangers Arising from Medical Exposure to Ionising Radiation) Regulations 2018 and 2019 (referred to in this document as the "Regulations") designate the Health Information and Quality Authority (HIQA) as the competent authority for the establishment and review of national diagnostic reference levels (DRLs) in Ireland.[1]

National DRL values are typical radiation dose levels set for common medical imaging procedures and clinical tasks in Ireland. These values allow medical facilities to compare local facility DRLs, which represents patient dose, to a national standard.

The data in this report will update existing general radiography and mammography national DRLs and establish national dual-energy X-ray absorptiometry (DXA) DRLs for the first time.

1.1 Previous work on national DRLs in Ireland

In 2013, the Health Service Executive (HSE) Medical Exposure Radiation Unit (MERU) published a template for developing a Patient Radiation Protection Manual,[2] which included national DRLs for the following:

- dental radiography
- adult radiography
- mammography
- nuclear medicine
- positron emission tomography (PET) computed tomography (CT)
- adult CT
- paediatric CT.

The national DRLs were based on survey work in CT, general radiography and nuclear medicine and preliminary results of national DRL surveys in PET CT, fluoroscopy and interventional radiology previously undertaken by the HSE and the Dental Council.

In 2017, the HSE updated the Radiation Protection Manual,[3] incorporating the results from the *National Survey on Population Dose from Computed Tomography 2017*.[4] This survey also produced national DRLs for medical radiological procedures based on clinical task or clinical indications (clinical DRLs) for the first time in Ireland. Previously, DRLs were traditionally associated with a specific body part to be imaged, for example CT head or CT neck, but more recently DRLs have been established based on the clinical reason for the medical radiological procedure. Clinical reasons for diagnostic medical radiological procedures can influence the imaging protocols and may subsequently deliver different patient doses. The use of

clinical DRLs has been acknowledged as a more appropriate descriptor in the establishment of DRLs and is particularly applicable to CT and interventional radiology.[5]

1.2 Establishment of national DRLs by HIQA

HIQA adopted pre-existing national DRLs[6] in February 2020 following consultation with its Expert Advisory Group (EAG), which includes representation from relevant professional bodies in radiation protection (see Appendix A). These national DRLs were developed based on the diagnostic medical radiological procedures, or clinical tasks, included in the existing national DRLs established by HSE MERU,[2,3] Public Health England's DRL guidance,[7] European guidelines on paediatric DRLs,[8] the EUCLID DRL review,[9] the Administration of Radioactive Substances Advisory Committee (ARSAC) guidance[10] and other published international literature.[11,12]

In February 2020, HIQA published *Guidance on the establishment, use and review of diagnostic reference levels for medical exposure to ionising radiation,*[6] which provided information for service providers[†] on establishing local facility DRLs. The guidance also explains how HIQA establishes national DRLs for common medical radiological procedures used in dental X-rays, general radiography, mammography, fluoroscopy, interventional radiology and interventional cardiology, computed tomography (CT) and nuclear medicine.

As part of the statutory requirement for HIQA to regularly review national DRLs and in identifying that a review of general radiography and mammography doses had not been conducted since 2010, it was proposed to focus the first survey in this sector. Furthermore, a national review of DXA DRLs had not been carried out in Ireland and this presented a new opportunity to establish national DXA DRL values. DXA, or dual energy X-ray absorptiometry, is a type of medical exposure commonly used to assess bone density in service users where low bone density or osteoporosis is suspected.

[†] For the purpose of this document, a service provider is an undertaking or a person or body who has a legal responsibility for carrying out, or engaging others to carry out, a medical radiological procedure, or the practical aspects of a medical radiological procedure, as defined by the Regulations.

2. National review of DRLs by HIQA

2.1 Methodology

2.1.1 Survey design and distribution

A literature review of published national and international DRLs was conducted and a list of typical procedures and clinical tasks were reviewed by select members of HIQA's EAG with relevant clinical knowledge and expertise in the field of DRLs. The final DRL procedures and clinical tasks to be reviewed were agreed by the EAG in October 2020.

As part of the DRL survey roll-out, HIQA identified 137 service providers in its directory of declared undertakings that provide a general radiography service, including DXA and mammography. Access to an online portal system was set up for these service providers to receive and subsequently submit the completed survey to HIQA.

In November 2020, HIQA issued the DRL survey to 137 service providers and each service provider had 28 days to complete and submit the survey on the online portal system. The survey was divided into four distinct sections relating to discrete aspects of service provided by the service provider (adult radiography, paediatric radiography, mammography and DXA) (see Appendix B).

Medical imaging facilities were asked to:

- indicate which service(s) they provided
- supply general radiography and DXA equipment details (where appropriate)
- indicate local facility radiation doses, which would be representative of the radiation dose given to service users and
- supply information on the frequency of the diagnostic medical radiological procedures.

2.1.2 Equipment information

Each survey also requested service providers to give information on the number of individual items of general X-ray equipment used within the service. Service providers were also asked to place equipment into one of three age categories, zero to five years (0-5 years), six to 10 years (6-10 years) and older than 10 years (10+ years). This categorisation aligned with the European Society of Radiology's (ESR) position on equipment age, the aim of which is to provide suggested criteria of when replacement or upgrade of equipment should be considered.[13]

2.1.3 Local facility DRLs and procedure numbers

Service providers were asked to supply local facility DRLs for a range of diagnostic medical radiological procedures or clinical tasks, as a median dose received by all or

a sample of patients attending their service, as outlined in HIQA's *Guidance on the establishment, use and review of diagnostic reference levels for medical exposure to ionising radiation*.[6]

National DRLs are set as the 75th percentile of the distribution of median values obtained. A national median, or 50th percentile dose of median values obtained was also established. For services striving for another quality metric, a national median, while not a national DRL, allows facilities to further optimise patient doses locally.[14] For mammographic procedures, the 95th percentile was also generated as a supplementary national dose level. The 95th percentile dose is widely quoted when considering mammography specific DRLs and may be more suitable to well-established screening environments, whose variation in dose is likely to be small.[15]

For radiography (adult radiography, paediatric radiography and mammography) and DXA, the type of radiography image receptor used and DXA beam geometry, has the potential to influence the subsequent patient dose.[16,17,18] As a result of the potential influence of equipment types, providers were also asked to indicate the equipment types used to establish local facility DRLs.

Finally, service providers were also requested to include the numbers of procedures and clinical tasks undertaken annually at their facilities.

3. Results

The results of this national survey are categorised under four main areas relating to the imaging modalities surveyed, namely general radiography, paediatric radiography, mammography and DXA. The results associated with each imaging modality are further subdivided into distinct sections outlining the specific findings of the survey:

- national DRL doses
- age profile of equipment
- equipment types used to establish local facility DRLs surveyed
- annual procedure numbers.

The results section uses a combination of table, figure and histogram format to communicate survey findings. National DRL doses are displayed in a format, or quantity, commonly used and easily measured by radiological equipment. This quantity indicates the amount of ionising radiation used to perform the medical radiological procedure. In general radiography and DXA, this quantity is the Gray centimetre squared ($Gy.cm^2$), which measures the amount of radiation (measured in Grays, Gy) and the area to which it is delivered (measured in centimetres squared). In mammography, this unit is the milli Gray (mGy), which measures the amount of radiation delivered to the breast tissue.

3.1 General radiography

The outcome of the survey established adult radiography national DRLs, which are displayed in Table 1. National median values are also presented for services to consider further optimisation of dose.

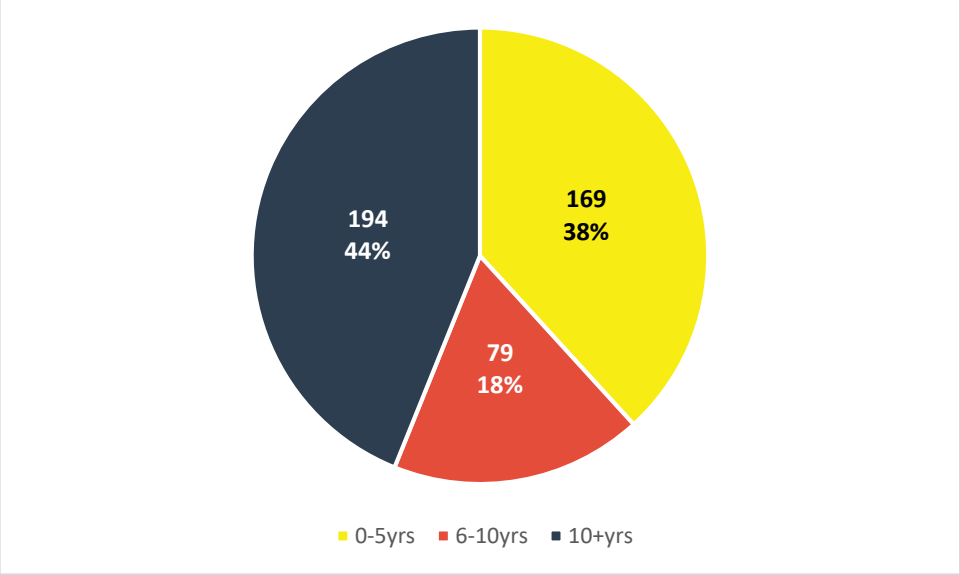
Table 1. Adult radiography national DRLs and national median doses

Procedure	New National DRL (Gy.cm²)	National Median Dose (Gy.cm²)
Chest PA‡	0.12	0.08
Chest AP§	0.13	0.10
Portable Chest AP	0.16	0.13
Abdomen AP	1.70	1.39
Pelvis AP	1.91	1.39
Cervical Spine AP	0.16	0.13
Cervical Spine LAT**	0.19	0.14
Thoracic Spine AP	0.76	0.53
Thoracic Spine LAT	1.80	0.92
Lumbar Spine AP	1.60	1.20
Lumbar Spine LAT	2.24	1.56
Extremities (Foot/Ankle/Wrist/Hand)	0.06	0.04

In Ireland, the adult and paediatric general radiography service is supplied in 101 medical radiological facilities and by 442 individual pieces of X-ray equipment, including mobile X-ray equipment. Over one third of equipment was classed as new according to ESR guidance,[13] however, over 40% of general radiography equipment was 10 years old or older (Figure 1).

