November 2023

Medical exposure to ionising radiation

National diagnostic reference levels (DRLs) for nuclear medicine procedures

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.

Table of Contents

Table of Figures

Table of Tables

1 Executive summary

In Ireland, the Health Information and Quality Authority (HIQA) is designated as the competent authority for regulating medical exposures to ionising radiation. This includes establishing and reviewing national diagnostic reference levels (DRLs) for medical procedures which use ionising radiation.

In October 2022, HIQA issued a DRL survey to 24 medical radiological installations (referred to as facilities in this report) that provide diagnostic nuclear medicine procedures in Ireland. As there is a regulatory requirement to provide such data to HIQA, 100% of facilities responded and this data was compiled and reviewed. Diagnostic nuclear medicine procedures describe a type of medical exposure where a radiopharmaceutical*, designed to go to a target organ, is administered to a patient to generate an image.

While recommended administered activities have traditionally been used to set national nuclear medicine DRL values, establishing recommended administered activities for nuclear procedures is outside the scope of the regulatory authority. This report represents a national review of diagnostic nuclear medicine DRLs which are based on a survey of local facility DRLs. Following this survey, national DRLs have been established at the 75th percentile of a sample of these local facility DRLs.

The 18 national DRL values established in this document are typical activities and radiation dose levels administered for common medical imaging procedures and clinical tasks across nuclear medicine facilities in Ireland. DRLs can aid staff in optimisation by providing a reference point for facilities to compare doses from a representative sample of their patients to these national DRL figures. DRLs must also be used to identify medical radiological procedures that require review and subsequently to enable corrective actions to be put in place where needed.

National DRLs for nuclear medicine procedures established from this survey data broadly align with DRLs previously set by HIQA. However, a decrease from the previous national DRLs was found in three procedures and slight increases were identified in four procedures. Four new DRLs were established for nuclear medicine procedures and seven national DRLs for computed tomography (CT) hybrid imaging were established for the first time in Ireland. National DRLs could not be re-established for seven nuclear medicine procedures.

In 2022, 39,767 nuclear medicine procedures were conducted in Ireland. Adult planar imaging procedures accounted for the largest proportion of these (46%,

* A radiopharmaceutical is where pharmaceuticals (drugs) that are labelled (attached) with a radioactive tracer designed to go to a target organ such as the thyroid or bones. Radiopharmaceuticals can have diagnostic or therapeutic uses, but only those used for diagnosistic purposes were included in this survey.

n=18,379). Information about the age profile of nuclear medicine equipment in Ireland was also obtained as part of this review. Over half of medical radiological equipment (55%, n=21) used in Ireland to perform nuclear medicine procedures was greater than 10 years old. It is important to note that although it is not a specific regulatory requirement to replace equipment based on age, undertakings should consider equipment replacement as part of ongoing capital costs and ensure that all necessary measures are taken to improve inadequate or defective performance of medical radiological equipment if identified.

Information provided in this report should be used by undertakings to drive quality improvement and radiation protection strategies. Undertakings are encouraged to consider incorporating the use of weight-based administered activity for adult nuclear medicine procedures in line with international best practice guidelines. HIQA will continue to build upon its programme of promoting patient safety in relation to radiation protection.

2 Introduction

Since 8 January 2019, following transposition into Irish law of the European Union (Basic Safety Standards for Protection Against Dangers Arising from Medical Exposure to Ionising Radiation) Regulations 2018 (and associated amendments), referred to in this document as the regulations, the Health Information and Quality Authority (HIQA) is the competent authority for the establishment and review of national diagnostic reference levels (DRLs).[1]

National DRL values are typical radiation dose levels set for common medical imaging procedures and clinical tasks. These values allow staff working at facilities to compare their local facility DRLs[†] which represent patient dose, to a national standard. DRLs have been traditionally based on anatomical areas. However, the use of clinical indications or clinical tasks has been acknowledged as a more appropriate descriptor in the establishment of DRLs.[2] The clinical indication or task is the reason a medical radiological procedure is carried out. The clinical task of diagnostic medical radiological procedures can influence the imaging protocols used which may result in different doses being delivered to patients.[2]

To date, HIQA has published *Guidance on the establishment, use and review of diagnostic reference levels for medical exposure to ionising radiation* and undertaken three national DRL surveys, all of which are available on our website www.hiqa.ie.[3-5] This DRL survey on nuclear medicine procedures follows on from previous surveys in general radiology and fluoroscopy and fluoroscopically guided interventions (FGI) and fulfils one of HIQA's regulatory functions set out under the regulations.[4-6]

2.1 National review of nuclear medicine DRLs by HIQA

The process used when establishing national DRLs for nuclear medicine procedures is discussed in this section. As part of this process, HIQA carried out a literature review and engaged with stakeholders with knowledge and expertise in this speciality. This approach ensured that the number and type of procedures or clinical tasks surveyed was representative of routine procedures carried out by a wide range of facilities nationally.

In general, and historically in Ireland, nuclear medicine DRL values have been based on recommended administered activities rather than a survey of the doses administered to patients. Such recommended doses were established following trials and with the involvement of specialised professional groups.[7-9] This approach differed to that of other diagnostic imaging modalities, such as computed

[†] Local facility DRLs are typical values established at facility level based on the median (50th percentile) of a representative sample of patients. For more information please refer to *Guidance on the establishment, use and review of diagnostic reference levels for medical exposure to ionising radiation.*

tomography (CT) and general radiography, where DRLs are established based on a survey of patient doses which, if consistently exceeded, require an investigation to be carried out and appropriate corrective actions implemented, if needed.[2, 7, 8] Given the evolution in the literature regarding the methodologies used for establishing nuclear medicine DRLs, HIQA has established DRLs for nuclear medicine procedures at a 75th percentile following a national survey of local facility DRLs.[2, 7, 8, 10-13]

It is important to note that, in line with other national DRLs, these values are not recommended administered activities but are a mechanism for staff working in facilities to use to compare their practice against a national typical dose for quality assurance purposes. They are intended as an optimisation tool for staff involved in carrying out nuclear medicine procedures and do not replace evidence-based clinical judgment for individual situations.[10-12]

Undertakings have a regulatory requirement to compare their local facility DRLs to these national DRLs and where consistently exceeded, this should be evaluated and reviewed to provide an assurance to the undertaking that their procedures are optimised, and appropriate corrective actions implemented, where necessary.

National DRLs for the CT hybrid component of SPECT and PET imaging were also established as part of this survey. The clinical indication or tasks for the CT component were all attenuation correction and or localisation, linked to specific types of nuclear medicine procedures or body areas. Consequently, the DRL values differ from standalone diagnostic CT DRLs. These national DRLs for the CT hybrid component of SPECT and PET imaging are provided as separate national DRLs to the administered activity component of the procedures.[2]

2.2 Survey design and distribution

A literature review of published national and international nuclear medicine DRLs was conducted. A list of typical procedures and clinical tasks were reviewed by members of HIQA's expert advisory group (EAG), or their delegates, with relevant clinical knowledge and expertise in the field of nuclear medicine DRLs. The final DRL procedures and clinical tasks were agreed based on feedback from these individuals.

It is important to note that the inclusion of a particular practice, clinical task, procedure, radioisotope and or pharmaceutical as part of the list of procedures surveyed did not mean that this practice had been generically justified by HIQA. All procedures that are considered a new type of practice involving medical exposure must be justified in advance before being generally adopted in Ireland in line with Regulation 7.

HIQA identified 24 facilities in the directory of undertakings‡ that provide a diagnostic nuclear medicine service. Facilities that only provided therapeutic nuclear medicine procedures were excluded from this survey. In October 2022, HIQA issued the DRL survey to these facilities and each facility had 35 days to complete and submit the survey using the online system.

The survey was divided broadly into eight sections relating to the service provided, namely:

- adult nuclear medicine procedures
- paediatric nuclear medicine procedures
- adult CT for correction or localisation for single-photon emission computed tomography (SPECT)
- paediatric CT for attenuation correction or localisation for SPECT
- adult positron emission tomography (PET)
- paediatric PET
- adult CT for attenuation correction or localisation for PET
- paediatric CT for attenuation correction or localisation for PET.

Staff in facilities were also asked to supply information on:

- the service(s) provided
- the equipment (where appropriate)
- how local facility DRLs (typical doses) were established
- the source of recommended administered activities (where applicable)
- the local facility radiation doses, representative of the radiation dose given to patients and
- the frequency of the medical radiological procedures carried out at the facility.

2.3 Equipment information

The survey requested information from staff in each facility on the number of planar nuclear medicine, SPECT, SPECT CT and PET CT equipment used within the service. For each category of equipment, staff in facilities were also asked to select from one of three equipment age categories;

- zero to five years (0-5 years)
- six to ten years (6-10 years)
- older than 10 years (10+ years).

‡ An undertaking is defined as 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.

This categorisation aligned with the European Society of Radiology's (ESR) position paper on equipment age, the aim of which is to provide suggested criteria of when equipment should be considered for upgrading or replacement.[14]

2.4 Local facility DRLs and procedure numbers

Local facility DRLs from each facility were supplied for a range of diagnostic medical radiological procedures or clinical tasks as a median dose received by all or a sample of patients attending the service, in line with the methodology outlined in HIQA's *Guidance on the establishment, use and review of diagnostic reference levels for medical exposure to ionising radiation*.[3]

In particular, for each individual category of nuclear medicine procedures (for example, planar imaging, SPECT, PET) the following information was requested:

- Are local facility DRLs calculated as **weight-based administered activity** (MBq Kg^{-1})?
- Are values for local facility DRLs calculated using the **median administered activity** of a sample of patients?
- If values are not calculated using a median administered activity, what reference dose card (guidance) is used to determine administered activity for patients?

Ideally, DRLs for nuclear medicine should be calculated using weight-based calculations of administered activity for adult patients.[2] Feedback provided during stakeholder engagement indicated that weight-based calculations were not yet common practice in Ireland. Therefore, for this survey, staff in facilities were also asked to provide a value of administered activity (MBq) based on the median administered activity for an average size patient[§].

Where administered activity (MBq) for nuclear medicine procedures in a facility is not calculated based on the median administered activity for an average size patient, the administered activity and the reference dose card used were requested. Finally, undertakings were also requested to include the number of procedures and clinical tasks undertaken annually at its facilities.

[§] Average patient size for the purposes of establishing DRLs is considered to be typically 70 ± 15 kg.

