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Medical exposure to ionising radiation

National Diagnostic Reference Levels (DRLs) for Fluoroscopy and Fluoroscopically Guided Interventions

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 establishing and reviewing national diagnostic reference levels (DRLs) for medical procedures using ionising radiation. National DRL values are typical radiation dose levels set for common medical imaging procedures and clinical tasks. DRLs help support medical radiological installations (referred to as facilities in this report) to compare their local facility patient dose to a national standard, and allows facilities to use this as a benchmark to optimise patient radiation dose.

In November 2021, HIQA issued a DRL survey to 64 facilities in Ireland that provide either fluoroscopy or fluoroscopically guided interventions, or a combination of these services. Fluoroscopically guided intervention (FGI) describes minimally invasive diagnostic, therapeutic or biopsy procedures. For example, interventional radiology or cardiology procedures and where fluoroscopy* is used for surgical procedures in an operating theatre. As there is a regulatory requirement to provide such data to HIQA, 100% of facilities responded and this data was compiled and reviewed.

National DRLs are set as the 75th percentile of the distribution of median values obtained. A 75th percentile means that out of all values obtained 25% lie above this national DRL value and 75% of values are below this figure. A national median, or 50th percentile of median values was also established, where appropriate. This means that out of all values obtained, 50% of values will be above, and 50% will be below this figure. This new national data allows facilities to compare doses from a representative sample of service users to national DRL figures, identify medical radiological procedures that require review and put corrective actions in place where needed.

This work represents an extensive national DRL review, based on a census patient dose survey. Therefore, it should be used as a basis for all ongoing national patient dose reviews in fluoroscopy and FGI. When comparisons are made with previously established DRL values adopted by HIQA in 2020, all but one of the newly established DRLs are below that of the previously established figures.

The majority of medical radiological equipment used in Ireland to deliver the fluoroscopic and FGI service is relatively new and is less than five years old. This reflects that current technology and the use of newer equipment has the potential to improve quality and safety in medical imaging.

* Fluroscopy is a type of medical exposure that uses a continuous beam of ionising radiation to create a real time image on a monitor.

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 radiological installations, which will be referred to as facilities in this report, to compare local facility DRLs which represents patient dose, to a national standard.

1.1 Previous work on national DRLs in Ireland

In 2013, the Irish Health Service Executive (HSE) Medical Exposure Radiation Unit (MERU) published national DRLs for a range of standard medical radiological procedures across a range of imaging modalities.[2] These national DRLs were updated in 2017 [3] incorporating the results from the *National Survey on Population Dose from Computed Tomography 2017*. [4]

The 2017 survey also produced national DRLs for medical radiological procedures based on clinical tasks (clinical DRLs) for the first time in Ireland. The clinical indication or task is the reason for which 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 or service users.

DRLs have been traditionally based on anatomical areas, however the use of clinical tasks has been acknowledged as a more appropriate descriptor in the establishment of DRLs and is particularly applicable to computed tomography (CT) and fluoroscopy or fluoroscopically guided intervention (FGI).[5]

1.2 National DRLs established by HIQA

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 facilities on establishing local facility DRLs. The 2020 guidance documentation included national fluoroscopy and interventional radiology and interventional cardiology DRLs.

FGI describes minimally invasive diagnostic, therapeutic or biopsy procedures such as those performed in interventional radiology and interventional cardiology procedures and where fluoroscopy† is used for surgical procedures in an operating theatre. National

† Fluoroscopy a type of medical exposure that uses a continuous beam of ionising radiation to create a real time image on a monitor.

fluoroscopy and FGI DRLs were adopted following engagement with HIQA's Expert Advisory Group (EAG), which was in place in 2020 and which included representation from relevant professional bodies in radiation protection (see Appendix 1).

These national DRLs were developed based on the 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] and other published international literature.[10,11]

2. National review of DRLs by HIQA

The process of establishing national fluoroscopy and FGI DRLs is discussed in this section and involved an extensive literature review as well as stakeholder engagement to ensure that the number and type of procedures or clinical tasks surveyed was representative of routine procedures carried out by a wide range of radiology departments nationally.

2.1 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 key 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 following feedback from members of the EAG.

HIQA identified 64 facilities in the directory of undertakings[‡] that provide a fluoroscopy and or a FGI service. In November 2021, HIQA issued the DRL survey to these facilities and each facility had 35 days to complete and submit the survey on the online portal system. The survey was divided broadly into two sections (see Appendix 2) relating to the service provided namely:

- fluoroscopy and FGI
- cardiac fluoroscopy and FGI.