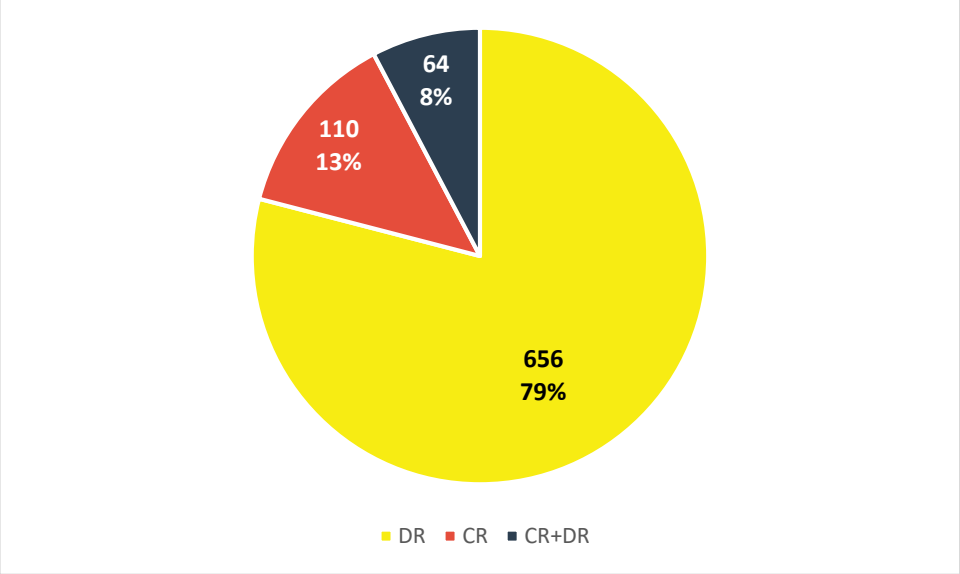
‡ A PA (posteroanterior) view is where the X-ray source is positioned so that the X-ray beam enters through the posterior (back) aspect of the body and exits out of the anterior (front) aspect, where the beam is detected.
§ An AP (anteroposterior) view is where the X-ray source is positioned so that the X-ray beam enters through the anterior (front) aspect of the body and exits out of the posterior (back) aspect, were the beam is detected.
** A LAT (lateral) view is where the X-ray is taken from the side of the body.

Figure 1. Age profile of radiography equipment



It was found that local facility DRLs were established using direct radiography (DR) equipment in 79% of facilities, computed radiography (CR) equipment in 13% of facilities and a combination of CR and DR in the remaining 8% of facilities (Figure 2).

Figure 2. Equipment type used to establish local facility DRLs

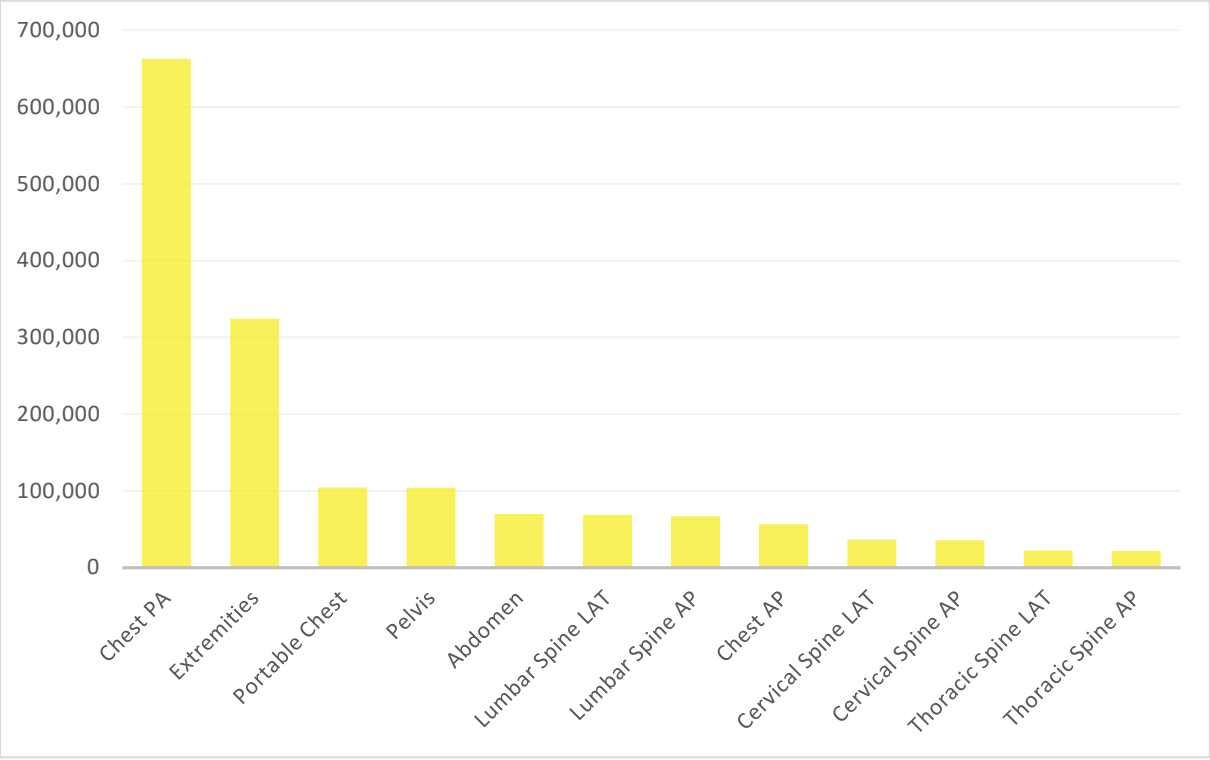


Annual procedure numbers for adult radiography are displayed in Table 2 and Figure 3. A chest X-ray is the most commonly performed adult radiograph, accounting for 52% of all radiographs reviewed.

Table 2. Adult radiography annual procedure numbers

Procedure	Total annual procedure projections
Chest PA	663,093
Chest AP	56,454
Portable Chest	104,467
Abdomen	69,813
Pelvis	104,050
Cervical Spine AP	35,677
Cervical Spine LAT	36,771
Thoracic Spine AP	22,105
Thoracic Spine LAT	22,389
Lumbar Spine AP	67,135
Lumbar Spine LAT	68,749
Extremities	324,485
Total	1,575,188

Figure 3. Adult radiography annual procedure numbers



3.2 Paediatric radiography

The result of the review of paediatric radiography national DRLs are displayed in Table 3. National median values are also presented for services to consider further optimisation of dose.

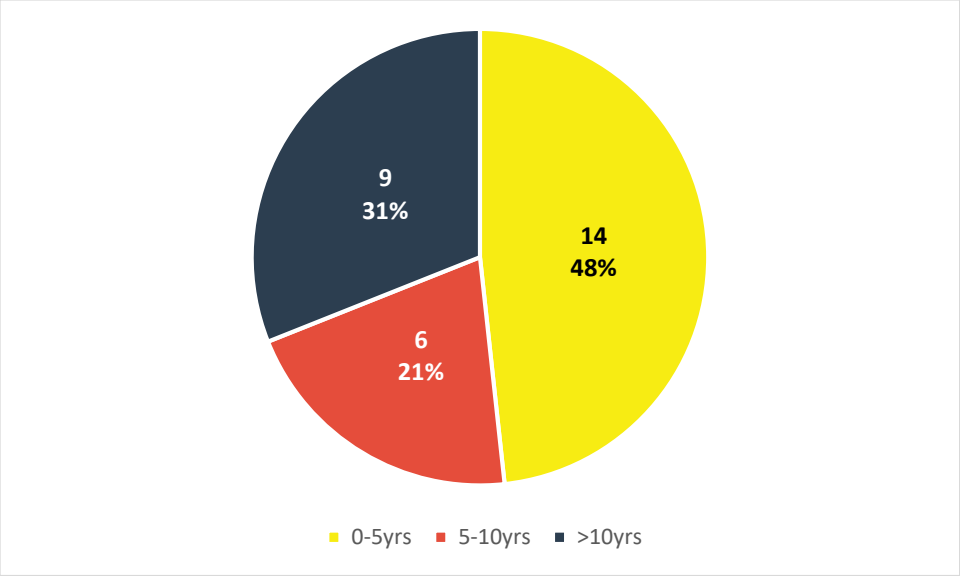
Table 3. Paediatric radiography national DRLs and national median doses[††]

Procedure/ Clinical task	Age/Weight categories	New National DRL (mGy.cm²)	National Median Dose (mGy.cm²)	(n)[∞]
Thorax AP/PA	<5kg	9	6	14
	5-<15kg	17	9	23
	15-<30kg	22	15	25
	30-<50kg	50	39	28
	50-80kg	70	54	27
Abdomen Pelvis AP	<5kg	13	9	8
	5-<15kg	63	41	15
	15-<30kg	100	63	18
	30-<50kg	286	175	15
	50-80kg	457	363	12
Pelvis/Hip AP	<5kg	27	20	7
	5-<15kg	39	22	30
	15-<30kg	111	64	23
	30-<50kg	412	274	22
	50-80kg	800	570	19
Cervical Spine AP	15-<30kg	28	16	10
	30-<50kg	59	38	11
	50-80kg	96	77	11
Cervical Spine LAT	15-<30kg	41	25	10
	30-<50kg	54	40	11
	50-80kg	68	54	9
Thoracic Spine AP	30-<50kg	244	199	10
	50-80kg	306	276	11
Thoracic Spine LAT	30-<50kg	566	443	10
	50-80kg	551	400	10
Lumbar Spine AP	15-<30kg	124	61	5
	30-<50kg	262	217	10
	50-80kg	445	379	12
Lumbar Spine LAT	15-<30kg	125	76	5
	30-<50kg	628	387	13
	50-80kg	850	620	12
Scoliosis AP	30-<50kg	980	576	13
	50-80kg	1630	526	12
Scoliosis LAT	30-<50kg	1869	990	9
	50-80kg	1840	1015	6

[††] Procedure or clinical task weight categories are omitted where there was insufficient data or data points collected to establish a National DRL.
∞ The (n) column indicates the number of medical radiological facilities that supplied local facility DRLs based on 10 or more service users. Providers should note that when n is low, confidence in the associated DRL value may also be low.