3 Results

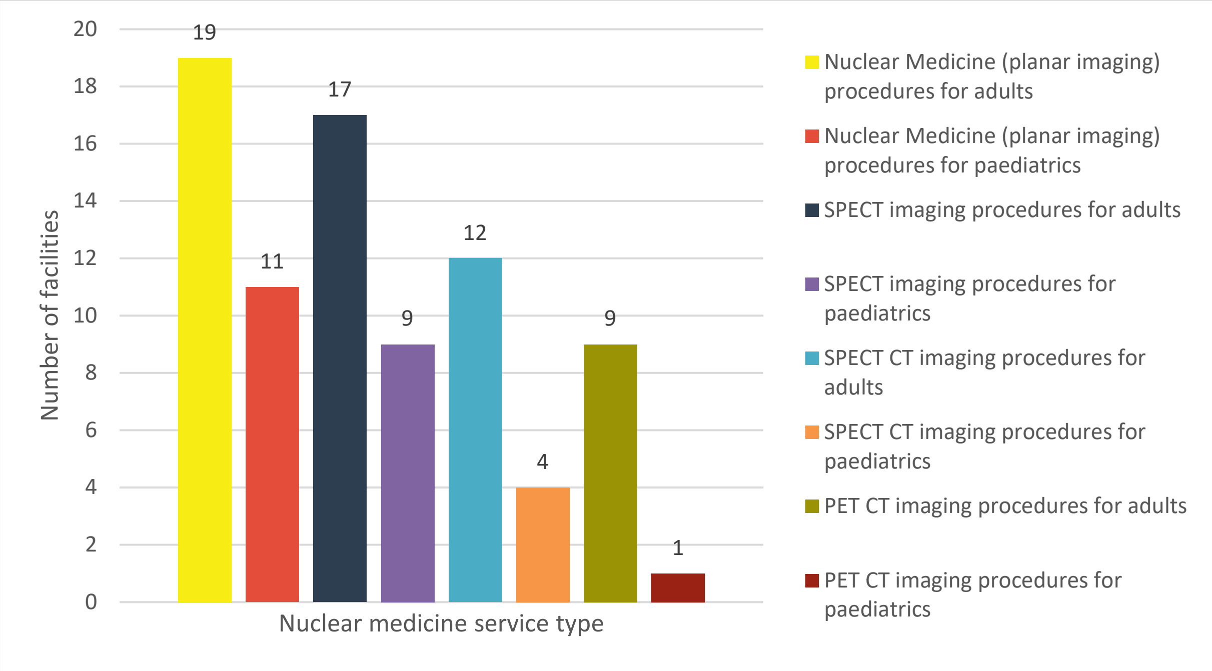
The results section uses a combination of tables and figures to demonstrate findings from this survey. National DRL doses are displayed in a format, or quantity, commonly used and easily measured by radiological equipment.[2]

In nuclear medicine, the quantity which measures the amount of radioactivity is the administered activity which is measured in mega Becquerel (MBq). For the CT component of nuclear medicine procedures, the DRL quantities used are dose length product (DLP) (mGy.cm) and Z-averaged weighted computed tomography dose index ($CTDI_{vol}$) (mGy).

3.1 Distribution of facilities providing diagnostic nuclear medicine procedures facilities

In total, 24 facilities provided diagnostic nuclear medicine services in Ireland in 2022. As displayed in Figure 1, 19 facilities provided planar imaging for adults with 17 and 11 providing SPECT and SPECT CT imaging respectively. 10 facilities provide PET CT imaging for adults**. Paediatric nuclear medicine procedures (excluding PET CT) are only provided in a small number of facilities in Ireland (n=11). Nine of these 11 facilities were found to provide both planar imaging and SPECT for paediatric patients, with four providing SPECT CT. Paediatric PET CT procedures were only provided in one facility.

Figure 1 Types of Nuclear medicine procedures performed in Irish facilities



** Please note that one piece of equipment was used by two facilities.

3.2 National nuclear medicine procedure DRLs

The outcome of the survey established national DRLs for adult nuclear medicine procedures which are displayed in Table 1, Table 2, Table 3 and Table 4. National DRLs for nuclear medicine procedures are set as the 75th percentile of the distribution of median values obtained. For the CT component of hybrid imaging only, a national median, or 50th percentile dose of median values obtained, was also established, where appropriate, as another quality metric for facilities striving to further optimise patient doses.[2]

Data from the survey was subject to cleaning and statistical analysis to identify significant outliers. Where no statistical difference was noted in data points provided for the same type of procedure in planar imaging and SPECT, a combined data set figure is provided as a national DRL. Where a significant difference between the two types of imaging was identified, separate national DRLs are provided. Similarly, where no combined data is available, a single national DRL is provided.

DRLs were established for procedures or clinical tasks when the following criteria was met:

- local DRLs were based on a sample size of 20 or more patients and
- five or more facilities provided a local facility DRL for a procedure or clinical task.

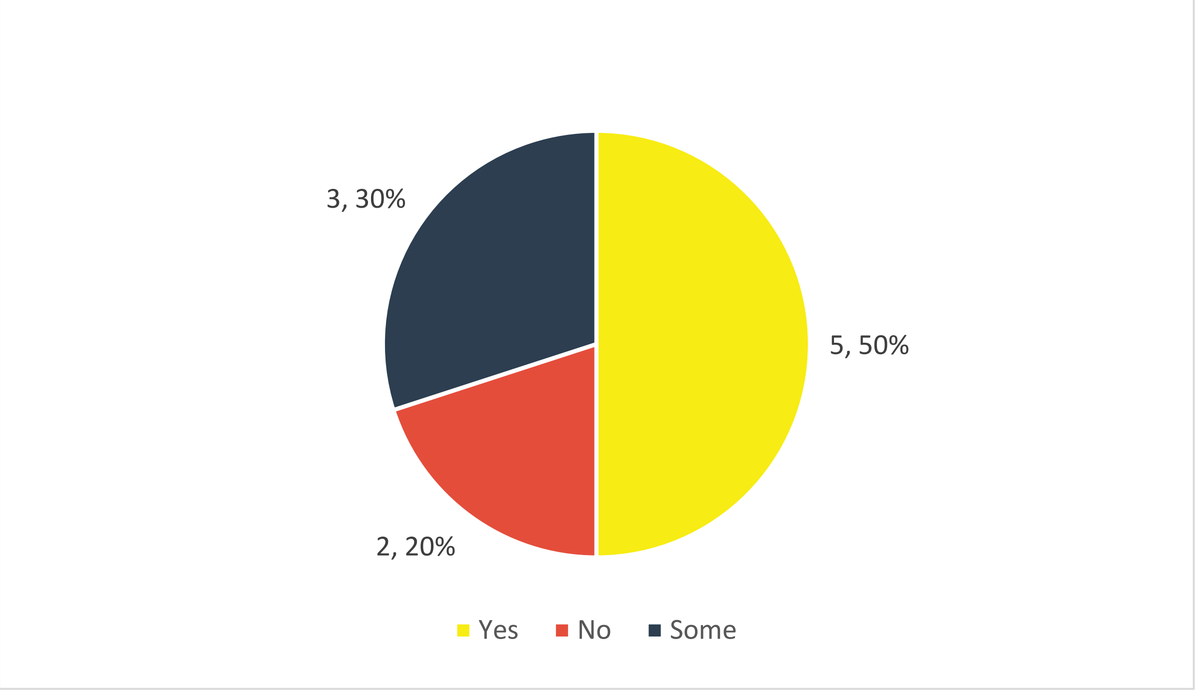
For example, where survey data showed only a small number of facilities (less than five) provided a type of procedure or clinical task, this data was excluded from the generation of national DRLs. Similarly, in some cases greater than five facilities across Ireland were providing the same procedures or clinical tasks but the sample size used to generate the local facility DRL (median value) was not large enough (less than 20) to be included.

In addition, if three or more facilities provided local facility DRLs with sufficient sample sizes, a national dose range has been provided, but a national DRL has only been established if data was available from five or more facilities. Table 1, Table 2, Table 3 and Table 4 include the number of facilities used to establish the national value for the particular procedure or clinical task. Where the number of facilities that carry out a particular procedure or clinical task is low, the associated procedure or clinical task may not be commonly performed across a large number of facilities nationally and the data provided represents practice at a smaller number of specialised facilities.

3.2.1 Use of weight-based administered activities for nuclear medicine procedures in Ireland.

Figure 2 shows that half (50%, n=5) of adult PET local facility DRLs are calculated as weight-based administered activity (MBq Kg^{-1}). One facility indicated that some planar nuclear medicine procedures are calculated using a weight-based administered activity (MBq Kg^{-1}). One of the facilities providing SPECT nuclear medicine procedures indicated that they use weight-based administered activity (MBq Kg^{-1}).

Figure 2 Local facility DRLs calculated as weight-based administered activity (MBq Kg-1) for adult patients undergoing PET imaging



For paediatric nuclear medicine procedures, information about the dose cards used for determining the administered activities for paediatric nuclear medicine was requested. Overall, from the data reviewed, weight-based administered activities based on the European Association of Nuclear Medicine (EANM) paediatric dosage card and or Administration of Radioactive Substances Advisory Committee (ARSAC) guidance were in use in all facilities. Data from three of the 11 facilities (25%) indicated that they used both guidance documents. It is worth noting that the ARSAC guidance references the EANM dosage calculator and directs its readers to the EANM website for specific practical information for paediatric nuclear medicine procedures.[15, 16]

3.2.2 National DRLs for adult nuclear medicine procedures (including CT hybrid imaging)

National DRLs established for 10 adult nuclear medicine planar and SPECT imaging procedures are presented in Table 1. Subsequently, five national DRLs for CT hybrid imaging for SPECT were also established for the first time (Table 2). Table 3 and Table 4 include national DRLs established for PET CT procedures.

Table 1 National adult DRLs for nuclear medicine procedures

Radionuclide	Pharmaceutical	Procedure or Clinical Task	Route of Administration	Type of Imaging (planar/ SPECT)	Previous National DRL (MBq)	2023 National DRL (MBq)	National Dose Range (MBq)	Number of Facilities (n)††
Endocrine								
^{99m}Tc	Sestamibi (MIBI)	Parathyroid imaging (washout method)	IV	Planar and SPECT combined	Not established (NE)‡‡	**740**	547 - 810	13
^{99m}Tc	Sestamibi (MIBI)	Parathyroid imaging (subtraction method)	IV	Planar and SPECT combined	NE	**NE**	739 - 860	3
^{99m}Tc	Pertechnetate	Thyroid imaging/uptake	IV	Planar	80	**100**	74 - 100	5

†† The (n) column indicates the number of facilities that supplied local facility DRLs based on 20 or more patients.

‡‡ Not established (NE) indicates that a national value has not been established for this procedure of clinical task due to insufficient data points.