Facilities were asked to supply information on:

- the service(s) they provided
- their equipment details (where appropriate)
- their local facility radiation doses, which would be representative of the radiation dose given to service users and
- the frequency of the medical radiological procedures carried out at their facility.

‡ 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.

2.2 Equipment information

The survey also requested each facility to provide information on the number of mobile and fixed items of fluoroscopic equipment used within the service. For each category of fixed or mobile items of equipment, facilities were also asked to select from one of three equipment 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 equipment should be considered for upgrading or replacement.[12]

Information on the image receptor type of the equipment used to establish local facility DRLs was also sought. These were broadly categorised as digital flat panel detector or image intensifier.

2.3 Local facility DRLs and procedure numbers

Each facility were asked to supply local 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, 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*.[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 where appropriate. For facilities striving to further optimise patient doses, a national median patient dose has been provided as another quality metric.[13]

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

3. Results

The results section uses a combination of tables, figures and graphs to demonstrate findings from this survey. 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 fluoroscopy 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).

3.1 National fluoroscopy and FGI DRLs

The outcome of the survey established national DRLs for fluoroscopy and FGI, and are displayed in Table 1, 2 and 3. National median values are also presented, where appropriate, as these can be used by undertakings when considering further optimisation of dose.

Data presented in the following tables was collated based on the information provided by facilities that supplied local facility DRLs based on 20 or more service users for adult data and 10 or more service users for paediatric data.

Tables 1, 2 and 3 include a column with the number of facilities (n) that had sufficient numbers of a particular procedure or clinical task to establish local facility DRLs. Where the number of facilities is low, it can be assumed that the associated procedure or clinical task is not commonly performed across a large number of facilities nationally and the data provided may represent practice at a smaller number of specialised facilities.

Facilities should note that a national DRL or median value was only established when five or more facilities carried out a procedure or clinical task. Where less than five facilities carried out a procedure or clinical task, this was insufficient for an informative median. In these cases, a national range has been provided to offer facilities a context for patient dose.

Table 1. Fluoroscopy and FGI national adult DRLs and national median doses

Procedure/Clinical task	National DRL (Gy.cm²)	National Median Dose (Gy.cm²)	National Dose Range (Gy.cm²)	Number of facilities (n)∞
Vascular				
Aortic endovascular aneurysm repair (EVAR)	**103**	84.4	51.6 – 272	9
Central line/central venous catheter (CVC) insertion excluding peripherally inserted central venous catheter (PICC)	**1**	0.4	0.1 – 1.8	17
Inferior vena cava (IVC) filter insertion/retrieval	**11.3**	7.4	3.6 – 20.1	8
Lumbar puncture under fluoroscopy	**3.1**	2.4	0.2 – 18.5	10
Peripherally inserted central venous catheter (PICC)	**0.8**	0.4	0.1 – 1.8	23
Transcatheter arterial chemoembolisation (TACE)	**127**	106	47.2 – 137.6	5
Gastrointestinal (GI)				
Barium (or water soluble) enema	**10.5**	8.3	4.6 – 14.6	10
Barium (or water soluble) meal + swallow	**10.6**	8.1	1.5 – 24.6	9
Barium (or water soluble) swallow	**5.8**	3.7	0.4 – 28.5	26
Barium swallow (video)/speech and language therapy (SLT) investigation	**2.4**	1.4	0.2 – 3.9	23
Endoscopic retrograde cholangiopancreatography (ERCP)	**3**	2	0.4 – 6.1	13
Percutaneous transhepatic biliary drainage	**11.5**	8.1	4.5 – 14.4	6
Urology				
Micturating or voiding cystourethrography (MCU/VCU)	#	#	2.6 – 4.6	3
Nephrostomy – bilateral	**5.6**	2.3	1.6 – 7.5	5

Nephrostomy – unilateral	**2.9**	1.6	0.6 – 3.7	11
Nephrostography – unilateral	**1.9**	1	0.3 – 6.2	14
Nephrostography + Ureteric stent insertion - unilateral	**4.5**	3.2	0.6 – 8.6	11
Gynaecological				
Hysterosalpingography (HSG)	**1.4**	0.8	0.1 – 3	15
Musculosketal				
Arthrography – extremity injection	**0.2**	0.07	0.01 – 1	19
Arthrography – pelvic injection	**0.3**	0.3	0.03 – 0.5	20
Arthrography – spinal injection	**1**	0.6	0.02-3.8	30
Intramedullary (IM) nail - femur	**1.9**	1.5	0.1 – 2.8	8
Intramedullary (IM) nail - tibia	**#**	**#**	0.3 – 0.9	4
Orthopaedic – extremity excluding Intramedullary (IM) nail	**0.1**	0.04	0.01 – 1	23
Orthopaedic – pelvis	**1.9**	1.1	0.4 – 3.6	11
Orthopaedic – spinal	**1.2**	0.5	0.08 – 1.7	10
Vertebroplasty	**#**	**#**	7.9 – 85.9	3

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

A national DRL or median value was only produced for procedures routinely carried out by five or more facilities.