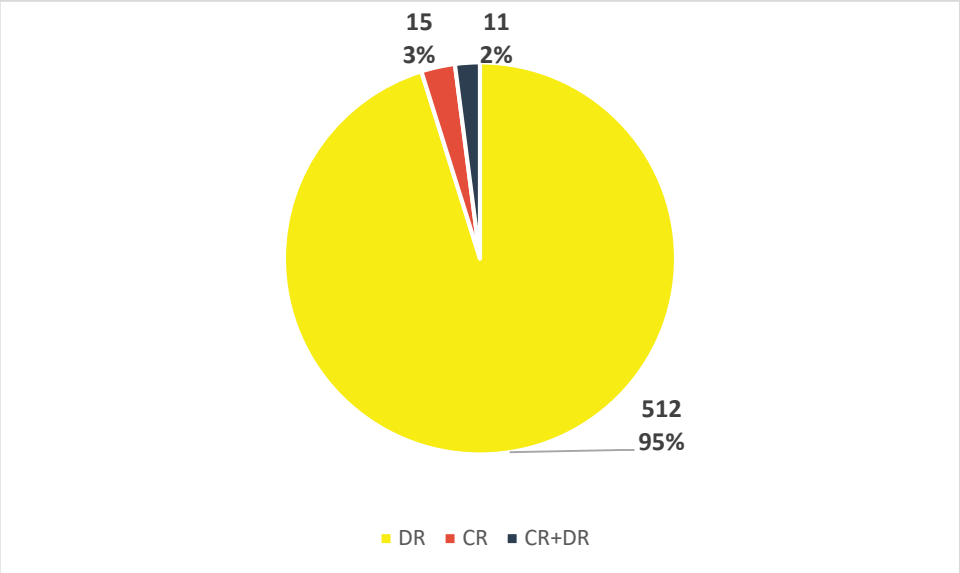
Although many facilities use the same radiographic equipment for both adult and paediatric radiography in Ireland, six medical radiological facilities deliver a dedicated paediatric service using 29 items of radiographic equipment, including mobile radiographic equipment. From Figure 4, nearly half of dedicated paediatric imaging was conducted on new equipment (0-5years).

Figure 4. Age profile of dedicated paediatric radiography equipment



The type of radiological equipment used to establish local facility DRLs is displayed in Figure 5. Local facility DRLs were established using DR equipment in 95% of facilities, CR equipment in 3% of facilities and a combination of CR and DR in the remaining 2% of facilities.

Figure 5. Equipment type used to establish local facility DRLs

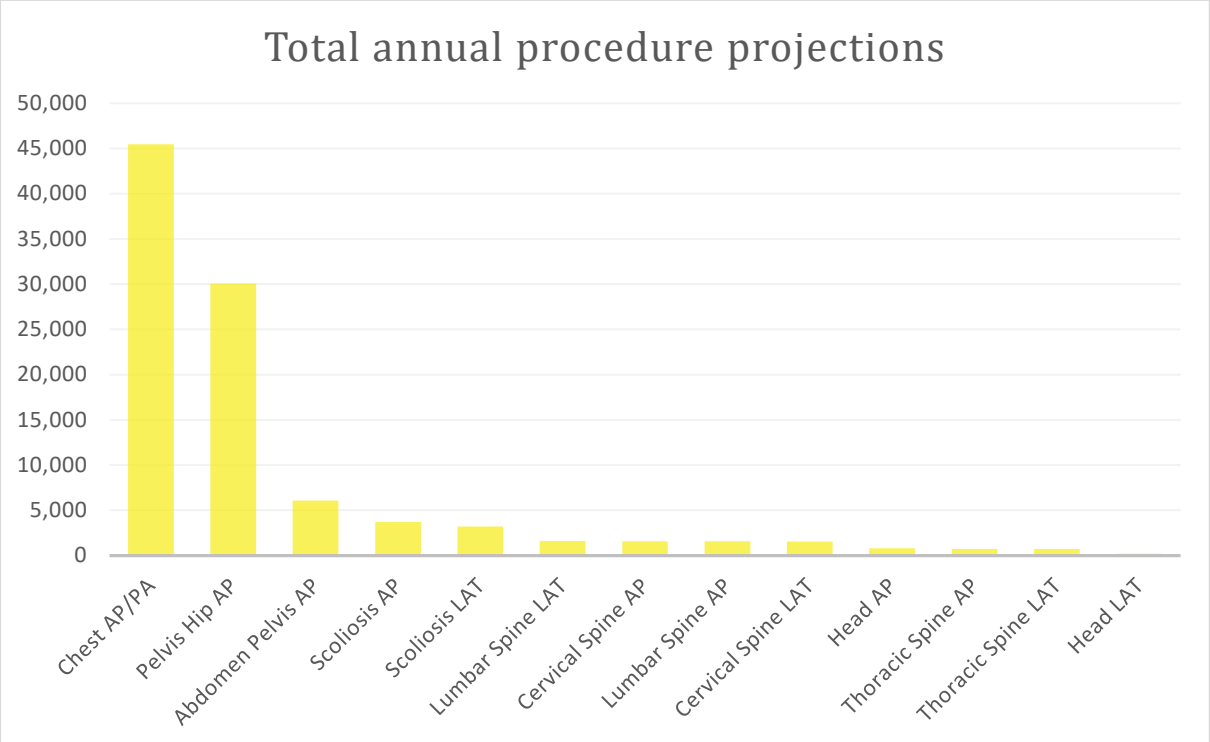


Annual procedure numbers for paediatric radiography are displayed in Table 4 and Figure 6. Like adult radiography, a chest X-ray is the most common paediatric procedure conducted, accounting for 47% of all paediatric radiographs reviewed. Paediatric pelvis X-rays account for a further 31% of paediatric radiographs surveyed.

Table 4. Paediatric radiography annual procedure numbers

Procedure	Total annual procedure projections
Head AP	806
Head LAT	210
Chest AP/PA	45,474
Abdomen Pelvis AP	6,094
Pelvis Hip AP	30,056
Cervical Spine AP	1,593
Cervical Spine LAT	1,557
Thoracic Spine AP	741
Thoracic Spine LAT	736
Lumbar Spine AP	1,577
Lumbar Spine LAT	1,636
Scoliosis AP	3,691
Scoliosis LAT	3,228
Total	97,399

Figure 6. Paediatric radiography annual procedure numbers



3.3 Mammography

The outcome of the survey established mammography national DRLs, which are displayed in Table 5. National median values are also presented for services to consider further optimisation of dose and national 95th percentile doses are also displayed.

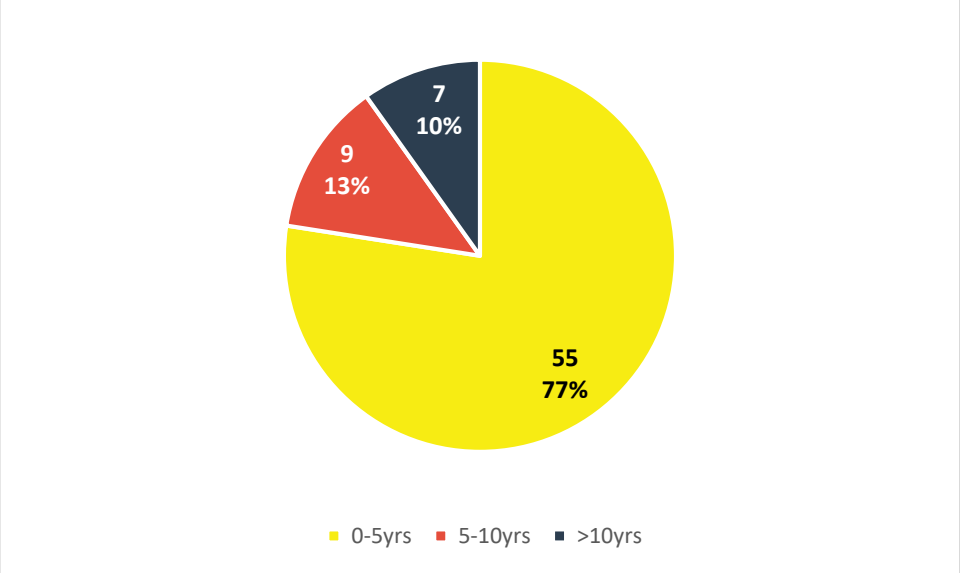
Table 5. Mammography national DRLs, national median doses and national 95th percentile doses

Procedure	New National DRL (mGy)	National Median Dose (mGy)	National 95th Percentile
Mediolateral Oblique (MLO) view	2.2	2	2.4
Craniocaudal (CC) view	2.2	2	2.5
Breast Tomosynthesis – MLO view	2.8	2.8	3
Breast Tomosynthesis – CC view	2.8	2.7	2.9

Twenty-one medical radiological facilities deliver a mammography service using 71 mammography units. In Figure 7, over three quarters of mammography imaging is conducted using new equipment (0-5years).

[‡‡] An MLO (mediolateral oblique) view looks through the breast from the side.
[§§] A CC (craniocaudal) view looks through the breast from above.