Radionuclide	Pharmaceutical	Procedure or Clinical Task	Route of Administration	Type of Imaging (planar / SPECT)	Previous National DRL (MBq)	2023 National DRL (MBq)	National Dose Range (MBq)	Number of Facilities (n)††
Gastrointestinal								
^{99m}Tc	Colloid	Gastric emptying	Oral	Planar	NE	**NE**	23 - 40	3
Genitourinary								
^{99m}Tc	DTPA	Renal imaging	IV	Planar	250	**300**	108 - 311	5
^{99m}Tc	MAG3	Renal imaging	IV	Planar and SPECT combined	100	**105**	98 - 105	8
^{99m}Tc	DMSA	Renal imaging	IV	Planar	NE	**84**	75 - 84	5
Hepatobiliary								
^{99m}Tc	Iminodiacetate (HIDA)	Functional biliary system imaging (HIDA)	IV	Planar	NE	**NE**	119 - 152	3
Lymphatic								
^{99m}Tc	Colloid/ Nanocolloid	Sentinel node (Breast) study – same day	Interstitial	Planar	NE	**23**	20 - 27	8

Radionuclide	Pharmaceutical	Procedure or Clinical Task	Route of Administration	Type of Imaging (planar / SPECT)	Previous National DRL (MBq)	2023 National DRL (MBq)	National Dose Range (MBq)	Number of Facilities (n)[††]
Nervous System / Brain								
^{123}I	Ioflupane	Brain imaging (Brain Dopaminergic System Imaging and or DAT scan)	IV	SPECT	185	**183**	167 - 187	8
Pulmonary								
^{99m}Tc	Macro-aggregated albumin (MAA)	Lung perfusion imaging (Pulmonary embolism)	IV	Planar	NE	**NE**	107 - 116	3
Skeletal								
^{99m}Tc	Phosphonates and phosphates	Bone imaging scan	IV	Planar	600	**613**	576 - 658	15
				SPECT	800	**680**	576 - 800	9
^{99m}Tc	Phosphonates and phosphates	Triple phase bone imaging scan	IV	Planar and SPECT combined	NE	**658**	584 - 705	13

Table 2 National adult DRLs and median doses for the CT hybrid imaging component of SPECT procedures

Procedure or clinical task	2023 National DRL		National Median Dose		National Dose Range		Number of facilities (n)[††]
	DLP (mGy.cm)	$CTDI_{vol}$ (mGy)	DLP (mGy.cm)	$CTDI_{vol}$ (mGy)	DLP (mGy.cm)	$CTDI_{vol}$ (mGy)	
Lower extremity							
Ankles and Feet – Orthopaedic or infection – Attenuation correction/localisation	**131**	**6.35**	104	4.4	41 - 295	1.3 - 11.5	6
Knees – Orthopaedic or infection – Attenuation correction/localisation	**NE**	**NE**	NE	NE	69 - 135	1.9 - 5.3	3
Pelvis and spine							
Pelvis (to include hips) – Orthopaedic or infection and possible bone metastasis – Attenuation correction/localisation	**171**	**4.85**	152	4.4	83 - 226	2 - 5.3	7
Lumbar spine – Orthopaedic or infection and possible bone metastasis – Attenuation correction/localisation	**160**	**4.15**	131	3.8	55 - 187	1.33 - 5.3	7
Pulmonary							
Thorax/Chest (to include imaging of ribs) – Possible bone metastasis – Attenuation correction/localisation	**NE**	**NE**	NE	NE	131 - 239	3.8 - 5.9	3

Sentinel Node							
Head and neck – Localise sentinel node – Attenuation correction/localisation	**NE**	**NE**	NE	NE	91 - 124	2.3 - 5.3	3
Parathyroid							
Neck – Parathyroid imaging – Attenuation correction/localisation	**124**	**5.46**	83	4.01	62 - 160	2.01 - 6.3	5
Oncology Imaging							
MIBG and Octreotide – Oncology imaging – Attenuation correction/localisation	**151**	**3.38**	137	2.6	119 - 181	1.77 - 4.5	6

Table 3 National adult DRLs for PET imaging procedures

Radionuclide	Pharmaceutical	Procedure or clinical task	Route of Administration	Previous National DRL (MBq)	2023 National DRL (MBq)	National Dose Range (MBq)	Number of facilities (n)[††]
Infection or Inflammation							
^{18}F	FDG	Infection imaging	IV	NE	**NE**	221 - 358	3
^{18}F	FDG	Inflammation imaging	IV	NE	**NE**	197 - 358	3
Nervous system / Head							
^{18}F	FDG	Differential diagnosis of dementia	IV	NE	**NE**	164 - 254	3
^{18}F	FDG	Focal epilepsy	IV	NE	**NE**	185 - 254	3
Oncology							
^{18}F	FDG	Whole body tumour imaging	IV	380	**368**	191 - 397	10
^{18}F	FDG	Brain tumour imaging	IV	NE	**NE**	198 - 254	3

Table 4 National adult DRLs and median doses for the CT hybrid imaging component of PET hybrid procedures

Procedure or clinical task	2023 National DRL		National Median Dose		National Dose Range		Number of facilities (n)[††]
	DLP (mGy.cm)	$CTDI_{vol}$ (mGy)	DLP (mGy.cm)	$CTDI_{vol}$ (mGy)	DLP (mGy.cm)	$CTDI_{vol}$ (mGy)	
Whole body (vertex to toes) – Attenuation correction/localisation	**665**	**5.7**	565	4.1	342 - 807	2.77 - 6	6
Whole body (eyes to thighs) – Attenuation correction/localisation	**559**	**5.7**	504	5.26	275 - 634	2.8 - 6.3	9
Brain/head – Attenuation correction/localisation	**NE**	**NE**	NE	NE	184 - 289	2 - 8	3

3.3 Nuclear medicine procedures numbers

This national DRL review also gathered information on the frequency of diagnostic nuclear medicine procedures carried out in facilities. Annual nuclear medicine procedure numbers provided by all services were collated and are displayed in Appendix 1. These tables are ordered by total number of annual procedures reported for 2022. Information on the number of facilities who carry out each particular procedure is also included. Not all procedures listed in the annual number tables have an associated national DRL. For procedures that are rarely performed, or are only performed in a limited number of facilities, local facility DRL values could not be established as insufficient data points were available for inclusion in the generation of national DRL values.

Comparison with procedure number data from surveys conducted in previous years can provide an insight into the increased or decreased use of particular imaging procedures and interventions nationally. However, based on the information available from previous years, this comparison is limited.

3.3.1 Annual procedure numbers for adult planar nuclear medicine and SPECT CT imaging

In 2022, the reported number of nuclear medicine procedures in Ireland was 39,767 with planar imaging nuclear medicine procedures of adults accounting for the largest contribution at 46% (n=18,379) of the total annual national procedure numbers (Figure 3). Nuclear medicine procedures can include a CT hybrid imaging component as part of SPECT CT and PET CT procedures. Adult SPECT procedures made up 18% (n=7,307) of nuclear medicine procedures. From this 18%, 4,934 (68%) procedures included a CT hybrid imaging component (SPECT CT).

Overall, as shown in Figure 4, bone imaging scans account for the majority of nuclear imaging procedures (41%, n=16,230) across the combined different procedure or clinical tasks and imaging equipment types. Sentinel node (breast) studies accounted for 5% of procedures (n=1,933). Adult nuclear medicine procedures with no imaging required, for example, GFR measurements, accounted for just 118 procedures in total (0.3%).

3.3.2 Annual procedure numbers adult PET and PET CT

PET CT procedures for adults was the second highest number of nuclear medicine procedures performed in 2022 (32%, n=12,836). An additional 186 CT hybrid scans for patients undergoing PET CT were reported for 2022, which exceeded the amount of PET procedures reported.

Whole body imaging using ^{18}F FDG was the most common type of adult PET procedure and the second most common type of nuclear medicine procedure overall in 2022 accounting for 26% (n=10,463) in 2022.

3.3.3 Annual procedure numbers for paediatric planar, SPECT, SPECT CT and PET CT imaging

Paediatric nuclear medicine procedures accounted for just 3% (n=1,127) of the total number of nuclear medicine procedures. This comprised of 910 planar imaging nuclear medicine procedures and 165 SPECT procedures. Of the 165 SPECT procedures, 64 included a hybrid CT imaging component. Paediatric PET CT numbers were even lower with just 52 PET CT procedures carried out in 2022.

3.3.4 Comparison of annual procedure numbers with previous surveys

In 2014, the Radiological Protection Institute of Ireland (RPII) published a report titled *Radiation Doses Received by the Irish Population* which extrapolated the number of procedures carried out in Ireland in 2010 and included the results of a HSE national survey on nuclear medicine procedures.[17, 18] Table 5 compares the results of this 2010 national survey to the procedure numbers obtained in Ireland in 2022.

From this comparison, nuclear medicine imaging of the skeletal system (^{99m}Tc bone scan) is still the most commonly performed nuclear medicine procedure and has increased by 8% (n=1250). ^{99m}Tc MAG3 renogram scan and ^{123}I DaTScan were the only other procedure types to show an increase in the nine year period. These increases were 43% (n=226) and 50% (n=217) respectively. All nine other scan types demonstrated a decrease ranging between 92% (n=618) for ^{99m}Tc myocardial scans to 13% (n=16) for ^{111}In octreotide scans.

Figure 4 illustrates the most commonly performed nuclear medicine procedures in 2022. Overall, three procedures accounted for 28,626 (71%) of all procedures in Ireland.

Table 5 Comparison of annual national procedures numbers

Procedure/clinical task	Extrapolated annual number of procedures 2010 [18]	Annual number of procedures 2022 (combined planar imaging and SPECT)
^{99m}Tc bone scan	14980	16230
^{99m}Tc thyroid scan	1140	558
^{99m}Tc V/Q lung perfusion scan (for pulmonary embolism)	940	428
^{99m}Tc myocardial scan	670	52
^{99m}Tc DTPA renogram scan	570	341
^{99m}Tc MAG3 renogram scan	530	756
^{123}I DaT Scan	430	647
^{99m}Tc Technegas V/Q lung ventilation scan	350	147
^{131}I thyroid metastases	330	67
^{111}In octreoscan	120	104
^{131}I thyroid uptake	110	25
^{123}I MIBG scan	80	65

Figure 3 Contribution of adult and paediatric nuclear medicine imaging procedures to total annual procedure numbers