Table 2. Cardiac fluoroscopy and cardiac FGI national adult DRLs and national median doses

Procedure/Clinical task	National DRL (Gy.cm²)	National Median Dose (Gy.cm²)	National Dose Range (Gy.cm²)	No. of facilities (n)∞
Coronary Arteries				
Angiography coronary arteries	26	19.2	8.7 – 38	21
Angiography coronary arteries (CA) + Grafts	39.2	32.9	18 – 74	12
Angiography coronary arteries (CA) + percutaneous coronary intervention (PCI) – single vessel	50.2	41.4	29 – 82	11
Angiography coronary arteries (CA) + percutaneous coronary intervention (PCI) – multi vessel	68.3	57.3	43.8 – 143	7
Percutaneous coronary intervention – chronic total occlusion (CTO)	#	#	47.9 – 254	4
Percutaneous coronary intervention (PCI) – multiple vessels	96.5	72.2	40.6 – 128	8
Percutaneous coronary intervention (PCI) –single vessel	51.9	34.9	16 – 76.5	18
Pacemaker Devices				
Implantable cardioverter defibrillator (ICD) insertion – dual chamber	6.3	1.9	0.5 – 15	6
Implantable cardioverter defibrillator (ICD) insertion – single chamber	1.3	1.1	0.7 – 1.8	5
Pacemaker insertion – cardiac resynchronization therapy pacemaker (CRT)	#	#	1.5 – 18	4
Pacemaker insertion – dual chamber	4	2	1 – 7.5	15
Pacemaker insertion – single chamber	3.3	2	0.7 – 5.7	13
Cardiac Pressure Studies				
Angiography coronary arteries (CA) + right + left heart catheterisation	#	#	19.2 – 26.4	3
Right heart study	4.2	3	1.3 – 9.1	8

Structural and Cardiac Valves				
Transcatheter aortic valve implantation (TAVI)	89.7	78.4	51.1 – 120	7
Cardiac Ablation (+/- Electrophysiological (EP) Study)				
Cardiac ablation +/- electrophysiological (EP) study - atrial flutter	6.7	5.5	2 – 9.8	6
Cardiac ablation +/- electrophysiological (EP) study – atrial fibrillations	7	5	2 – 7	5
Cardiac ablation +/- electrophysiological (EP) study – atrioventricular re-entrant tachycardia (AVRT)	#	#	2.1 – 7	4
Cardiac ablation +/- electrophysiological (EP) study – Ventricular tachycardia (VT)	#	#	3.9 – 7.9	4
Cardiac ablation +/- electrophysiological (EP) study- Premature ventricular contractions (PVC)	7	5.6	3 – 13	5

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

A national DRL or median value was only produced for procedures routinely carried out by five or more facilities.

Table 3. Fluoroscopy and FGI national paediatric DRLs and national median doses

Procedure/Clinical task	Weight categories	New National DRL (mGy.cm²)	National Median Dose (mGy.cm²)	National Dose Range (mGy.cm²)	No. of facilities (n)**
Paediatric gastro-intestinal (GI) tract – upper GI investigations	<5kg	#	#	45.8 – 389	4
	5-<15kg	177.4	173	80 – 218	5
	15-<30kg	#	#	114.4 – 630	4
	30-<50kg	#	#	255 – 623	3
Paediatric micturating or voiding cystourethrography (MCU/VCU)	5-<15kg	207	98.6	31 – 255	6

** The (n) column indicates the number of facilities that supplied local facility DRLs based on 10 or more service users.

A national DRL or median value was only produced for procedures routinely carried out by five or more facilities.

3.2 Fluoroscopy and FGI procedure numbers

This national DRL review also gathered information on procedure frequency from facilities providing fluoroscopy and FGI services nationally. Annual procedure numbers for fluoroscopy and FGI provided by all services were collated and are displayed in tables 4, 5 and 6.

Not all procedures listed in the annual procedure number tables (Tables 4, 5 and 6) have an associated national DRL established. This is because all facilities were required to give data on procedure numbers. However, for procedures that are rarely performed, local facility DRL values could not be established or were based on insufficient data points for inclusion in the generation of national DRL values.