Figure 7. Age profile of mammography equipment

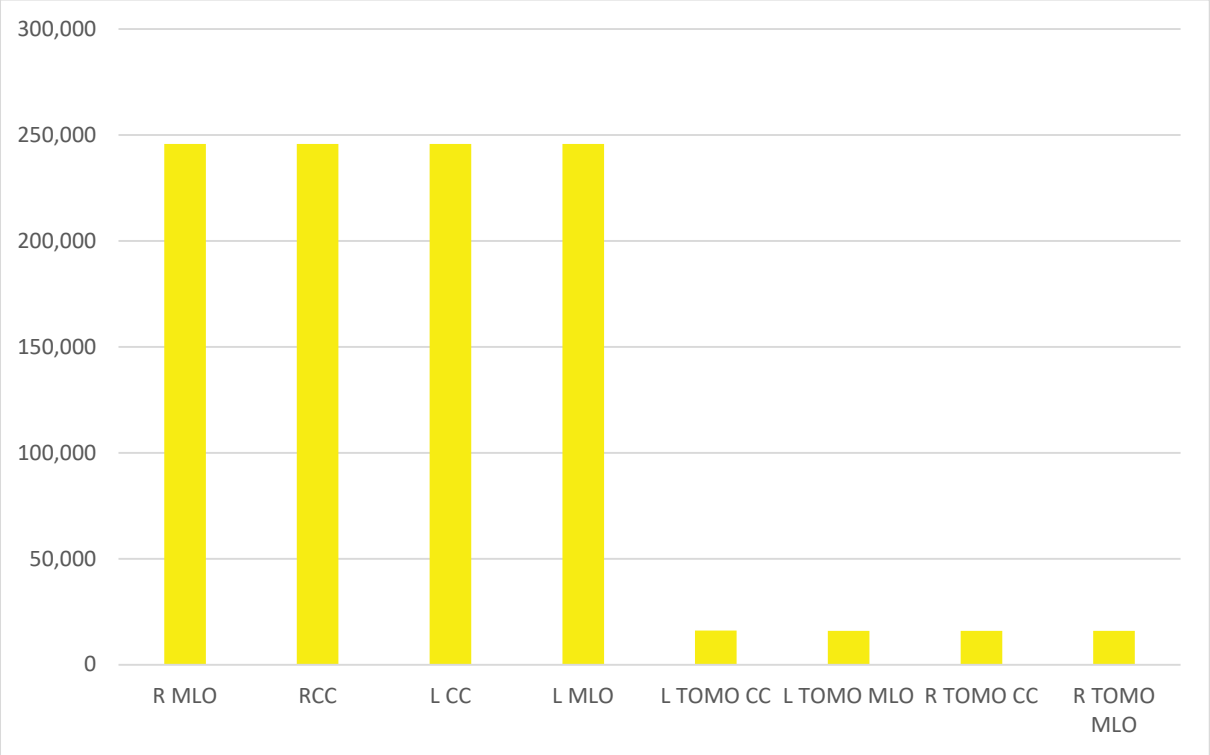


All facilities surveyed reported using DR equipment to establish local facility DRLs for mammography. Annual procedure numbers for mammography are displayed in Table 6 and Figure 8.

Table 6. Mammography radiography annual procedure numbers

Procedure	Total annual procedure projections
Right mediolateral oblique (R MLO)	245,753
Right craniocaudal (R CC)	245,741
Left mediolateral obliqueL (L MLO)	245,714
Left craniocaudal (L CC)	245,723
Tomosynthesis right mediolateral oblique (R MLO)	15,911
Tomosynthesis right craniocaudal (R CC)	15,941
Tomosynthesis Left mediolateral obliqueL (L MLO)	15,985
Tomosynthesis left craniocaudal (L CC)	16,040
Total	1,046,808

Figure 8. Mammography radiography annual procedure numbers



3.4 DXA

The outcome of the survey established adult DXA national DRLs, which are displayed in Table 7. National median values are also shown for services to consider further optimisation of dose.

Table 7. DXA national DRLs and national median doses

Procedure/Clinical task	National DRL (mGy.cm²)	National Median Dose (mGy.cm²)
L Spine/Bone Density Analysis (BDA)	20	12
Single Hip/ BDA	15	11
Distal forearm/ BDA	7	0.3
Lumbar spine/Vertebral Fracture analysis (VFA)	71	70

In Ireland, DXA services were supplied by 58 medical radiological facilities using 64 DXA scanners. The age profile of DXA equipment is displayed in Figure 9. The type of DXA equipment used to establish local facility DRLs is displayed in Figure 10 and annual procedure numbers for DXA are displayed in Table 8 and Figure 11.

Figure 9. Age profile of DXA radiography equipment

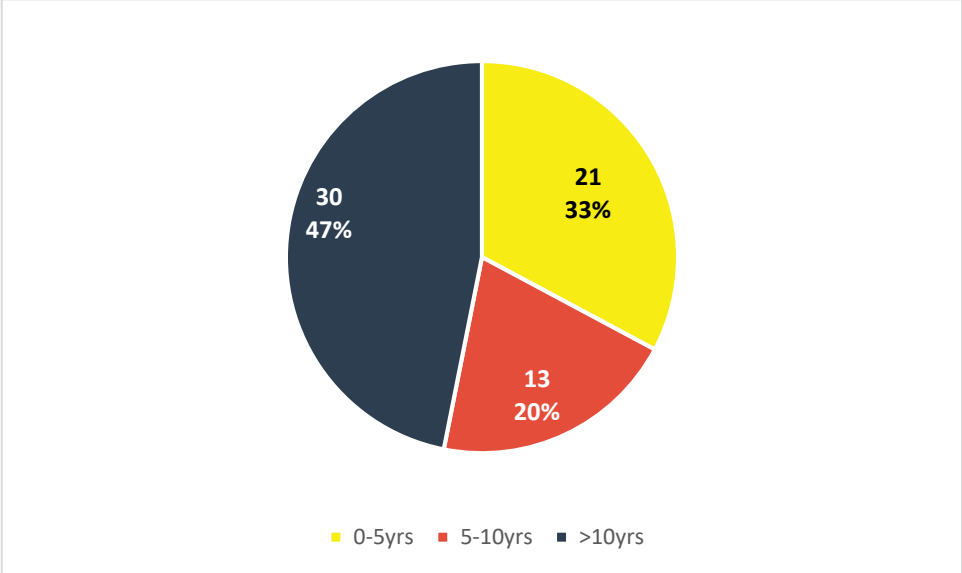
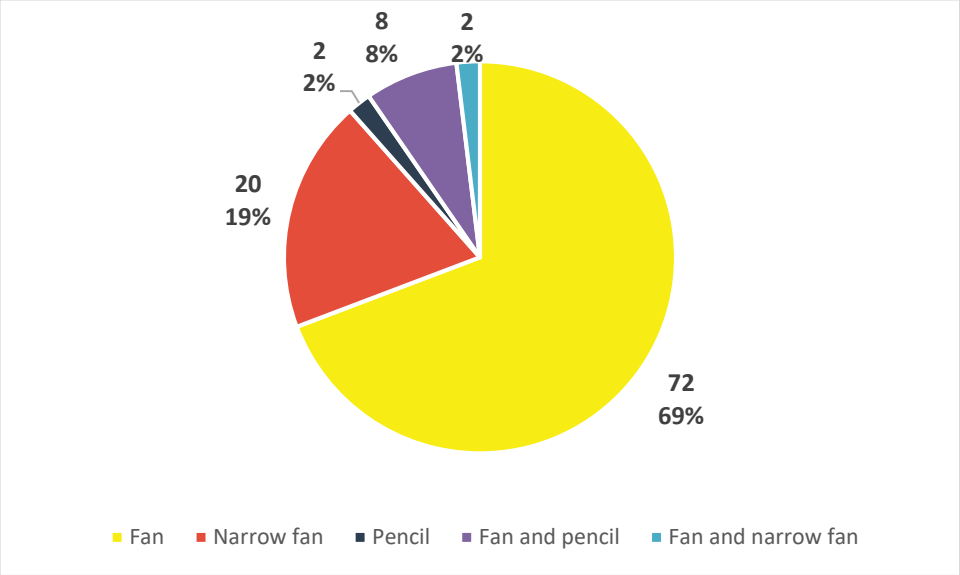


Figure 10. Equipment type used to establish local facility DRLs

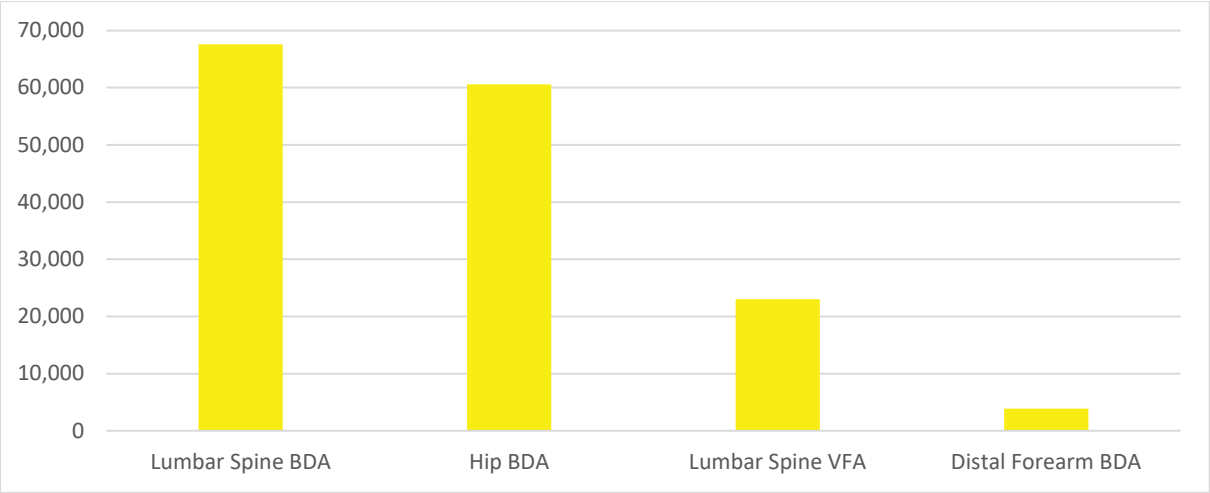


Local facility DRLs were established using fan beam in 69% of facilities, narrow fan beam in 19% of facilities, pencil fan beam in 2% of facilities, a combination of fan and narrow fan in 2% and a combination of fan and pencil beam in 8% of facilities.

Table 8. Annual DXA procedure numbers

Procedure	Total annual procedure projections
Lumbar Spine BDA	67,555
Hip BDA	60,602
Distal Forearm BDA	3,873
Lumbar Spine VFA	23,042
Total	155,072

Figure 11. DXA annual procedure numbers



4. Discussion

4.1 Survey response rate

The DRL survey was issued to 137 service providers that provide either a general radiography, mammography or DXA service or a combination of these services. 127 service providers returned a DRL survey which resulted in a response rate of approximately 93%. This high response rate resulted in a robust dataset from which HIQA determined representative national DRL values. Acknowledging that it is a regulatory requirement to provide information to HIQA when requested, the response rate is a positive indicator of service providers' cooperation with the regulator to establish patient dose optimisation standards in the form of national DRLs. While the high response rate represents a near complete dataset, there were a small number of service providers who did not supply information to HIQA as requested. These service providers were followed up as part of the standard regulatory process.