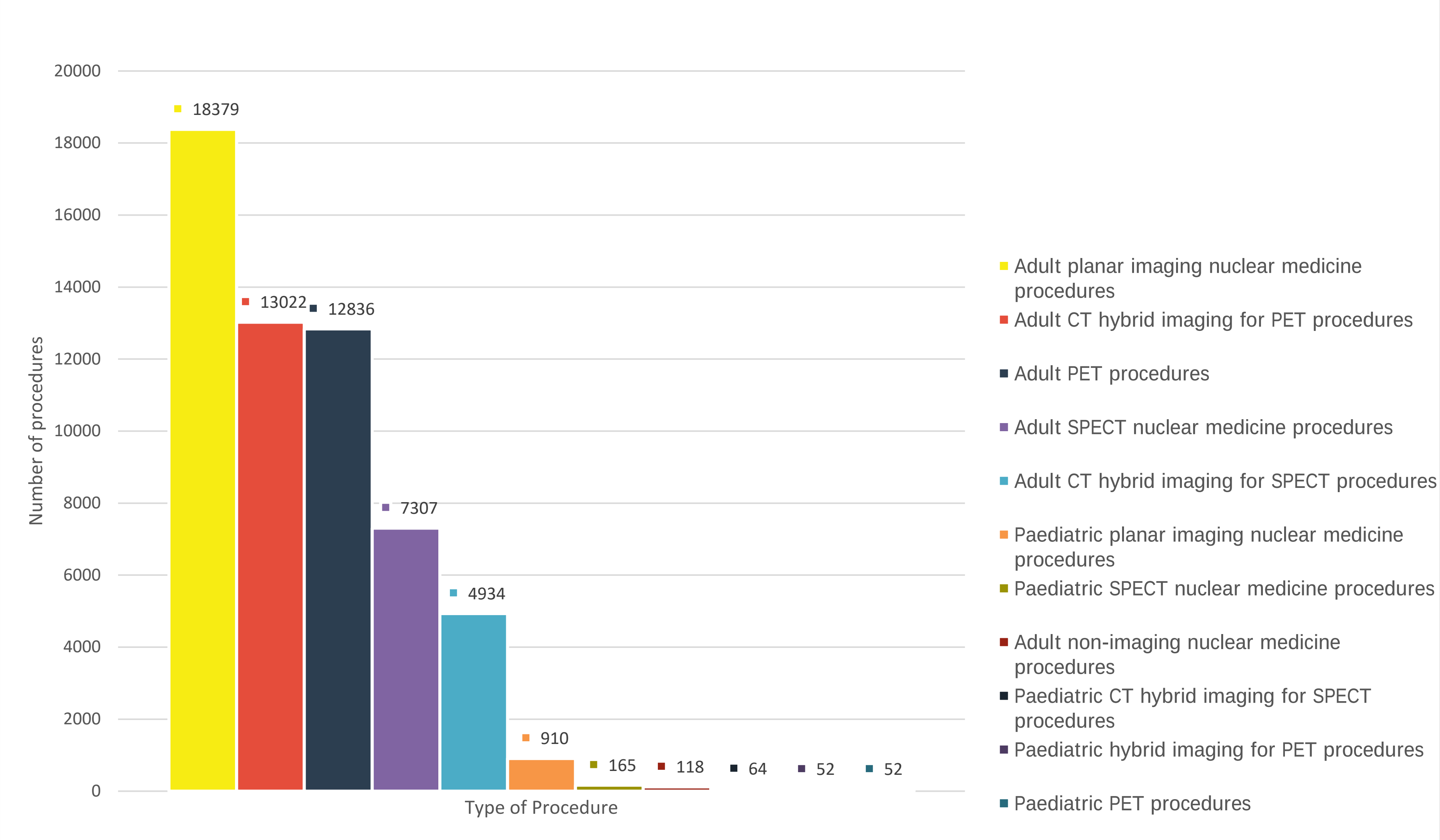


Figure 4 Most commonly performed nuclear medicine procedures in 2022

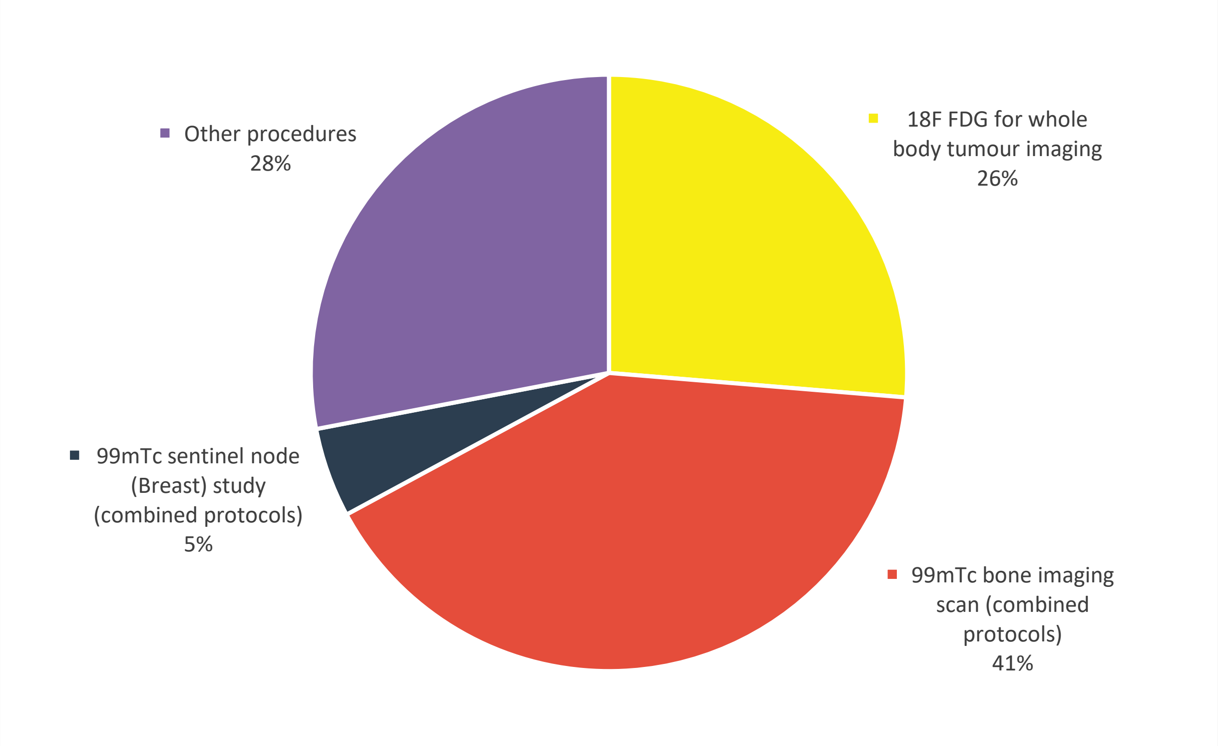
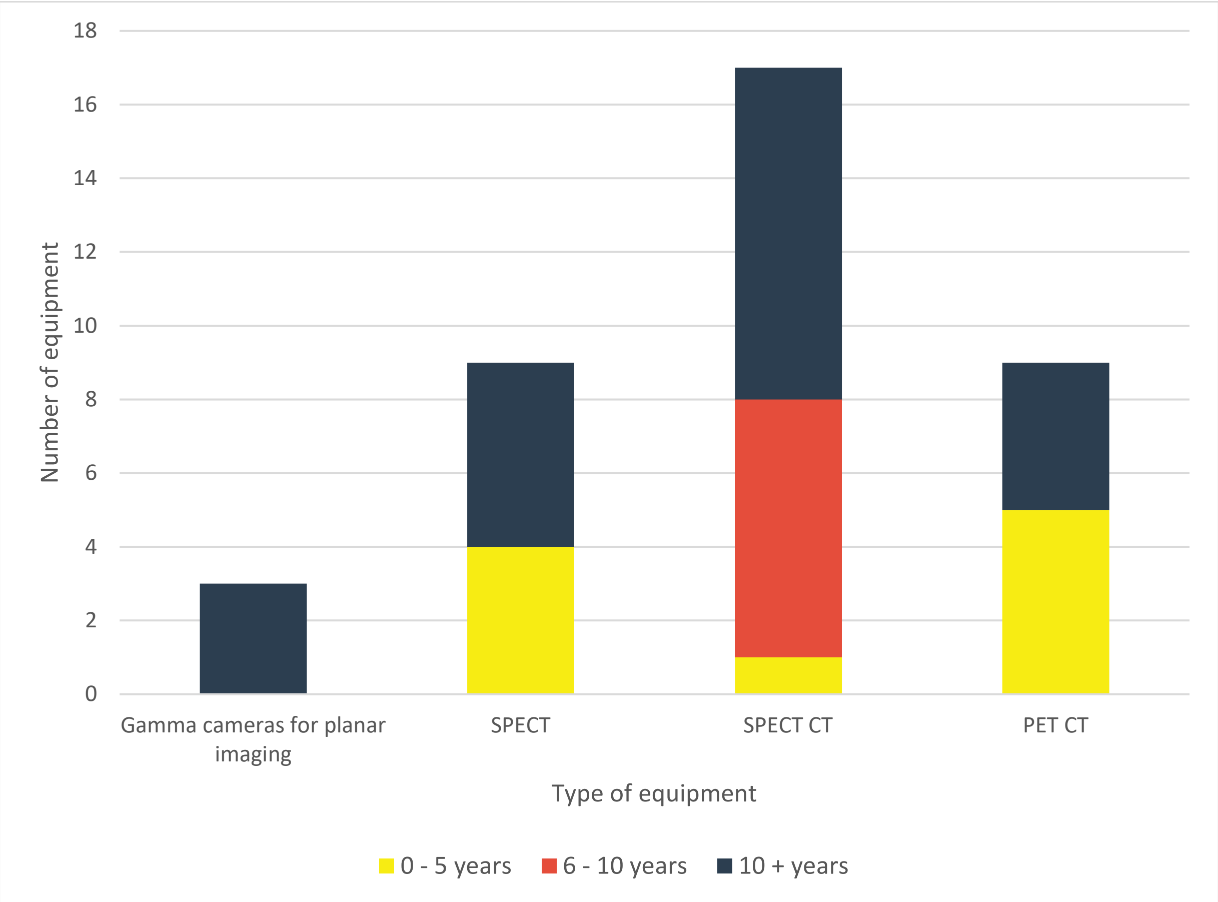


Figure 5 National nuclear medicine equipment age profile by type



3.4 Equipment type and age

In Ireland diagnostic nuclear medicine services are supplied by a total of 38 pieces of equipment. Facilities surveyed indicated that in Ireland nuclear medicine equipment is comprised of 3 gamma cameras for planar imaging, 9 SPECT units, 17 SPECT CT units and 9 PET CT units[**].

The age profile is similar across all types of equipment with 55% (n=21) of all equipment greater than 10 years old, 18% (n=7) were 6 - 10 years old and 28% (n=11) were 0 - 5 years old (Figure 5).

4 Discussion

This national DRL review was conducted as part of HIQA's regulatory responsibility for the establishment and review of national DRLs for medical procedures using ionising radiation. It provides undertakings, facilities and patients with important information on representative service user doses which can be used to optimise doses nationally.

4.1 Survey response rate

The DRL survey was issued to 24 facilities that provide diagnostic nuclear medicine procedures. All 24 facilities returned a DRL survey. This 100% response rate represents census data as all facilities providing medical exposures to ionising radiation are required to declare and provide information as requested by HIQA under the regulations.

4.2 National DRL figures

National DRLs established from survey data collected in 2022 are presented in this report under anatomical systems relevant to the clinical task or procedure. Similarly, recommendations on the use of a dose card for establishing weight-based administered activity for paediatric nuclear medicine procedures were also presented.