Table 4. Adult fluoroscopy and FGI annual procedure number

Fluoroscopy and fluoroscopically guided interventions	Annual Procedure Numbers
Arthrography - spinal injection	18177
Orthopaedic – extremity excluding intramedullary (IM) nail	10968
Peripherally inserted central venous catheter (PICC)	7208
Barium (or water soluble) swallow	4164
Arthrography - extremity injection	3649
Arthrography - pelvic injection	3304
Endoscopic retrograde cholangiopancreatography (ERCP)	3065
Orthopaedic - spinal	3028
Barium swallow (video)/speech and language therapy (SLT) investigation	2931
Central line/central venous catheter (CVC) insertion excluding peripherally inserted central venous catheter (PICC)	2367
Barium (or water soluble) meal + swallow	1643
Hysterosalpingography (HSG)	1515
Orthopaedic - pelvis	1451
Nephrostography - unilateral	1417
Angiogram cerebral arteries	1310
Orthopaedic - intramedullary (IM) nail - femur	960
Nephrostomy - unilateral	908
Nephrostography + Ureteric stent insertion - unilateral	706
Angiogram femoropopliteal artery - unilateral	524

Lumbar puncture under fluoroscopy	517
Barium (or water soluble) enema	464
Cerebral artery embolisation	376
Cerebral mechanical thrombectomy	370
Aortic endovascular aneurysm repair (EVAR)	353
Orthopaedic IM nail humerus	352
ERCP + drain replacement	330
Inferior vena cava (IVC) filter insertion/retrieval	328
Uterine fibroid embolisation (UFE)	290
Percutaneous transhepatic biliary drainage	276
Femoropopliteal artery stenting	220
Femoropopliteal angiogram + stenting	210
Micturating or voiding cystourethrography (MCU/VCU)	199
Angiogram Iliac arteries + stenting	183
Transcatheter arterial chemoembolisation (TACE) liver	180
Orthopaedic IM nail - tibia	178
Nephrostomy - bilateral	172
Nephrostography - bilateral	124
Barium (or water soluble) meal	114
Nephrostography + ureteric stent insertion - bilateral	114
Vertebroplasty	107
Oesophageal stenting	102
Carotid artery stenting	76
Barium (or water soluble) follow through	70
Angiogram carotid arteries	61
Iliac artery stenting	53
Angiogram Iliac arteries	52
Angiogram femoropopliteal artery - bilateral	50
Angiogram mesenteric arteries + embolisation	41
Angiogram renal artery + embolisation	31

Pelvic artery embolization	30
Transjugular intrahepatic portosystemic shunt (TIPS)	27
Angiogram renal artery	26
Angiogram mesenteric arteries	26
Thoracic aortic endovascular aneurysm repair (TEVAR)	25
Angiogram cerebral arteries + embolisation	21
Angiogram bronchial arteries	< 20
Angiogram carotid arteries + stenting	< 20
Angiogram + embolisation - bronchial arteries	< 20
Renal artery embolisation	< 20
Fallopian tube recanalisation	< 20
Total	**75484**

Table 5. Adult cardiac fluoroscopy and cardiac FGI annual procedure numbers

Procedure/Clinical task	**Annual Procedure Numbers**
Angiography coronary arteries (CA)	28570
Percutaneous coronary intervention (PCI) – single vessel	2870
Percutaneous coronary intervention (PCI) – multiple vessels	1934
Angiography coronary arteries (CA) + percutaneous coronary intervention (PCI) – multi vessel	1927
Angiography coronary arteries (CA) + Grafts	1585
Pacemaker insertion – dual chamber	1530
Angiography coronary arteries (CA) + percutaneous coronary intervention (PCI) – single vessel	1209
Pacemaker insertion – single chamber	1126
Right heart study	922
Transcatheter aortic valve implantation (TAVI)	507
Cardiac ablation +/- electrophysiological (EP) study- premature ventricular contractions (PVC)	465
Cardiac ablation +/- electrophysiological (EP) study - atrial flutter	404
Implantable cardioverter defibrillator (ICD) insertion – dual chamber	378
Cardiac ablation +/- electrophysiological (EP) study – atrioventricular re-entrant tachycardia (AVRT)	374
Cardiac ablation +/- electrophysiological (EP) study – ventricular tachycardia (VT)	360

Cardiac ablation +/- electrophysiological (EP) study – atrial tachycardia (AT)	345
Implantable cardioverter defibrillator (ICD) insertion – single chamber	326
Cardiac ablation +/- electrophysiological (EP) study – atrial fibrillations de novo	273
Pacemaker insertion – cardiac resynchronization therapy pacemaker (CRT)	261
Percutaneous coronary intervention – chronic total occlusion (CTO)	260
Cardiac ablation +/- electrophysiological (EP) study – Supraventricular tachycardia (SVT)	247
Angiography coronary arteries (CA) + right + left heart catheterisation	100
Right + left heart catheterisation	95
Cardiac ablation +/- electrophysiological (EP) study – atrial fibrillations – redo	41
Electrophysiological (EP) study – premature ventricular contractions (PVC)	34
Cardiac ablation +/- electrophysiological (EP) study – ventricular tachycardia (VT) substrate modification	< 20
Endomyocardial cardiac biopsy ± right heart catheterisation	< 20
Transcatheter mitral valve implantation	< 20
Total	**46172**