4.2 National DRL figures

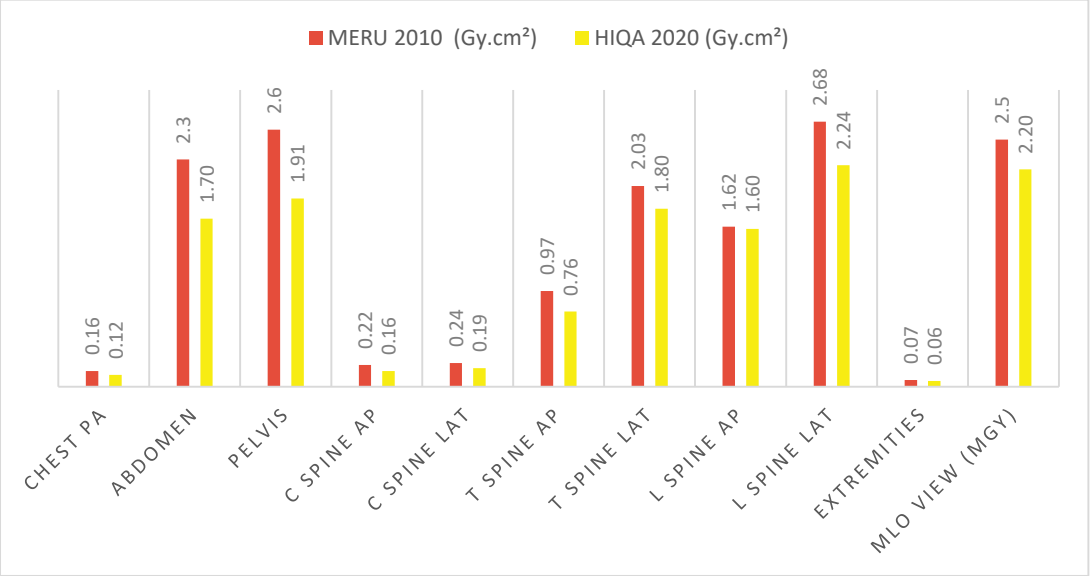
Local facility DRL median dose values were sought for the procedures and clinical tasks, and national DRLs were set as the 75th percentile of median values obtained as demonstrated in Table 1, Table 3, Table 5 and Table 7 of the results section. In line with International Commission on Radiological Protection (ICRP) guidance, a national median, or 50th percentile dose of median values obtained has also been published to promote the optimisation process further on a national basis.[14]

Local facility DRLs in mammography were sought for the right and left breast. Data was analysed for statistically significant differences between the right and left breast DRL information. No differences were identified and subsequent national DRLs were compiled for standard mediolateral oblique (MLO) and craniocaudal (CC) views. Breast tomosynthesis, sometimes called 3D mammography, uses a series of two-dimensional images to build a three-dimensional image of the breast was also reviewed to establish a national DRL. For mammographic procedures, the 95th percentile dose is also quoted, as this may be more suitable to well-established screening environments whose variation in dose is likely to be small.[15]

National DRLs for general adult radiography and mammography were surveyed in Ireland in 2010 and published by the HSE in 2013.[2,19] This allowed for a direct comparison of the updated national DRLs. Figure 12 displays a comparison of MERU HSE national DRLs from the 2010 survey alongside the new national DRLs as established by HIQA as part of this survey. The risks associated with low doses of radiation are currently assumed to be directly proportionate to the dose,[20] therefore any reduction of dose represents a similar reduction in associated risks for the

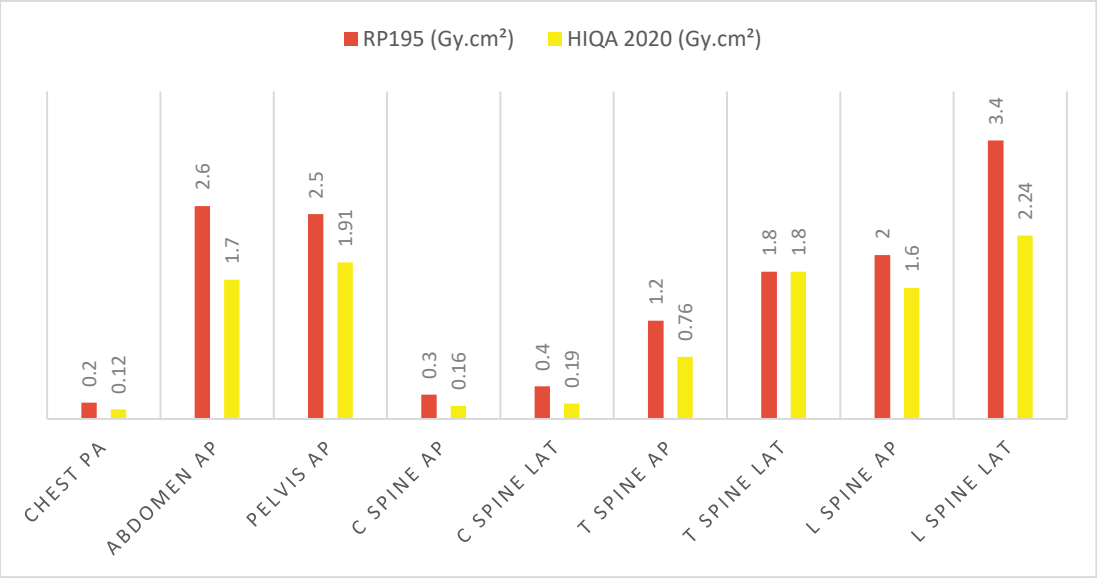
exposed population. Figure 12 demonstrates radiation dose reduction in all procedures ranging from 2-27%.

Figure 12. National DRL 2010 and 2020 comparison



Recent publications by the European Commission in 2018 and 2020[5,8] allow further comparison with Irish national DRLs and European DRLs. Figures 13 and 14 demonstrate that newly established national DRLs compare favourably with recently published European DRLs for adult and paediatric radiography.

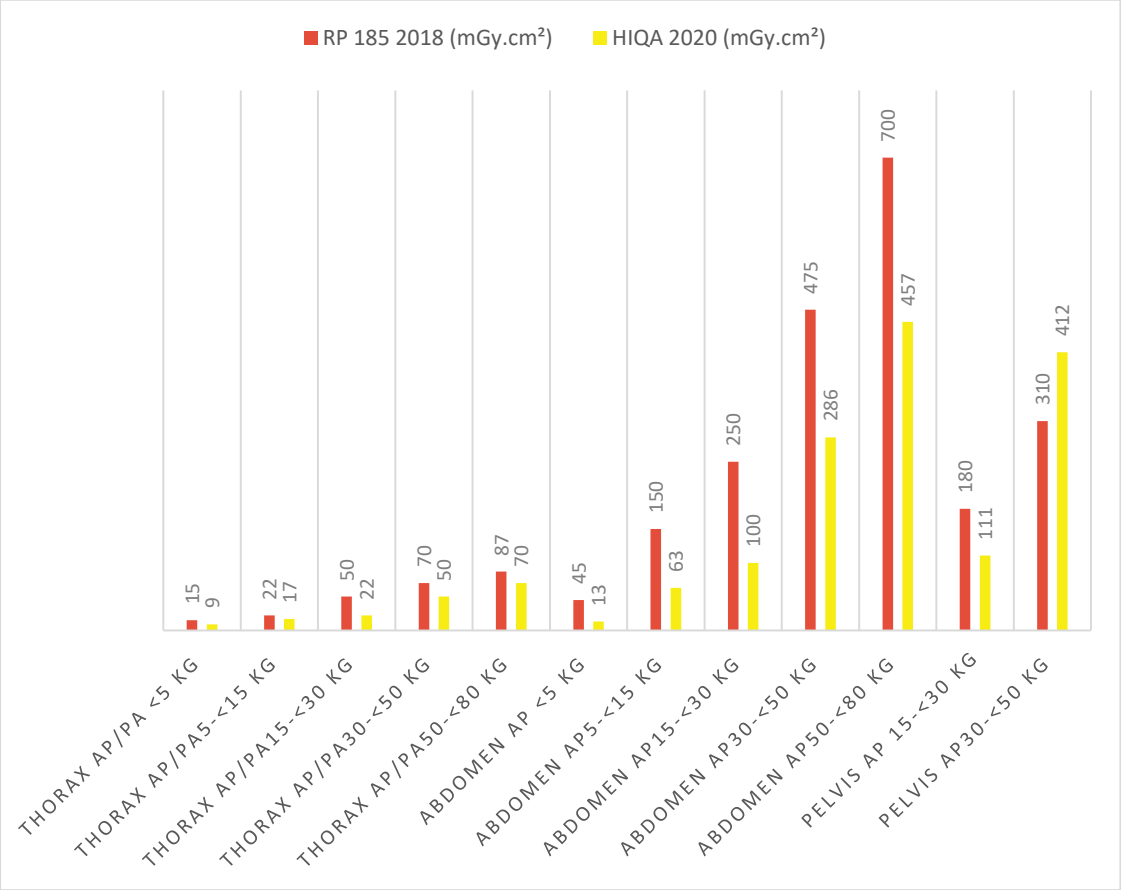
Figure 13. National and European DRLs (Adult)



The vast majority of national adult and paediatric DRLs are below those established for the European population, which reflects the lower patient doses, relative to a European average, received by the Irish population for the procedures surveyed. In only one instance the newly established national DRL is greater than the European

DRL (Figure 14, Pelvis AP 30-<50kg). It should be noted that the European figure for the same procedure is calculated using DRL data limited to three European countries. European guidance acknowledges the limitation of a small number of data points and recommends that national DRLs, based on adequate national patient dose surveys, are preferable to European DRLs. [8] This newly established Irish national DRL is based on a recent patient dose survey of 22 medical facilities across Ireland and, although higher than the European DRL, is a representative national reference value for local facility DRL review.