4.2.1 National DRLs for adult nuclear medicine procedures

Local facility DRL median dose values were sought for the procedures and clinical tasks and national DRLs were set as the 75th percentile of the median values obtained. In line with International Commission on Radiological Protection (ICRP) guidance, a national median has also been published for the CT hybrid imaging component of nuclear medicine to further promote the optimisation process on a national basis.[2]

Comparisons between the newly established national DRLs for planar and SPECT imaging procedures and previously established DRL values adopted by HIQA in 2020, where available, showed that all except two DRLs have increased. The previous planar imaging national DRL (185 MBq) for ^{123}I ioflupane brain imaging (Brain Dopaminergic System Imaging and or DAT scan) has been replaced by a SPECT DRL (183 MBq). ^{99m}Tc phosphonates and phosphates bone imaging SPECT imaging scan has also decreased from 800 MBq to 680 MBq. Additionally, the national DRL for ^{18}F PET whole body has also decreased from 380 MBq to 368 MBq.

The data collated from this survey represents a national picture of the nuclear medicine procedures delivered in Ireland in 2022, from which the 2023 DRL values were obtained. The list of clinical procedures or tasks for which the 2023 national DRLs were established differs from the 2020 HIQA DRLs due to insufficient data points. New national DRLs have been established for ^{99m}Tc Sestamibi (MIBI) parathyroid imaging (washout method), ^{99m}Tc DMSA renal imaging and ^{99m}Tc Colloid/Nanocolloid sentinel node (breast) study – same day.

Results from this survey indicated that some procedures (Appendix 1) were only performed in a small number of facilities or had only a small number performed in each facility and therefore national DRLs were not revised. These procedures and clinical tasks were ^{123}I MIBG scan, ^{111}In Octreotide scan, ^{99m}Tc myocardial, cerebral blood flow and lung ventilation perfusion (VQ) scans. Similarly, a national DRL for ^{18}F PET brain scan was not established in 2023.

Additionally, Figure 2 shows that 50% (n=5) of Irish PET CT facilities responded that they use weight-based protocols for all procedures, with three facilities (30%) using weight-based protocols for some of its procedures. Using a weight-based protocol for all nuclear medicine procedure is recommended by the ICRP and has been adopted by other European countries.[2, 13, 19] HIQA encourages all facilities to consider this approach to further optimise nuclear medicine procedures.[2]

4.2.1.1 Methodology for establishing local facility DRLs for adult nuclear medicine procedures

Ideally, based on the current literature, the administered activity should be based on weight for all nuclear medicine procedures.[2] However, it is noted that the use of weight-based administered activity is not yet common practice in Ireland for adult nuclear medicine procedures. As a result, local facility DRLs can be established using the value of administered activity (MBq) based on the administered activity for an average size patient in facilities where they are not weight-based. However, undertakings should strive to align with international best practice, where possible.

Following this national review of nuclear medicine procedures the methodology for establishing nuclear medicine DRLs has been updated in HIQA's guidance document for establishing DRLs.

4.2.2 National DRLs for adult CT hybrid imaging

National DRLs were established for the first time in Ireland for the CT hybrid imaging component of SPECT CT (n=5) and PET CT (n=2) (Table 2 and Table 4).

The ICRP guidance recommends that a CT DRL for attenuation correction and or localisation as part of a nuclear medicine procedure should be provided separately given the different dose metrics involved.[2] Hybrid imaging procedures in SPECT CT and PET CT involves exposure to two sources of ionising radiation (the radionuclide and the CT imaging) which are measured in different units and presented as separate DRLs even though they are components of the same procedure.

Two sets of figures are provided for the CT components, $CTDI_{vol}$ and DLP. However, given the potential for scan length differences for nuclear medicine scans for different cohorts of patients, the $CTDI_{vol}$ maybe the more useful figure for optimisation of this aspect of SPECT CT and PET CT procedures.[9, 20, 21]

4.2.3 National DRLs for paediatric nuclear medicine procedures

Only four procedure or clinical task types for CT hybrid imaging for SPECT were conducted in 2022, with eight procedure or clinical tasks conducted for CT hybrid imaging for PET. However, all of these procedures and clinical tasks were conducted in very low numbers and in less than three facilities. Given the low number of hybrid nuclear medicine procedures carried out in the paediatric population (n=116), no national DRLs were established.

As part of this survey, facilities conducting paediatric nuclear medicine procedures were asked what dose card was used as a reference for calculating administered activity. The use of smaller volumes of administered activities as a fraction of the corresponding adult administered activity is common practice for paediatric nuclear medical procedures in line with national, European and international best practice.[15, 16, 22]

Based on the results of this survey, the recommended weight-based administered activities provided by the EANM paediatric dosage card and the ARSAC guidance are considered as the paediatric nuclear medicine DRLs for the purposes of optimisation.[15] These references include information on the scaling of adult administered activity for children and young persons and also provide information on recommended minimum administered activity.[15, 16] However, all individual paediatric nuclear medicine procedures must be optimised in line with intended clinical outcomes under the clinical responsibility of a practitioner for each individual patient.[1, 23]

4.3 Annual procedure numbers

In 2010, the extrapolated number of nuclear medicine procedures performed annually in Ireland was 29,993 (excluding PET CT[§§]).[17] However, it should be noted when reviewing the findings, that the 2010 data was extrapolated on a survey of 15 procedures across 19 facilities.[18] In comparison with the 2010 figures, the figure for nuclear medicine procedures in 2022 was 25,804 (excluding PET CT and

[§§] Previous figures for PET CT procedures in Ireland were unavailable for this comparison.

paediatrics). This indicates a 14% decrease in the number of adult nuclear medicine procedures carried out.

Paediatric nuclear medicine procedures were very low representing just 2% (n=1,127) of all procedures conducted in 2022 (Figure 3). These were carried out across 11 facilities. Interestingly, the number of facilities providing paediatric nuclear medicine remains unchanged since a previous study conducted 15 years ago.[22] This 2008 study from Gray et al [22] reported that bone scans were the most commonly performed paediatric procedure type with renal imaging with ^{99m}Tc DMSA also commonly performed. However, in this 2022 survey, ^{99m}Tc DMSA is the most commonly performed imaging scan (n=480), followed by ^{99m}Tc Bone imaging (combined planar and SPECT) (n=217).

4.4 Equipment type and age profiles

In the current survey, most of the equipment used in Ireland to deliver the nuclear medicine service was categorised as greater than 10 years old (55%, n=21) (Figure 5). The results of the survey showed that SPECT CT was the most common type of equipment in use in facilities providing nuclear medicine procedures in Ireland (45%, n=17). The majority (42%, n=9) of SPECT CT was greater than 10 years with only one piece of equipment less than five years old.

Standalone SPECT equipment accounts for 24% of equipment (n=9). Overall, internationally, since SPECT, SPECT CT and PET CT technology have become widely available there has been an overall move towards these newer technologies and away from the traditional 2D planar imaging.[21, 24, 25] This trend appears to be reflected in Ireland with the installation of SPECT CT equipment between 2012 and 2018 followed by PET CT in the last five years (2018 to 2022). Only three gamma cameras for planar imaging were in place in 2022 and these were all greater than 10 years old.

The European Society of Radiology (ESR) states that medical radiological equipment has a definite life cycle.[14] Equipment that is five years old or less reflects the current stage of technology and should improve quality and safety in medical imaging. Medical radiological equipment older than 10 years is no longer considered to be state of the art and a replacement strategy should be considered. It is important to note that although it is not a specific regulatory requirement to replace equipment based on age, undertakings should ensure equipment is fit for purpose and meets the criteria of acceptability for medical radiological equipment.[2]

Categorising equipment age helps determine a national profile of equipment, which may influence requirements for upgrade and replacement. Undertakings should consider equipment replacement as part of ongoing capital costs and ensure that all necessary measures are taken to improve inadequate or defective performance of medical radiological equipment if identified. Independent of age, equipment may continue to perform to regulatory standards and meet quality assurance criteria. However, older equipment may be associated with increased breakdown, reduced image quality and increased operating costs.[14]

5 Conclusion

National DRL values are typical radiation dose levels set for common medical imaging procedures and clinical tasks undertaken in Ireland. These allow facilities to compare local facility DRLs, which represent patient dose, to a national standard. These levels are used as a benchmark to optimise patient radiation dose, while maintaining the required diagnostic information.

As part of this survey, HIQA has established national 75th percentile DRLs for nuclear medicine procedures. This will enable facilities to further optimise patient dose, acknowledging the requirement to also maintain the diagnostic quality of medical imaging procedures based on clinical judgment of the responsible practitioner.

As these DRL values are based on a nationwide survey of all medical facilities (100% response rate) providing diagnostic nuclear medicine imaging in Ireland in 2022, they are established based on census data. The information included in this report has also been used as part of the on-going work on population dose from medical radiological procedures.

Noting that historically, DRLs in nuclear medicine were based on recommended administered activities, HIQA has aligned the national nuclear medicine DRLs with values provided for other modalities, such as fluoroscopy to reflect the evolving literature around the establishment of nuclear medicine DRLs. While these DRLs are national typical values and should be used as a tool for optimisation, they do not replace clinical judgment and do not apply to individual patients. However, as per the regulations, they must be used to benchmark facility dose levels and where consistently exceeded, undertakings should carry out a review to ensure that all medical exposures are optimised in line with the as low as reasonably achievable (ALARA) principle of radiation protection.

This survey has produced a range of DRLs for procedures and clinical tasks that had not been previously established nationally. Conversely, new national DRL figures for some national DRLs previously established were not set as part of this work as there was not sufficient data to calculate up-to-date values from data points provided. This indicates that the number of procedures associated with these previous DRLs have fallen and are not carried out routinely or at a frequency to enable DRLs to be established.

Previously established national DRLs were adopted by HIQA in 2020 and drew from limited national surveys, international surveys and scientific literature. When the current DRLs are compared to those adopted by HIQA in 2020, these were found to largely align with previous doses where comparisons could be made. DRL values for CT used for nuclear medicine hybrid imaging were also established in Ireland for the first time.

This survey identified that the age of equipment used to provide nuclear medicine procedures nationally was predominantly older equipment greater than 10 years old. However, despite this finding the survey also shows that Ireland has moved towards installing newer technologies such as SPECT CT and PET CT. While there is no regulatory requirement to replace equipment older than 10 years that has been found to meet quality assurance testing and functioning well, a replacement strategy should be implemented.

The frequency data obtained has also established annual procedure numbers for nuclear medicine procedures performed nationally. Procedure numbers in the field of paediatric nuclear medicine were found to be very low when compared to that in the adult population.

In light of this new set of national DRLs in nuclear medicine, undertakings should continue to review their local facility DRLs having regard to this updated national DRL procedure and clinical task list. In addition, where a national DRL has not been set, but sufficient data points for three or more facilities were available, a dose range has been provided to allow facilities to benchmark against the national dose range.