Table 6. Paediatric fluoroscopy and FGI annual procedure numbers

Procedure/Clinical task	**Annual Procedure Numbers**
Gastro-intestinal (GI) tract - upper GI examinations	1306
Urinary Tract - MCU/VCU	1037
GI tract contrast enema	309
GI intervention	192
Diagnostic cardiac catheterisation right + left heart	149
Peripherally inserted central venous catheter (PICC) line	127
Patent ductus arteriosus (PDA) Closure	71
EP + Ablation	49
Atrial septal defect (ASD) closure	35
Nasogastric (NG)/nasojejunal (NJ) tube placement	24
Ventricular septal defect (VSD) closure	<20
Pulmonary valve dilation	<20
Total	**3333**

Comparison with previous years procedure number data can give insight into the increased or decreased use of particular imaging procedures and interventions nationally. However, based on the information available, this comparison is limited to three procedures in this instance.

In 2008, the Radiological Protection Institute of Ireland (RPII) published a report titled *Radiation Doses Received by the Irish Population* [14] which estimated the number of procedures carried out in Ireland in 2005 and included the Barium Enema, Angiocardiography and Percutaneous Transluminal Coronary Angioplasty (PTCA) procedures. Table 7 compares the estimated annual procedure numbers in 2005 to actual procedure numbers obtained in Ireland in 2021 and shows a decrease in the use of barium enema procedures, a decrease in the use of the percutaneous coronary intervention and an increase in the use of the angiography of the coronary arteries.

Table 7. Annual procedure number comparison

Procedure/Clinical task	Annual Procedure Numbers 2005[14]	Annual Procedure Numbers 2021
Barium enema	5800	484
Angiography coronary arteries	24000	28570
Percutaneous coronary intervention (PCI)	13900	7940

When considered by broad categorisations of paediatric, adult cardiac and adult fluoroscopy and FGI, adult fluoroscopy and FGI accounted for the largest contribution at 60% (n=75484) of the total annual procedure numbers. Paediatric fluoroscopy and FGI, accounted for 3% (n=3333) of the total annual fluoroscopy and FGI carried out in Ireland (Figure 1).

Just over half (52%) of all annual fluoroscopy and FGI carried out were angiography of the coronary arteries, spinal injections, orthopaedic extremity procedures and PICC line insertions. Angiography of the coronary arteries was the most commonly performed fluoroscopy and FGI, accounting for 23% (n=28570) of all fluoroscopy and FGI annually.

Figure 1. Percentage contribution of paediatric, adult cardiac and adult fluoroscopy and FGI to total annual procedure numbers.