Figure 14. National and European DRLs (Paediatric)



4.3 Equipment age profiles

Categorising equipment age helps determine a national profile of equipment, which may influence requirements for upgrade and replacement. Service providers should consider equipment replacement as part of ongoing capital costs and ensure that any necessary measures are taken to improve inadequate or defective performance of medical radiological equipment when identified. Service providers may consider best practice guidance such as that produced by the ESR[13] when determining need for equipment upgrade and prioritising certain equipment for upgrade and

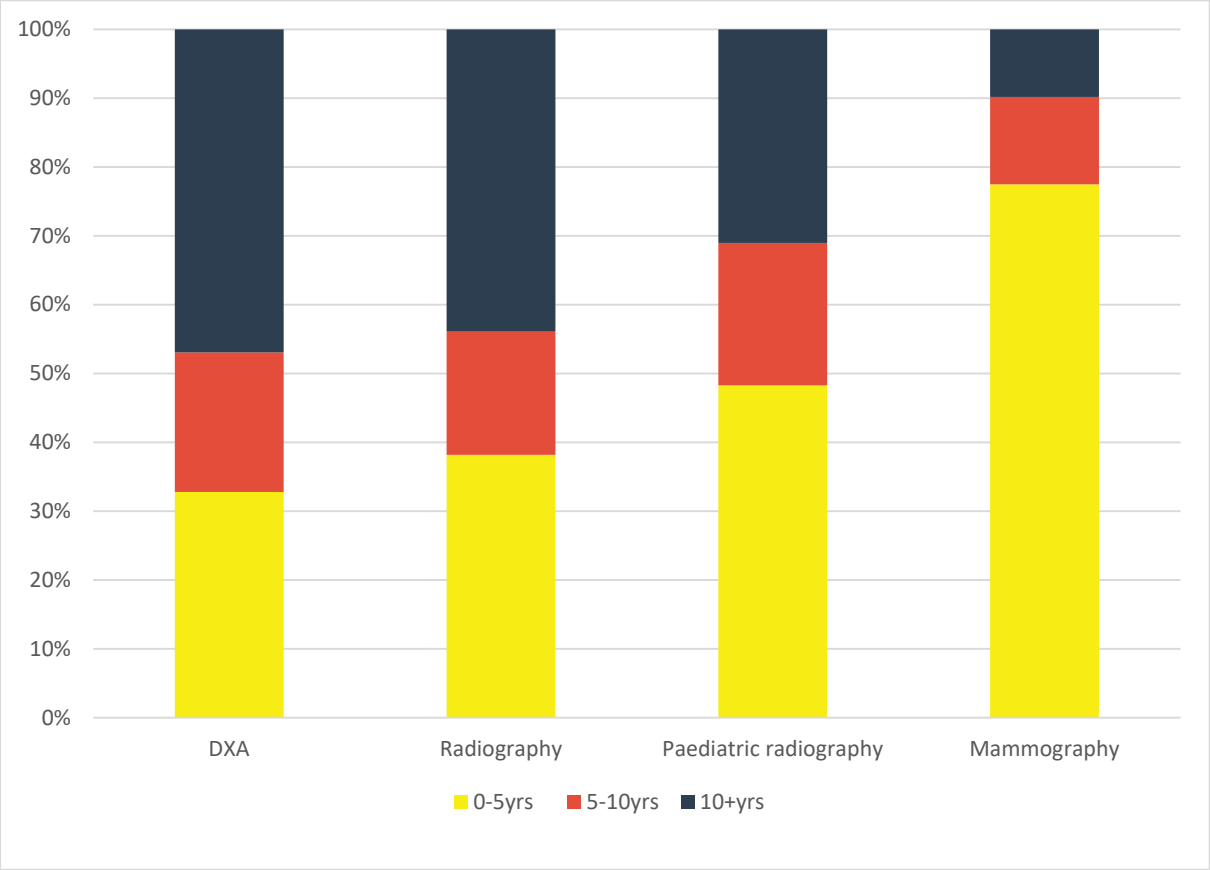
replacement. Indeed, equipment may continue to perform to regulatory standards aligned to quality assurance criteria independent of age. However, older equipment may be associated with increased breakdown, reduced image quality and increased operating costs.[13] It is important to note, however, that it is not a current regulatory requirement to replace equipment based on age.

The age profile of this equipment was analysed for each of the services surveyed and is displayed in Table 9 and Figure 15. The majority (77%) of mammography equipment was aged between zero and five years. Conversely, only 33% of DXA equipment used fell into the same category.

Table 9. Age profile for equipment used to deliver general radiography

Age profile of radiographic equipment				
	DXA	Radiography	Paediatric radiography	Mammography
0-5yrs	32.8%	38.2%	48.3%	77.5%
5-10yrs	20.3%	17.9%	20.7%	12.7%
10+yrs	46.9%	43.9%	31%	9.8%

Figure 15. Equipment age profiles



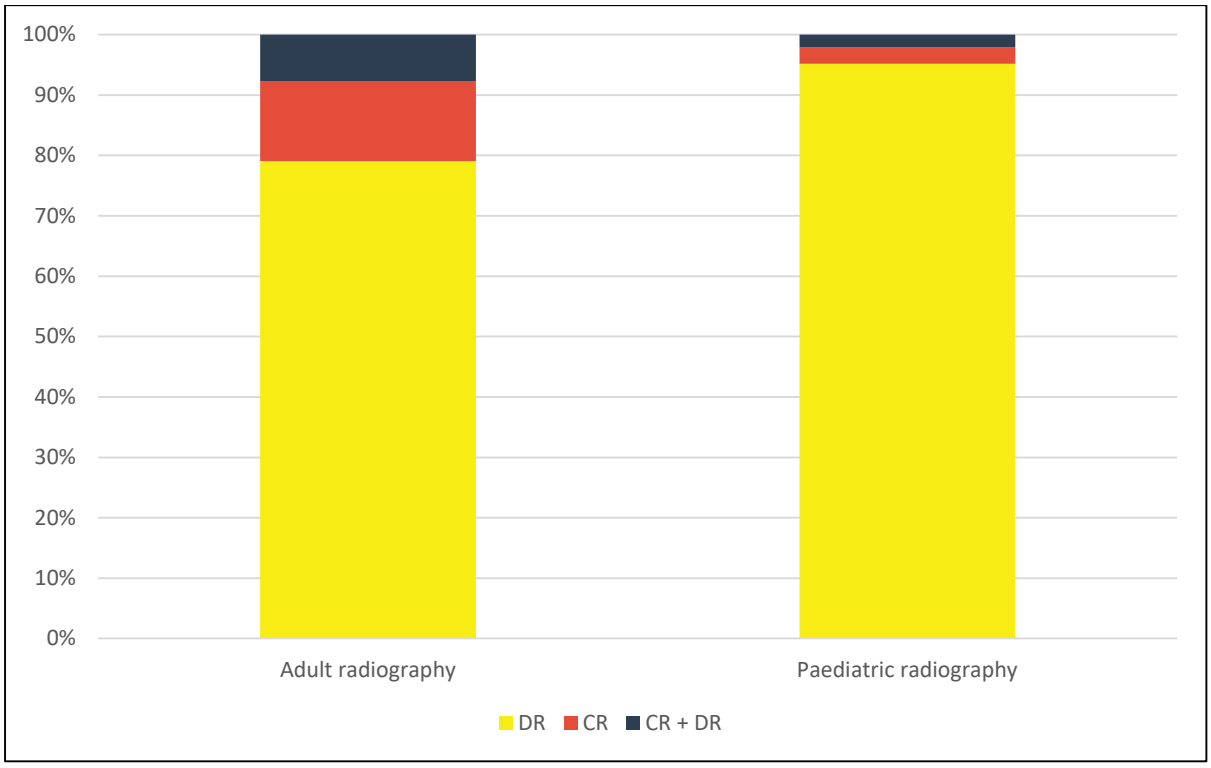
4.4 Equipment technology analysis

In modern radiography, the more traditional film screen method of capturing X-ray images has now been largely replaced by digital radiography. Digital radiography can be further subdivided into computed radiography (CR) and direct radiography (DR). Computed radiography uses a digital image acquisition system that, like film, requires a processing stage, but specifically designed imaging plates are used rather than X-ray film. DR uses a digital image acquisition system, where images immediately transfer to a computer screen without the need for processing, film or imaging plates.

In DXA scanning, the shape and movement of the X-ray beam, known as beam geometry, has also evolved since the introduction of DXA scanning. For both radiography and DXA, the image capture systems and beam geometry, respectively, have been shown to have the potential to influence the subsequent patient dose.[16,17,18]

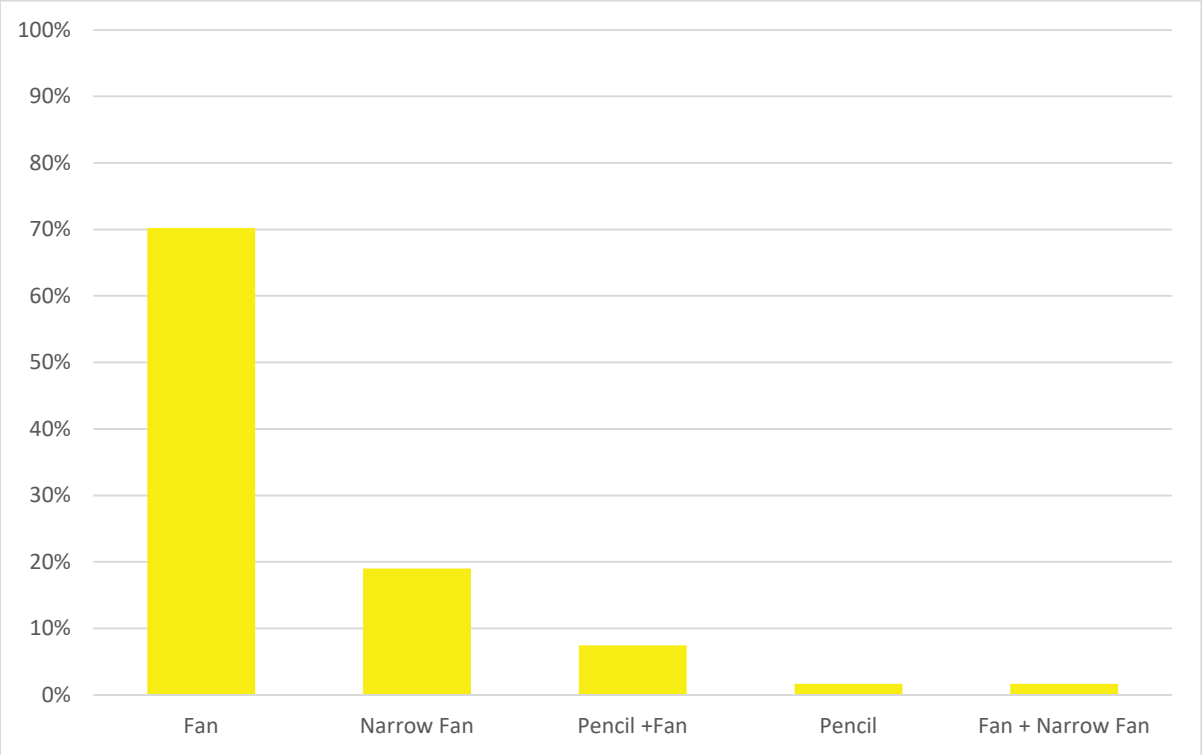
Contribution to national DRL by image receptor type for adult radiography, and paediatric radiography is displayed in Figure 16. Nationally, all mammographic procedure DRLs reported for this survey were established using DR equipment only.