In the coming years, HIQA will continue to establish national DRLs in other areas of imaging. Moreover, dose information collected 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 population dose will help in identifying significant pathways of medical exposure to further dissemination of information, policy adaptations and regulation of medical exposures.

It is hoped that the knowledge gained from this survey will help undertakings drive quality improvement and radiation protection strategies for service users. HIQA will continue to build upon its programme to date of promoting 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 patients undergoing nuclear medicine procedures in Ireland.

6 Glossary

Becquerel (Bq): is a measure of radioactivity used to measure the radioactivity of radiopharmaceuticals used in nuclear medicine procedures.

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.

Computed tomography dose index (CTDI): is the dose value from a single CT slice scanned. It is measured in milli Gray (mGy).

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 patients or standard phantoms for broadly defined types of equipment.

Dose length product (DLP): is the dose arising from a CT examination which incorporates the average dose per slice and the length of the scan. It is measured in milli Gray per centimetre (mGy.cm).

Gamma camera: equipment used to detect gamma radiation which is emitted during a nuclear medicine procedures.

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

Hybrid imaging: is where two (or more) different types of imaging are fused together. For example, a SPECT CT scanner combines the physical equipment and software of a tomographic gamma camera (SPECT) and a CT scanner to produce images used in the diagnosis of disease.

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.

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

Medical exposure (ionising radiation): an exposure of ionising radiation delivered to patients 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.

Nuclear medicine procedure: a type of medical exposure where a radiopharmaceutical or radioactive substance 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 using a detector such as a gamma camera.

Planar imaging (using a gamma camera): is a technique using a gamma camera to provide two dimensional (2-D) image as part of nuclear medicine procedure.

Positron emission tomography (PET): 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.

Radiopharmaceutical: pharmaceuticals (drugs) that are labelled (attached) with a radioactive tracer designed to go to a target organ such as the thyroid or bones. Radiopharmaceuticals can have diagnostic or therapeutic uses.

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

Single-photon emission computed tomography (SPECT): is an imaging technique which uses a tomographic (imaging in slices or sections) gamma camera to provide a three dimensional (3-D) image as part of a nuclear medicine procedure.

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.

7 References

1. European Union (Basic Safety Standards for Protection Against Dangers Arising from Medical Exposure to Ionising Radiation) Regulations 2018, S.I. No. 256 of 2018, (2019).
2. ICRP. Diagnostic Reference Levels in Medical Imaging. ICRP publication 135. Annals of the ICRP. 2017;46.
3. Health Information and Quality Authority. Diagnostic Reference Levels Guidance on the establishment, use and review of diagnostic reference levels for medical exposure to ionising radiation. Cork: Health Information and Quality Authority; 2022. Available from: https://www.hiqa.ie/reports-and-publications/guide/guidance-establishment-use-and-review-diagnostic-reference-levels. Accesssed on 1 November 2023.
4. Health Information and Quality Authority. National diagnostic reference levels (DRLs) for general radiography, mammography and DXA scanning. Cork: Health Information and Quality Authority; 2021. Available from: https://www.hiqa.ie/reports-and-publications/key-reports-and-investigations/national-drls-general-radiography. Accesssed on 1 November 2023.
5. Health Information and Quality Authority. National diagnostic reference levels (DRLs) for Fluoroscopy and Fluoroscopically Guided Interventions Cork: Health Information and Quality Authority; 2022. Available from: https://www.hiqa.ie/reports-and-publications/key-reports-investigations/national-drls-fluoroscopy-and-fluoroscopically. Accesssed on 1 November 2023.
6. O'Hora L, Neville N, Tuffy J, Craig A, O'Brien K, Sugrue K, et al. Establishing national diagnostic reference levels in radiography, mammography, and dual-energy x-ray absorptiometry services in Ireland and comparing these with European diagnostic reference levels. European Radiology [online]. 2023. Available from: https://doi.org/10.1007/s00330-023-09992-4. Accesssed on 28 July 2023.
7. ICRP. The 2007 Recommendations of the International Commission on Radiological Protection. ICRP publication 103. Annals of the ICRP. 2007;37(2-4).
8. European Commission. Radiation Protection 109 Guidance on Diagnostic (DRLs) for Medical Exposures: Publications Office of the European Union; 1999. Available from: https://energy.ec.europa.eu/system/files/2014-11/109_en_1.pdf. Accesssed on 1 November 2023.
9. Alessio AM, Farrell MB and Fahey FH. Role of Reference Levels in Nuclear Medicine: A Report of the SNMMI Dose Optimization Task Force. Journal of Nuclear Medicine. 2015;56(12):1960-4.
10. Australian Radiation Protection and Nuclear Safety Agency (ARPANSA). Australian Diagnostic Reference Levels (DRLs) for Nuclear Medicine Australian Radiation Protection and Nuclear Safety Agency; 2019. Available from: https://www.arpansa.gov.au/sites/default/files/tr180.pdf. Accesssed on 17 July 2023.

11. Rep S, Santos A and Testanera G. Radiation Protection and Dose Optimistation. A Technologist's Guide. Vienna: European Association of Nuclear Medicine; 2016. Available from: https://www.eanm.org/content-eanm/uploads/2016/12/EANM_2016-TG_RadiationProtection_lowres.pdf. Accesssed on 17 July 2023.

12. International Atomic Energy Agency, editor. Radiation Protection and Safety of Radiation Sources: Internaltional Basic Saftety Standards. Vienna: International Atomic Energy Agency; 2014.

13. Bundesamt für Strahlenschutz. Bekanntmachung der aktualisierten dianosticschen Referenzwerte für nuklearmedizinische Untersuchungen 2021 [Available from: https://www.bfs.de/SharedDocs/Downloads/BfS/DE/fachinfo/ion/drw-nuklearmedizin.pdf?__blob=publicationFile&v=5.

14. European Society of Radiology. Renewal of radiological equipment. Insights into Imaging. 2014;5(5):543-6.

15. Administration of Radioactive Substances Advisory Committee (ARSAC). Notes for guidance on the clinical administration of radiopharmaceuticals and use of sealed radioactive sources2023. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1137032/guidance-clinical-administration-of-radiopharmaceuticals-and-use-of-sealed-radioactive-sources-2023.pdf. Accesssed on 25 July 2023.

16. European Society of Nuclear Medicine. Dosage Calculator [updated 2016. Available from: https://www.eanm.org/initiatives/dosage-calculator/.

17. Radiological Protection Institute of Ireland. Radiation Doses Received by the Irish Population. Dublin: Radiological Protection Institute of Ireland; 2014. Available from: https://www.epa.ie/publications/compliance--enforcement/radiation/RPII_Radiation_Doses_Irish_Population_2014.pdf. Accesssed on

18. Health Service Executive. Population Dose from General X-ray and Nuclear Medicine: 2010. Dublin: Health Service Executive; 2013.

19. L'Institut de Radioprotection et de Sûreté Nucléaire (IRSN). Analysis of Data for Updateing Diagnostic Reference Levels in Radiology and Nuclear Medecine 2019 - 2021 Report: L'Institut de Radioprotection et de Sûreté Nucléaire (IRSN),; 2023. Available from: https://www.irsn.fr/sites/default/files/2023-10/IRSN_Rapport_2023-00577_NRD_EN.pdf. Accesssed on 27 October 2023.

20. Lima TVM, Gnesin S, Ryckx N, Strobel K, Stritt N and Linder R. Swiss survey on hybrid imaging CTs doses in Nuclear Medicine and proposed national dose reference levels. Zeitschrift für Medizinische Physik. 2018;28(4):265-75.

21. Verfaillie G, Franck C, De Crop A, Beels L, D'Asseler Y and Bacher K. A systematic review and meta-analysis on the radiation dose of computed tomography in hybrid nuclear medicine imaging. EJNMMI Physics. 2023;10(1).

22. Gray L, Torreggiani W and O'Reilly G. Paediatric diagnostic reference levels in nuclear medicine imaging in Ireland. The British journal of radiology. 2008;81(971):918-9.

23. Piccardo A, Albert NL, Borgwardt L, Fahey FH, Hargrave D, Galldiks N, et al. Joint EANM/SIOPE/RAPNO practice guidelines/SNMMI procedure standards for imaging of paediatric gliomas using PET with radiolabelled amino acids and [18F]FDG: version 1.0. European Journal of Nuclear Medicine and Molecular Imaging. 2022;49(11):3852-69.

24. Israel O, Pellet O, Biassoni L, De Palma D, Estrada-Lobato E, Gnanasegaran G, et al. Two decades of SPECT/CT – the coming of age of a technology: An updated review of literature evidence. European Journal of Nuclear Medicine and Molecular Imaging. 2019;46(10):1990-2012.

25. Van Den Wyngaert T, Elvas F, De Schepper S, Kennedy JA and Israel O. SPECT/CT: Standing on the Shoulders of Giants, It Is Time to Reach for the Sky! Journal of Nuclear Medicine. 2020;61(9):1284-91.

8 Appendix 1 Total number of Nuclear medicine procedure numbers conducted in Ireland

Table 6 Annual adult nuclear medicine procedures for planar and SPECT imaging

Radionuclide	Pharmaceutical	Procedure or clinical task	Route of Administration	Type of imaging (planar / SPECT)	Number of facilities ***	Annual number of procedures ***
^{99m}Tc	Phosphonates and phosphates	Bone imaging scan	IV	Planar imaging	17	10367
^{99m}Tc	Phosphonates and phosphates	Bone imaging scan	IV	SPECT	14	2992
^{99m}Tc	Colloid/ Nanocolloid	Sentinel node (Breast) study – same day	Interstitial	Planar imaging	10	1750
^{99m}Tc	Phosphonates and phosphates	Triple phase bone imaging scan	IV	Planar imaging	11	798
^{99m}Tc	Phosphonates and phosphates	Bone scan peripheral dual phase imaging	IV	SPECT	<3	780
^{99m}Tc	Phosphonates and phosphates	Bone scan peripheral dual phase imaging	IV	Planar imaging	<3	716
^{99m}Tc	MAG3	Renal imaging	IV	Planar imaging	11	686
^{23}I	Ioflupane	Brain imaging (Brain Dopaminergic System Imaging and DAT scan)	IV	SPECT	11	647
^{99m}Tc	Sestamibi (MIBI)	Parathyroid imaging (washout method)	IV	SPECT	9	599
^{99m}Tc	Phosphonates and phosphates	Triple phase bone imaging scan	IV	SPECT	5	577