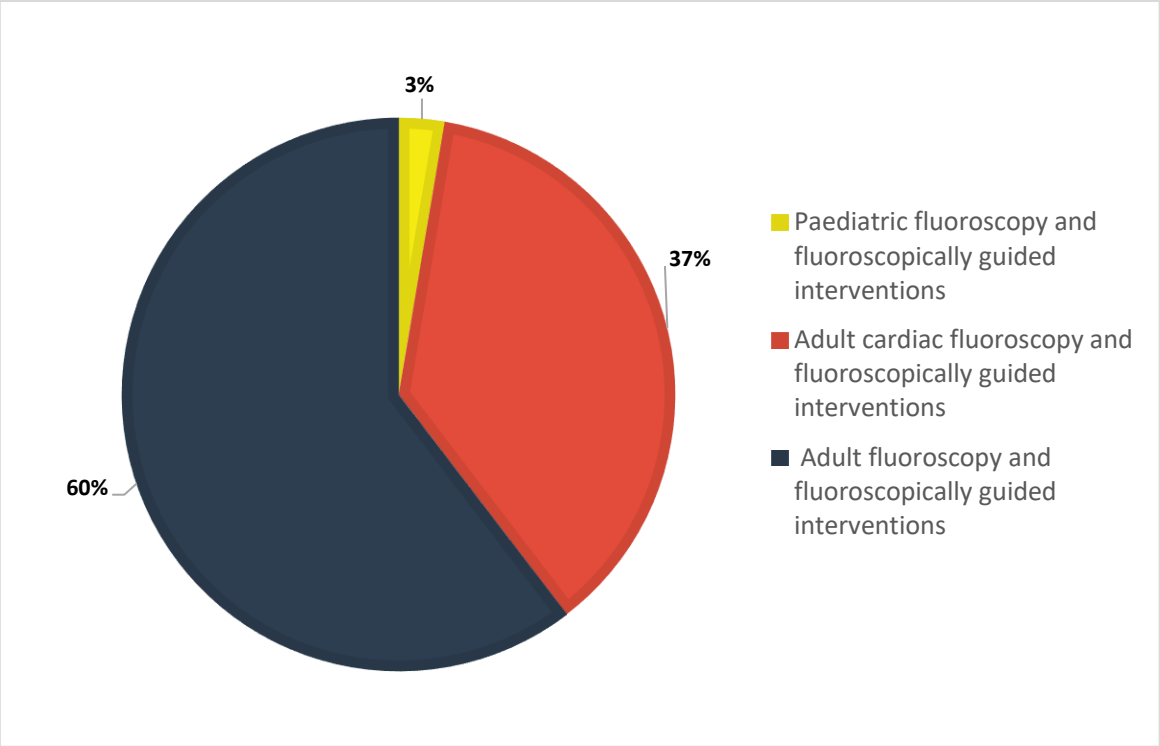
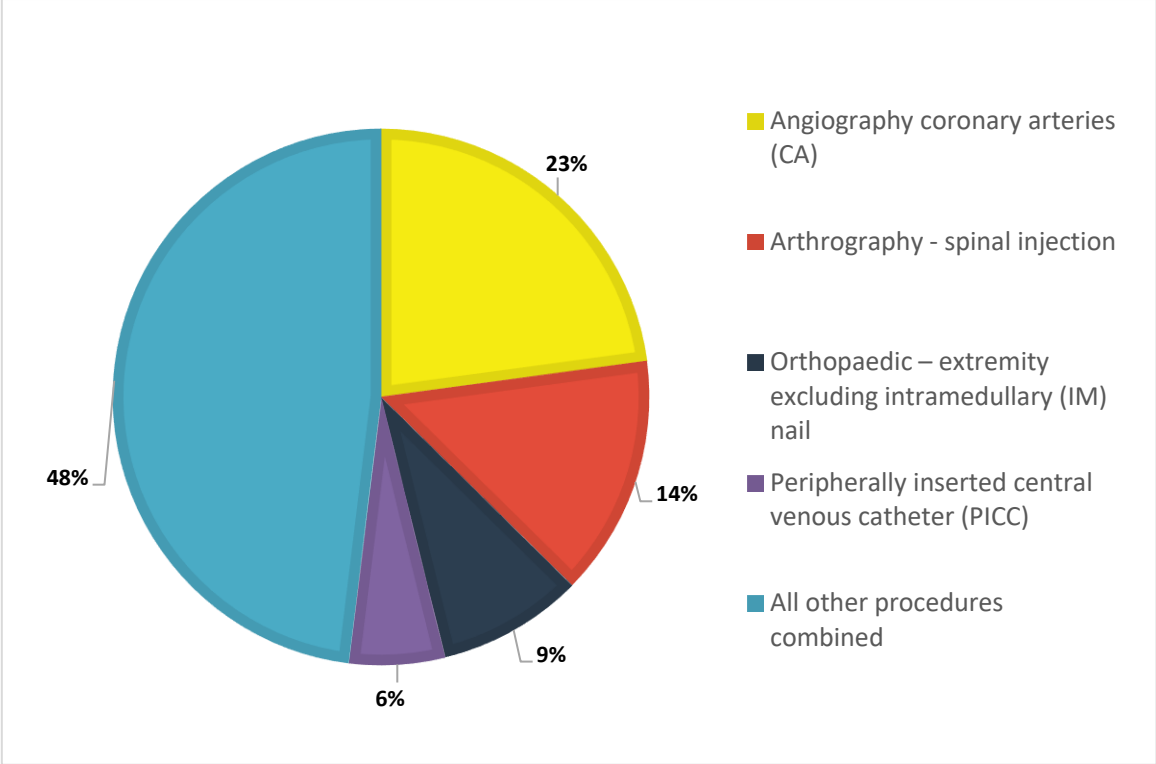


Figure 2. Commonly performed fluoroscopy and FGI procedures.