Figure 16. Contribution to national DRL by image receptor type (Adult and Paediatric Radiography)



Contribution to national DRL by beam geometry for DXA is displayed in Figure 17.

Figure 17. Contribution of different DXA equipment types to national combined DRLs (DXA)



Local facility DRLs were established using DR equipment in all mammography facilities, 95% of facilities delivering paediatric radiography and 79% of facilities delivering adult radiography. Adult and paediatric national radiography DRLs are established using combined data which is largely based on DR equipment. Nationally, it demonstrates that all mammography and the majority of local facility DRLs are established using DR equipment. Furthermore, this means that National mammography DRLs are DR specific dose levels.

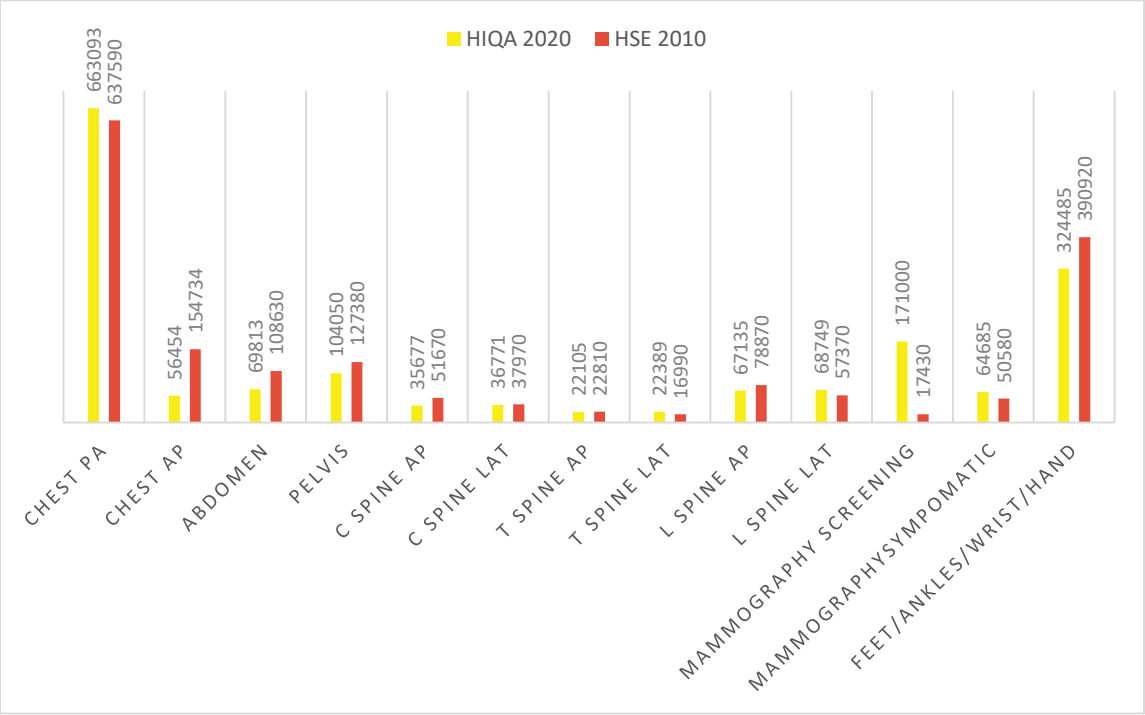
Local facility DXA DRLs were established using fan beam equipment in 70% of medical facilities, while 19% of facilities used narrow fan beam geometry. Pencil fan beam geometry equipment was used to establish local facility DXA DRLs in less than 2% of medical facilities delivering a DXA service. The remaining local facility DXA DRL data was accounted for by various combinations of different beam geometries (7% pencil plus fan and 2% fan plus narrow fan).

4.5 Annual procedure numbers

The previous survey for general X-ray in 2010 extrapolated national annual procedure numbers for 23 procedures.[19] The current survey sampled total national annual procedure numbers for 13 of these procedures, allowing a comparison in procedure frequency represented in Figure 18.

A notable increase in the use of mammography was observed with examinations increasing from 68,010 in 2010 to 235,733 in 2020. This increase is likely due to the marked increase in the annual number of mammography screening examinations conducted in 2020 (171,000 in 2020 compared with 17,430 in 2010). For the procedures compared, a slight reduction in total annual procedure numbers was observed across all procedures compared (1.7 million in 2020 and 1.75 million in 2010).

Figure 18. Annual procedure number comparison, 2010 and 2020



5. Conclusion

National DRL values are typical radiation dose levels set for common medical imaging procedures and clinical tasks undertaken in Ireland. These allow medical facilities to compare local facility DRLs, which represent patient dose, to a national standard and use them as a benchmark to optimise patient radiation dose. A reduction in level of dose received is of benefit to the patient as it reduces the risks associated with exposure to ionising radiation.

As part of this survey, HIQA has produced national 75th percentile DRLs for general radiography, mammography and DXA imaging. In addition, national 50th percentile values, or median values, have been produced. This will enable facilities with local facility DRLs below national DRLs to further optimise patient dose, acknowledging the requirement to also maintain the diagnostic quality of medical imaging procedures. National DXA DRLs have been produced for the first time in Ireland, helping service providers optimise patient dose within their service.

The last survey of adult radiography and mammography DRLs was conducted in 2010. This study has demonstrated typical dose reductions, dependent upon the type of procedure, ranging from 2-27% since the previous survey for the medical imaging procedures reviewed. It is important to note that the doses measured as part of this survey are not actual doses received by users of services, but rather a reference value of typical doses. However, the dose data compares favourably with recently published European DRLs. Indeed, the vast majority of Irish DRLs generated for adult and paediatric radiography are below that referenced in guidance issued by the European Commission.

The volume of X-ray procedures has remained largely consistent since last surveyed in 2010, although an increase has been seen in screening mammography services, which may be due to the expansion of the service in the last 10 years.

In addition to determining the types of equipment being used by service providers, the age profile of equipment was measured. In Ireland, it was found that 46.9% of DXA equipment, 43.9% of general radiography equipment, 31% of dedicated paediatric equipment and only 9.8% of mammography equipment fell into the older category of equipment. Although equipment may continue to operate within tolerances, the incorporation of a rolling equipment replacement strategy by service providers would be seen as a positive measure, noting the potential for rapidly changing technologies in diagnostic imaging equipment.

This survey did not find significant evidence for the cause of dose reductions since the previous study. However, the reasons are likely to be multifactorial. It may be related to improved education and training of users of X-ray equipment, improved efficacy of imaging technology, or indeed as a result of increased regulatory scrutiny

of patient safety requirements. In any case, dose reductions benefit each patient by maintaining the diagnostic ability of an X-ray image while also reducing risk to service users.

In light of this new set of national DRLs in radiography and mammography, service providers can now continue to review DRLs having regard to the updated national DRLs in general radiography and mammography. For the first time in Ireland, service providers of DXA imaging can review DRLs following the establishment of new national DRLs in this area. Service providers can also use the national median (50th percentile) doses produced in this report to further optimise patient doses locally by comparison with an average national dose, should they so wish.

In the coming years, HIQA will continue to establish national DRLs for interventional radiology, nuclear medicine, dental radiology and computed tomography (CT). Following a comprehensive national DRL review, dose information will be used along with procedure numbers acquired throughout this survey process to establish a population dose, which can be defined as a collective dose, or the average per caput effective dose. Estimates of the population dose provide useful information on the relative contribution of different sources of ionising radiation to population exposure. Monitoring of population dose will help in identifying significant pathways of medical exposure to further future dissemination of information, policy adaptations and regulation of medical exposures.

It is hoped that the knowledge gained from this survey will help drive quality improvement and safety strategies for service providers. HIQA will continue to build upon its programme to date to promote patient safety in relation to radiation protection. HIQA is committed to sharing lessons learned from its monitoring of exposure to ionising radiation in Ireland and continue to investigate and inspect facilities in which these services are provided to promote a high quality of service and care for Irish patients.

Glossary

Air kerma: the kinetic energy released per unit mass of air; measured in Gray (Gy).

Computed radiography (CR): a digital image acquisition and processing system for radiography that uses computers and laser technology.

Computed tomography (CT): a technique for imaging the body in sections or slices using specialised computers and imaging equipment. An alternative name for CT is computer-aided tomography or CAT scan.

Diagnostic reference levels (DRLs): dose levels in medical radiodiagnostic or interventional radiology practices, or, in the case of radiopharmaceuticals, levels of activity, for typical examinations for groups of standard-sized service users or standard phantoms for broadly defined types of equipment.

Direct radiography (DR): a digital image acquisition and processing system for radiography that captures data and immediately transfers it to a computer system.

Dose limit: the value of the effective dose (where applicable) or the equivalent dose in a specified period which shall not be exceeded for an individual.

Dual-energy X-ray absorptiometry (DXA or DEXA): a type of medical exposure typically used to assess bone density in service users where low bone density or osteoporosis is suspected.