*** In some facilities for individual patients a combined protocol (planar imaging and SPECT) may have been carried out.

Radionuclide	Pharmaceutical	Procedure or clinical task	Route of Administration	Type of imaging (planar / SPECT)	Number of facilities ***	Annual number of procedures ***
^{99m}Tc	Pertechnetate	Thyroid imaging/uptake	IV	Planar imaging	16	549
^{99m}Tc	Sestamibi (MIBI)	Parathyroid imaging (washout method)	IV	Planar imaging	7	424
^{99m}Tc	DTPA	Renal imaging	IV	Planar imaging	6	341
^{99m}Tc	Colloid/ Nanocolloid	Sentinel node (Melanoma) study – same day	Interstitial	Planar imaging	7	315
^{99m}Tc	DMSA	Renal imaging	IV	Planar imaging	15	311
^{99m}Tc	Macro-aggregated albumin (MAA)	Lung perfusion imaging (Pulmonary embolism)	IV	SPECT	9	252
^{99m}Tc	Colloid/ Nanocolloid	Sentinel node (Melanoma) study – same day	Peritumoural	Planar imaging	4	208
^{99m}Tc	DPD	Cardiac amyloid imaging	IV	SPECT	7	181
^{99m}Tc	Colloid	Gastric emptying	Oral	Planar imaging	9	164
^{99m}Tc	Sestamibi (MIBI)	Parathyroid imaging (subtraction method)	IV	Planar imaging	<3	157
^{99m}Tc	Sestamibi (MIBI)	Parathyroid imaging (subtraction method)	IV	SPECT	<3	157
^{99m}Tc	Iminodiacetate (HIDA)	Functional biliary system imaging	IV	Planar imaging	13	149

Radionuclide	Pharmaceutical	Procedure or clinical task	Route of Administration	Type of imaging (planar / SPECT)	Number of facilities ***	Annual number of procedures ***
^{99m}Tc	Technegas	Lung ventilation imaging	Inhalation	SPECT	5	147
^{99m}Tc	Colloid/ Nanocolloid	Sentinel node (Breast) study – next day	Interstitial	Planar imaging	<3	140
^{99m}Tc	Iminodiacetate (HIDA)	Gallbladder scan	IV	Planar imaging	<3	134
^{99m}Tc	DPD	Cardiac amyloid imaging	IV	Planar imaging	4	128
^{99m}Tc	Erythrocytes	MUGA blood pool imaging	IV	Planar imaging	<3	120
^{99m}Tc	HYNIC-Ty-octreotide	Tumour detection scintigraphy	IV	SPECT	6	115
^{99m}Tc	Pertechnetate	Parathyroid imaging (subtraction method)	IV	Planar imaging	<3	104
^{99m}Tc	DTPA	DTPA GFR measurement	IV	None	<3	90
^{99m}Tc	Macro-aggregated albumin (MAA)	Lung perfusion imaging (Pulmonary embolism)	IV	Planar imaging	8	88
^{99m}Tc	Macro-aggregated albumin (MAA)	Lung perfusion imaging (Pulmonary embolism in pregnant individual)	IV	SPECT	5	85
^{99m}Tc	Colloid/ Nanocolloid	Lymphatic drainage (Lymphedema) study	Interstitial	Planar imaging	11	83
^{99m}Tc	Colloid/ Nanocolloid	Sentinel node (Melanoma) study – same day	Peritumoural	SPECT	<3	79

Radionuclide	Pharmaceutical	Procedure or clinical task	Route of Administration	Type of imaging (planar/ SPECT)	Number of facilities ***	Annual number of procedures ***
^{99m}Tc	Macro-aggregated albumin (MAA)	Lung shunt/ Transplant/Lung volume recruitment (LVR)/Valve insertion assessment	IV	Planar imaging	<3	79
^{99m}Tc	DTPA	Lung ventilation imaging	Inhalation	Planar imaging	6	74
^{99m}Tc	Colloid/ Nanocolloid	Sentinel node (Melanoma) study – same day	Interstitial	SPECT	4	73
^{99m}Tc	MAG3	Renal imaging	IV	SPECT	<3	70
^{111}In	Octreotide/ pentetreotide	Somatostatin receptors	IV	SPECT	7	70
^{99m}Tc	Pertechnetate	Parathyroid imaging (subtraction method)	IV	SPECT	<3	69
^{99m}Tc	HYNIC-Ty-octreotide	Tumour detection scintigraphy	IV	Planar imaging	4	64
^{131}I	Sodium Iodide	Thyroid metastases imaging (after ablation)	Oral	Planar imaging	<3	56
^{99m}Tc	Macro-aggregated albumin (MAA)	Lung shunt/ Transplant/Lung volume recruitment (LVR)/Valve insertion assessment	IV	SPECT	<3	45
^{99m}Tc	HYNIC-Ty3-octreotide	Somatostatin receptor imaging	IV	SPECT	2	44
^{123}I	Sodium Iodide	Whole body scan for thyroid cancer	IV	Planar imaging	<3	41

Radionuclide	Pharmaceutical	Procedure or clinical task	Route of Administration	Type of imaging (planar / SPECT)	Number of facilities ***	Annual number of procedures ***
^{99m}Tc	HYNIC-Ty3-octreotide	Somatostatin receptor imaging	IV	Planar imaging	<3	41
^{131}I	Sodium Iodide	Whole body scan	Oral	SPECT	<3	40
^{99m}Tc	Tetrofosmin	Myocardial imaging - 2 day protocol	IV	SPECT	<3	39
^{111}In	Octreotide/ pentetreotide	Somatostatin receptors	IV	Planar imaging	<3	34
^{123}I	MIBG	Tumour imaging (infusion)	IV	SPECT	6	31
^{131}I	Sodium Iodide	Whole body scan	Oral	Planar imaging	<3	31
^{99m}Tc	Colloid/ Nanocolloid	Sentinel node (Breast) study – same day	Peritumoural	SPECT	<3	28
^{123}I	Sodium Iodide	Thyroid imaging	IV	Planar imaging	<3	26
^{111}In	Leucocyte	Infection imaging	IV	Planar imaging	<3	25
^{131}1	Sodium Iodide	Thyroid uptake	Oral	None	<3	30
^{99m}Tc	Pertechnetate	Ectopic gastric mucosa imaging (Meckel's diverticulum)	IV	Planar imaging	10	24
^{99m}Tc	DMSA	Renal imaging	IV	SPECT	4	23
^{99m}Tc	MAG3	Renal transplant imaging	IV	Planar imaging	<3	22

Radionuclide	Pharmaceutical	Procedure or clinical task	Route of Administration	Type of imaging (planar / SPECT)	Number of facilities ***	Annual number of procedures ***
^{123}I	Sodium Iodide	Whole body scan for thyroid cancer	IV	SPECT	<3	21
^{99m}Tc	Macro-aggregated albumin (MAA)	Lung shunt assessment as part of Selective Internal Radiation Therapy (SIRT) planning	IV	SPECT	<3	<20
^{99m}Tc	Non-absorbable compounds	Oesophageal, gastric and or intestinal motility studies	Oral	Planar imaging	<3	<20
^{99m}Tc	Colloid/ Nanocolloid	Sentinel node (Breast) study – next day	Peritumoural	Planar imaging	<3	<20
^{99m}Tc	Colloid/ Nanocolloid	Sentinel node (Gynaecological) study	Peritumoural	Planar imaging	4	<20
^{131}I	MIBG	Tumour imaging	IV	Planar imaging	<3	<20
^{131}I	MIBG	Tumour imaging	IV	SPECT	<3	<20
^{131}I	Sodium Iodide	Thyroid metastases imaging (after ablation)	Oral	SPECT	<3	<20
^{99m}Tc	Sestamibi (MIBI)	Myocardial imaging - 2 day protocol	IV	SPECT	<3	<20
^{123}I	MIBG	Tumour imaging (infusion)	IV	Planar imaging	<3	<20
^{99m}Tc	Pertechnetate	Thyroid imaging/uptake	IV	SPECT	4	<20
^{99m}Tc	Colloid	Gastric emptying	Oral	SPECT	<3	<20

Radionuclide	Pharmaceutical	Procedure or clinical task	Route of Administration	Type of imaging (planar/ SPECT)	Number of facilities ***	Annual number of procedures ***
^{99m}Tc	Colloid	Liver and spleen imaging	IV	SPECT	<3	<20
^{75}Se	23-seleno-25-homotaurocholic acid (SeHCAT)	Bile salt absorption	Oral	Planar imaging	<3	<20
^{99m}Tc	Sulesomab	Infection imaging	IV	Planar imaging	<3	<20
^{99m}Tc	DTPA	Lung ventilation imaging	Inhalation	SPECT	<3	<20
^{99m}Tc	Macro-aggregated albumin (MAA)	Lung shunt assessment as part of Selective Internal Radiation Therapy (SIRT) planning	IA	Planar imaging	<3	<20
^{99m}Tc	Erythrocytes	Gastrointestinal bleeding and or blood loss	IV	Planar imaging	<3	<20
^{99m}Tc	Pertechnetate	Salivary gland imaging	IV	Planar imaging	<3	<20
^{99m}Tc	MAG3	Renal transplant imaging	IV	SPECT	<3	<20
^{99m}Tc	Exametazime/ HM-PAO or similar	White blood cell labelling	IV	Planar imaging	<3	<20
^{99m}Tc	Colloid/ Nanocolloid	Sentinel node (Gynaecological) study	Peritumoural	SPECT	<3	<20
^{99m}Tc	HMPAO or Bicisate	Brain imaging (Cerebrovascular diseases)	IV	SPECT	<3	<20

Radionuclide	Pharmaceutical	Procedure or clinical task	Route of Administration	Type of imaging (planar / SPECT)	Number of facilities ***	Annual number of procedures ***
^{99m}Tc	Pertechnetate	Ectopic gastric mucosa imaging (Meckel's diverticulum)	IV	SPECT	<3	<20
^{99m}Tc	Erythrocytes	Gastrointestinal bleeding and or blood loss	IV	SPECT	<3	<20
^{99m}Tc	Sulesomab	Infection imaging	IV	SPECT	<3	<20
^{99m}Tc	Colloid/ Nanocolloid	Sentinel node (Penile) study	Intradermal injection	Planar imaging	<3	<20
^{99m}Tc	Colloid/ Nanocolloid	Sentinel node (Penile) study	Intradermal injection	SPECT	<3	<20
^{99m}Tc	MIBG	Tumour imaging	IV	Planar imaging	<3	<20
^{99m}Tc	MIBG	Tumour imaging	IV	SPECT	<3	<20
^{99m}Tc	Tetrofosmin	Myocardial imaging - 1 day protocol	IV	SPECT	<3	<20
^{123}I	MIBG	Sympathetic innervation imaging of the heart	IV	SPECT	<3	<20
^{99m}Tc	Colloid	Liver and spleen imaging	IV	Planar imaging	<3	<20
^{99m}Tc	Colloid/ Nanocolloid	Sentinel node (Breast) study – next day	Peritumoural	SPECT	<3	<20
^{99m}Tc	Macro-aggregated albumin (MAA)	Lung perfusion imaging (Pulmonary embolism in pregnant individual)	IV	Planar imaging	<3	<20