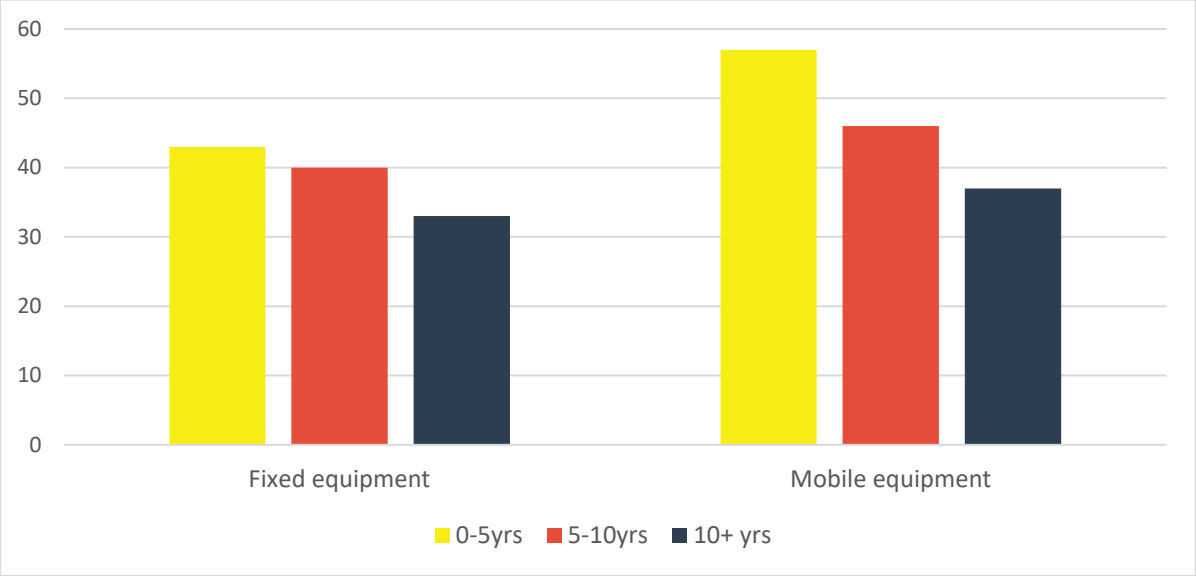


3.3 Equipment type and age

In Ireland, fluoroscopy and FGI services are supplied by a total of 256 pieces of fluoroscopic equipment. Facilities surveyed indicated that 116 (45%) of these pieces of equipment were fixed and 140 were mobile equipment.

The age profile is similar across fixed and mobile equipment with 39% (n=100) of both fixed and mobile equipment being 0-5years old, 34% (n=86) being 6-10 years old and 27% (n=70) being more than 10 years old (Figure 3).

Figure 3. National fluoroscopic equipment age profile



3.4 Image receptor used to establish local facility DRLs

Each facility was asked to indicate the image receptor type used to establish local facility DRLs. The categories available to choose from were digital flat panel detector§, image intensifier detector** or a combination of both. The results of the equipment image receptor type used by facilities for each procedure and clinical task is displayed in Figure 4.

Most facilities used digital flat panel detector technology to establish local facility DRL data. The following procedures local facility DRLs were also established using only digital flat panel technology; TACE (n=5); percutaneous transhepatic biliary drainages (n=6); nephrostomy – bilateral (n=5). For paediatric fluoroscopy and FGI,