Fluoroscopy: a type of medical exposure that uses a continuous beam of ionising radiation to create an image on a monitor. During a fluoroscopy procedure, the image that is transmitted to the monitor displays the movement of a body part, instrument or contrast agent through the body in real-time.

Gray (Gy): a unit of measurement for absorbed dose. It is equivalent to one joule of energy absorbed per kilogram of material.

Interventional cardiology or radiology: procedures that use fluoroscopy equipment to obtain real-time imaging to help introduce and guide devices and equipment used for diagnostic or treatment purposes.

Ionising radiation: is radiation with enough energy that it can remove tightly bound electrons from the orbit of an atom, causing the atom to become charged or ionised which has the potential to cause damage to cells and tissues. It has a higher energy than light and therefore can pass through the body. However, ionising radiation is a valuable medical tool for the diagnosis and treatment of diseases and injuries. Types of ionising radiation commonly used in medical exposures are X-rays.

Mammography: the specialised area of radiology involved in the imaging of breast tissue.

Median: is the middle number in a sorted list of numbers.

Medical exposure (ionising radiation): an exposure of ionising radiation delivered to service users or asymptomatic individuals as part of their own medical or dental diagnosis or treatment and intended to benefit an individual's own health.

Medical radiological installation: means a facility where medical exposures are carried out.

MERU: the HSE Medical Exposure Radiation Unit audited radiation practice in medical radiological installations in Ireland on behalf of the Department of Health prior to the commencement of European Union (Basic Safety Standards for Protection Against Dangers Arising from Medical Exposure to Ionising Radiation) Regulations 2018 and 2019.

Nuclear medicine: a type of medical exposure where a radiopharmaceutical or radioactive dye designed to go to a target organ and administered to a service user by injection, inhalation or ingestion. Areas of disease and injury can then be diagnosed by imaging the service user under a detector called a gamma camera.

Positron emission tomography (PET): a specialist, functional type of nuclear medicine which uses a radiopharmaceutical to assess the metabolic processes within the body. PET scanners are often combined with CT scanners which allow highly detailed images to be obtained. This procedure is often referred to as PET/CT imaging.

Service user: a person or persons who attends an undertaking for the purpose of undergoing a medical exposure. This includes a patient, comforters and carers and volunteers participating in research.

Undertaking: a person or body who has a legal responsibility for carrying out, or engaging others to carry out, a medical radiological procedure, or the practical aspects of a medical radiological procedure, as defined by the regulations.

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Appendix A: Membership of Expert Advisory Group

Member	Nominated on behalf of
Anne Tobin	Health Products Regulatory Authority
David Pollard	Environmental Protection Agency
Dean Harper	Irish Institute of Radiographers and Radiation Therapists (Radiation Oncology)
Geraldine O' Reilly	Irish Association of Physicists in Medicine (Diagnostic)
Gerarda Warnes	Private Hospitals Association
Jane Renehan	Irish Dental Association
Janet Wynne	HSE National Radiation Protection Office
Joe Martin	HSE National Cancer Control Programme
John Feeney	Faculty of Radiologists (Radiology)
Margaret Moore	Irish Association of Physicists in Medicine (Radiation Oncology)
Niall Phelan	HSE National Screening Service
Peter Kavanagh	HSE National Clinical Programme for Radiology
Robert O'Connor	Irish Cancer Society
Ronan Margey	Irish Cardiac Society
Shane Foley	Irish Institute of Radiographers and Radiation Therapists (Radiology)

Independent experts	
Jim Malone	International expert on generic justification
Steve Ebdon-Jackson	International expert in the assessment of regulatory compliance of ionising radiation
Susan Smith	Methodological expert on the assessment of clinical practice

Appendix B: Sample DRL survey template

Section A. General Radiography details - Adult			
A1. General Radiography equipment details - Adult			
1.	Total no. of General Radiography units in the facility (fixed and mobile)		
2.	Age profile of General Radiography equipment (select multiple options if relevant)	Age range (years)	No. of units
		0 – 5	
		6 – 10	
		10+	

A2. General Radiography patient dose details - Adult						
	Procedure/Clinical task	National DRL	Local facility DRL ($Gy.cm^2$)	Local facility DRL sample size (n)	Annual no. of procedures	Image receptor type used to establish DRL (Film/screen, CR, DR, combinations)
1.	Chest PA	0.16 $Gy.cm^2$				
2.	Chest AP	0.18 $Gy.cm^2$				
3.	Portable Chest AP	N/A				
4.	Abdomen AP	2.3 $Gy.cm^2$				
5.	Pelvis AP	2.6 $Gy.cm^2$				
6.	Cervical spine AP	0.22 $Gy.cm^2$				
7.	Cervical spine LAT	0.24 $Gy.cm^2$				
8.	Thoracic spine AP	0.97 $Gy.cm^2$				
9.	Thoracic spine LAT	2.03 $Gy.cm^2$				
10.	Lumbar spine AP	1.62 $Gy.cm^2$				
11.	Lumber spine LAT	2.68 $Gy.cm^2$				
12.	Extremities (Foot/Ankle/Wrist/Hand)	0.07 $Gy.cm^2$				

Section B. General Radiography details - Paediatric					
B1. General Radiography equipment details - Paediatric					
1.	Total no. of General Radiography units used for paediatric patients is the same as for adult patients as listed in Section B1. If yes, please proceed to Section C2. If no, please complete Section C1.	Yes		No	
2.	Total no. of General Radiography units in the facility (fixed and mobile).				
3.	Age profile of General Radiography equipment (select multiple options if relevant)	Age range (years)	No. of units		
		0 – 5			
		6 – 10			
		10+			

B2. General Radiography patient dose details - Paediatric							
	Procedure/Clinical task	Weight category	National DRL	Local facility DRL ($mGy.cm^2$)	Local facility DRL sample size (n)	Annual no. of procedures	Image receptor type used to establish DRL (Film/screen, CR, DR, combinations)
1.	Head (skull) AP/PA	0 to < 3 months	N/A				
		3 months to < 1 y	215				
		1 to < 6 y	295				
		≥ 6 y	350				
2.	Head (skull) LAT	0 to < 3 months	N/A				
		3 months to < 1 y	200				
		1 to < 6 y	250				
		≥ 6 y	N/A				
3.	Thorax (chest) AP/PA	< 5 kg	15				
		5 to < 15 kg	22				
		15 to < 30 kg	50				
		30 to < 50 kg	70				
		50 to < 80 kg	87				
4.	Abdomen/pelvis AP	< 5 kg	45				
		5 to < 15 kg	150				
		15 to < 30 kg	250				
		30 to < 50 kg	475				
		50 to < 80 kg	700				
5.	Pelvis/hip AP	< 5 kg	N/A				
		5 to < 15 kg	N/A				
		15 to < 30 kg	180				
		30 to < 50 kg	310				
		50 to < 80 kg	N/A				
6.	Cervical spine AP/PA	< 5 kg	N/A				
		5 to < 15 kg	N/A				
		15 to < 30 kg	N/A				
		30 to < 50 kg	N/A				
		50 to < 80 kg	N/A				
7.	Cervical spine LAT	< 5 kg	N/A				
		5 to < 15 kg	N/A				
		15 to < 30 kg	N/A				
		30 to < 50 kg	N/A				
		50 to < 80 kg	N/A				
8.	Thoracic spine AP/PA	< 5 kg	N/A				
		5 to < 15 kg	N/A				
		15 to < 30 kg	N/A				
		30 to < 50 kg	N/A				
		50 to < 80 kg	N/A				
9.	Thoracic LAT	< 5 kg	N/A				
		5 to < 15 kg	N/A				
		15 to < 30 kg	N/A				
		30 to < 50 kg	N/A				
		50 to < 80 kg	N/A				
10.	Lumbar spine AP/PA	< 5 kg	N/A				
		5 to < 15 kg	N/A				
		15 to < 30 kg	N/A				
		30 to < 50 kg	N/A				
		50 to < 80 kg	N/A				
11.	Lumbar spine LAT	< 5 kg	N/A				
		5 to < 15 kg	N/A				
		15 to < 30 kg	N/A				
		30 to < 50 kg	N/A				
		50 to < 80 kg	N/A				
12.	Whole spine/Scoliosis AP/PA	< 5 kg	N/A				
		5 to < 15 kg	N/A				
		15 to < 30 kg	N/A				
		30 to < 50 kg	N/A				
		50 to < 80 kg	N/A				
13.	Whole spine/Scoliosis LAT	< 5 kg	N/A				
		5 to < 15 kg	N/A				
		15 to < 30 kg	N/A				
		30 to < 50 kg	N/A				
		50 to < 80 kg	N/A				

Section C. Mammography details			
C1. Mammography equipment details			
1.	Total no. of Mammography units in the facility		
2.	Age profile of Mammography equipment (select multiple options if relevant)	Age range (years)	No. of units
		0 – 5	
		6 – 10	
		10+	

C2. Mammography patient dose details						
	Procedure/Clinical task	National DRL	Local facility DRL (mGy)	Local facility DRL sample size (n)	Annual no. of procedures	Image receptor type used to establish DRL (Film/screen, CR, DR, combinations)
1.	Right single mediolateral oblique (MLO) view	2.5 mGy				
2.	Right single craniocaudal (CC) view	N/A				
3.	Left single mediolateral oblique (MLO) view	2.5 mGy				
4.	Left single craniocaudal (CC) view	N/A				
5.	Breast tomosynthesis – Right single CC	N/A				
6.	Breast tomosynthesis – Right single MLO	N/A				
7.	Breast tomosynthesis – Left single CC	N/A				
8.	Breast tomosynthesis – Left single MLO	N/A				

Section D. DXA details			
D1. DXA equipment details			
1.	Total no. of DXA units in the facility		
2.	Age profile of DXA equipment (select multiple options if relevant)	Age range (years)	No. of units
		0 – 5	
		6 – 10	
		10+	

D2. DXA patient dose details					
	Procedure/Clinical task	Local facility DRL (Gy.cm2)	Local facility DRL sample size (n)	No. of procedures undertaken per year	Equipment beam geometry type used to establish DRL (Pencil, fan, narrow fan, combination)
1.	Lumbar spine/Bone density analysis				
2.	Single hip/Bone density analysis				
3.	Distal forearm/Bone density analysis				
4.	Lumbar spine/Vertebral fracture assessment				

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