Radionuclide	Pharmaceutical	Procedure or clinical task	Route of Administration	Type of imaging (planar/ SPECT)	Number of facilities ***	Annual number of procedures ***
^{99m}Tc	Labelled RBC	Blood Volume Test	IV	None	<3	<20
^{99m}Tc	Colloid/ Nanocolloid	Sentinel node (Melanoma) study – next day	Interstitial	Planar imaging	<3	<20
^{99m}Tc	Colloid/ Nanocolloid	Sentinel node (Melanoma) study – next day	Interstitial	SPECT	<3	<20
^{99m}Tc	HMPAO or Bicisate	Brain imaging (ICTAL scan)	IV	SPECT	<3	<20
^{99m}Tc	Pertechnetate	CSF leak	Intrathecal	SPECT	<3	<20
^{123}I	MIBG	Sympathetic innervation imaging of the heart	IV	Planar imaging	<3	<20
^{99m}Tc	Iminodiacetate (HIDA)	Functional biliary system imaging	IV	SPECT	<3	<20
^{99m}Tc	Pertechnetate	Lacrimal drainage	Eye drops	Planar imaging	<3	<20
^{111}In	DTPA	CSF shunt patency	Cisternal	SPECT	<3	<20

Table 7 Annual procedure numbers for the adult CT hybrid imaging component of SPECT

Procedure or clinical task	Number of facilities	Annual number of procedures
Ankles and feet- Orthopaedic or infection - Attenuation correction/localisation	8	652
Neck anatomical area - Parathyroid imaging -Attenuation correction/localisation	11	627
Lumbar spine - Possible bone metastasis - Attenuation correction/localisation	8	560
Pelvis - Possible bone metastasis - Attenuation correction/localisation	7	478
Lumbar spine - Orthopaedic or infection - Attenuation correction/localisation	5	383
Thorax/Chest (to include imaging of ribs) - Possible bone metastasis - Attenuation correction/localisation	7	378
Pelvis (to include hips) - Orthopaedic or infection - Attenuation correction/localisation	6	356
Cervical spine - Possible bone metastasis - Attenuation correction/localisation	<3	234
Thoracic spine - Possible bone metastasis - Attenuation correction/localisation	<3	225
Shoulder and humerus - Possible bone metastasis - Attenuation correction/localisation	<3	224
Knees - Orthopaedic or infection - Attenuation correction/localisation	6	133
Octreotide - Oncology imaging - Attenuation correction/localisation	9	131
Head and neck - Localise sentinel node - Attenuation correction/localisation	7	93

Thorax/Chest anatomical area - Pulmonary imaging - Attenuation correction/localisation	7	79
Whole body (thorax/abdomen/pelvis) - Localise sentinel node - Attenuation correction/localisation	<3	57
Whole spine - Orthopaedic or infection - Attenuation correction/localisation	<3	57
MIBG- Oncology imaging- Attenuation correction/localisation	8	52
Thorax/chest anatomical area (Cardiac amyloid imaging) - Cardiac imaging - Attenuation correction only	4	49
Thorax/chest anatomical area (Myocardial imaging) - Cardiac imaging - Attenuation correction only	<3	43
Thoracic spine - Orthopaedic or infection - Attenuation correction/localisation	<3	36
Neck anatomical area - Post thyroid ablation imaging - Attenuation correction/localisation	<3	31
Lower limb (whole leg) - Orthopaedic or infection - Attenuation correction/localisation	<3	20
Cervical spine - Orthopaedic or infection - Attenuation correction/localisation	<3	<20
Upper limb - Localise sentinel node - Attenuation correction/localisation	<3	<20
Lower limb - Localise sentinel node - Attenuation correction/localisation	<3	<20
Abdominal anatomical imaging - Liver and spleen imaging - Attenuation correction/localisation	<3	<20
Abdominal anatomical imaging - Ectopic gastric mucosa imaging (Meckel's diverticulum) - Attenuation correction/localisation	4	<20
Shoulder - Orthopaedic or infection - Attenuation correction/localisation	<3	<20

Brain/Head anatomical area - Attenuation correction/localisation	4	<20
Upper limb(s)/extremity- Orthopaedic or infection - Attenuation correction/localisation	<3	<20
Whole spine - Orthopaedic or infection - Attenuation correction/localisation	<3	<20
Abdomen/pelvis - Attenuation correction/localisation	<3	<20
Knees - Possible bone metastasis - Attenuation correction/localisation	<3	<20
Lower limb (knees and femur) - Possible bone metastasis - Attenuation correction/localisation	<3	<20
Brain/head anatomical area- Oncology imaging - Attenuation correction/localisation	<3	<20
Lower limb (knees and femur) - Orthopaedic or infection - Attenuation correction/localisation	<3	<20
Ankles and feet - Possible bone metastasis - Attenuation correction/localisation	<3	<20
Whole spine - Possible bone metastasis - Attenuation correction/localisation	<3	<20

Table 8 Annual procedure numbers for adult PET imaging

Radionuclide	Pharmaceutical	Procedure or clinical task	Route of Administration	Number of facilities	Annual number of procedures
18F	FDG	Whole body tumour imaging	IV	10	10463
18F	FDG	Brain tumour imaging	IV	4	882
68Ga	PMSA	Prostate cancer imaging	IV	<3	317
18F	PMSA	Prostate cancer imaging	IV	<3	301
68Ga	Donatate/Sonatoc/Dotanoc/ Dotatoc	Somatostatin receptor imaging	IV	<3	235
18F	FDG	Differential diagnosis of dementia	IV	6	198
68Ga	DOTA - peptide	Whole body tumour imaging	IV	<3	198
18F	FDG	Infection imaging	IV	<3	76
18F	FDG	Focal epilepsy	IV	<3	72
18F	FDG	Inflammation imaging	IV	<3	71

Table 9 Annual procedure numbers for adult CT hybrid imaging component of PET imaging

Procedure or clinical task	Number of facilities	Annual number of procedures
Whole body (eyes to thighs) - Attenuation correction/localisation	7	10285
Whole body (vertex to toes) - Attenuation correction/localisation	9	2224
Brain/head - Attenuation correction/localisation	7	430
Pelvic anatomical - Prostate imaging - Attenuation correction/localisation	<3	60
Thorax/chest anatomical - Cardiac imaging - Attenuation correction/localisation	<3	23

Table 10 Annual procedure numbers for paediatric nuclear medicine for planar and SPECT imaging

Radionuclide	Pharmaceutical	Procedure or clinical task	Route of Administration	Type of imaging (planar/ SPECT)	Number of facilities ***	Annual number of procedures ***
^{99m}Tc	Tc DMSA (III)	Renal imaging	IV	Planar imaging	10	480
^{99m}Tc	MAG3	Renogram scan/renal imaging/renography	IV	Planar imaging	6	152
^{99m}Tc	Phosphonates and phosphates	Bone imaging	IV	Planar imaging	8	138
^{99m}Tc	Phosphonates and phosphates	Bone imaging	IV	SPECT	5	79

^{123}I	MIBG	Tumour imaging	IV	Planar imaging	<3	45
^{99m}Tc	DMSA (III)	Renal imaging	IV	SPECT	4	43
^{123}I	MIBG	Tumour imaging	IV	SPECT	<3	36
^{99m}Tc	Pertechnetate	Thyroid scan imaging/uptake	IV	Planar imaging	<3	33
^{99m}Tc	Pertechnetate	Ectopic gastric mucosa imaging (Meckel's diverticulum)	IV	Planar imaging	7	31
^{99m}Tc	DTPA	Renogram scan/renal imaging renography	IV	Planar imaging	<3	<20
^{99m}Tc	Iminodiacetate	Functional biliary system imaging	IV	Planar imaging	<3	<20
^{99m}Tc	Colloid	Oesophageal/gastric/intestinal motility studies	Oral	Planar imaging	<3	<20
^{99m}Tc	Pertechnetate	Ectopic gastric mucosa imaging (Meckel's diverticulum)	IV	SPECT	<3	<20
^{99m}Tc	Sestamibi	Parathyroid MIBI	IV	Planar imaging	<3	<20
^{99m}Tc	Sestamibi	Parathyroid MIBI	IV	SPECT	<3	<20
^{99m}Tc	Nanocolloid	Sentinel node localisation and imaging	IV	Planar imaging	<3	<20
^{99m}Tc	Nanocolloid	Sentinel node localisation and imaging	IV	SPECT	<3	<20
^{99m}Tc	Macro-aggregated albumin (MAA)	VQ scan pulmonary embolism/lung perfusion imaging	IV	Planar imaging	<3	<20

^{123}I	Sodium iodide	Thyroid cancer imaging	Oral	Planar imaging	<3	<20

Table 11 Annual procedure numbers for paediatric CT hybrid imaging component of SPECT imaging

Procedure or clinical task	Number of facilities	Annual number of procedures
Lower limb - 30 to < 50kg - Orthopaedic or infection - Attenuation correction/localisation	<3	<20
Abdomen - 5 to < 15kg - Attenuation correction/localisation	<3	<20
Abdomen - 15 to < 30kg - Attenuation correction/localisation	<3	<20
Lower limb - 50 to < 80kg - Orthopaedic or infection - Attenuation correction/localisation	<3	<20

Table 12 Annual procedure numbers for paediatric PET imaging

Radionuclide	Pharmaceutical	Procedure or clinical task	Route of Administration	Number of facilities	Annual number of procedures
18F	FDG	Whole body tumour imaging	IV	<3	>20
18F	FDG	Brain tumour imaging	IV	<3	<20

Table 13 Annual procedure numbers for the paediatric CT hybrid imaging component for PET imaging

Procedure or clinical task	Number of facilities	Annual number of procedures
Whole body (eyes to thighs) - 30 to < 50kg - Attenuation correction/localisation	<3	<20
Whole body (eyes to thighs) - 50 to < 80kg - Attenuation correction/localisation	<3	<20
Whole body (vertex to toes) - 15 to < 30kg - Attenuation correction/localisation	<3	<20
Whole body (vertex to toes) - 50 to < 80kg - Attenuation correction/localisation	<3	<20
Whole body (vertex to toes) - 30 to < 50kg - Attenuation correction/localisation	<3	<20
Whole body (vertex to toes) - 5 to < 15kg - Attenuation correction/localisation	<3	<20
Whole body (eyes to thighs) - 15 to < 30kg - Attenuation correction/localisation	<3	<20
Brain/head - 30 to < 50kg - Attenuation correction/localisation	<3	<20

9 Version history

Publication date	Version	Summary of changes
November 2023	1.1	Typographical error in dose ranges updated in Tables 2 and 4.

Published by the Health Information and Quality Authority

info@hiqa.ie

George's Court, George's Lane
Dublin 7, D07 E98Y
(01) 814 7400