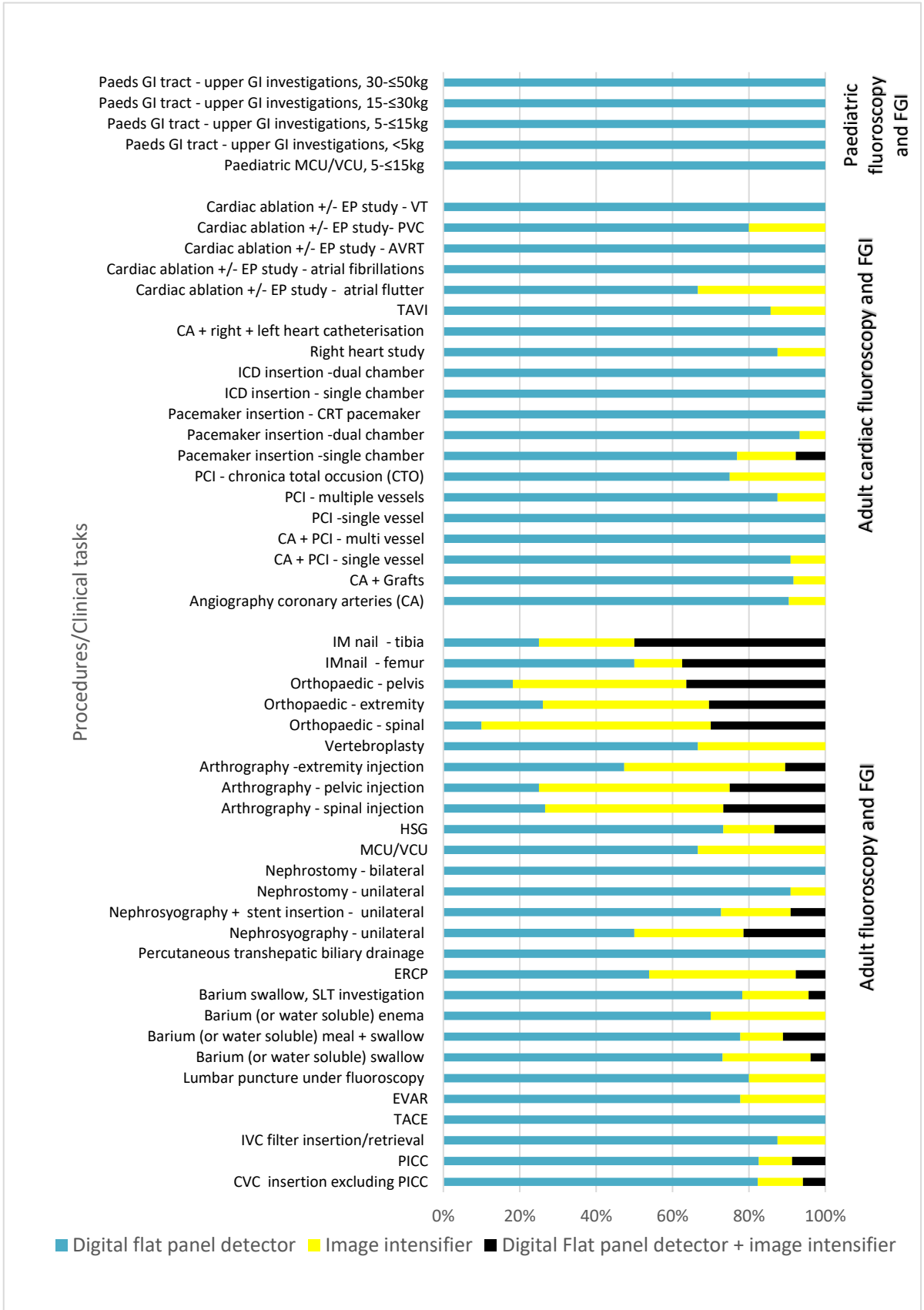
§ Digital flat panel detector fluoroscopy systems produce a digital electronic signal representing the pattern of x-ray radiation transmitted through the patient.
** Image intensifier detectors employ a very large vacuum tube that captures the pattern of x-ray radiation transmitted through the patient and converts it into an image.

facilities only use digital flat panel detector technology (n=5) when establishing local facility DRLs.

Cardiac services predominantly rely on digital flat panel detector technology to establish local facility DRLs with nine out of 20 (45%) of cardiac fluroscopy and FGIs using only digital flat panel detector technology. Additionally, this study found that 17 of 20 (85%) cardiac local facility DRLs were established using digital flat panel detector technology. A similar pattern was seen across many adult gastrointestinal investigations, urology procedures, line insertions and other abdominal FGI such as EVAR (78%, n=7), HSG (73%, n=11), PICC (83%, n=19) and IVC filter insertions (88%, n=7).

Image intensifier technology or a combination of both image intensifier technology and digital flat panel detector was used more frequently when establishing local facility DRLs for orthopaedic, arthrography and joint injections procedures, such as orthopaedic – extremity (80%, n=17), as well as ERCP procedures (46%, n=6).

Figure 4. Equipment image receptor type used to establish local facility DRLs



3.5 National and international DRL comparisons

Where possible, previously established national DRLs[6] for adult fluoroscopy and FGI procedures were compared with the current survey and displayed in Figure 5 and 6. This data is differentiated by patient dose for ease of display. Paediatric data was comparable for a single procedure and is displayed in Figure 7.

The national DRLs published by HIQA in February 2020 were developed based on the diagnostic medical radiological procedures, or clinical tasks, included in the 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] and other published international literature.[10,11]

In Figures 5, 6 and 7 comparisons are made between HIQA's 2020 and 2021, UK national national DRL values,[15] Australian national DRL values,**Error! Reference source not found.** French national DRL values[17]**Error! Reference source not found.** and German national DRL values.[18] Figure 7 is a comparison between HIQA's national DRL 2021, European DRL values[8] and German national DRL values for paediatric micturating or voiding cystourethrography (MCU/VCU). While the German national DRL figures have a different weight categorisation and may not provide a direct comparison, they are included to provide international context.

Figure 5. DRL comparison of adult national DRLs

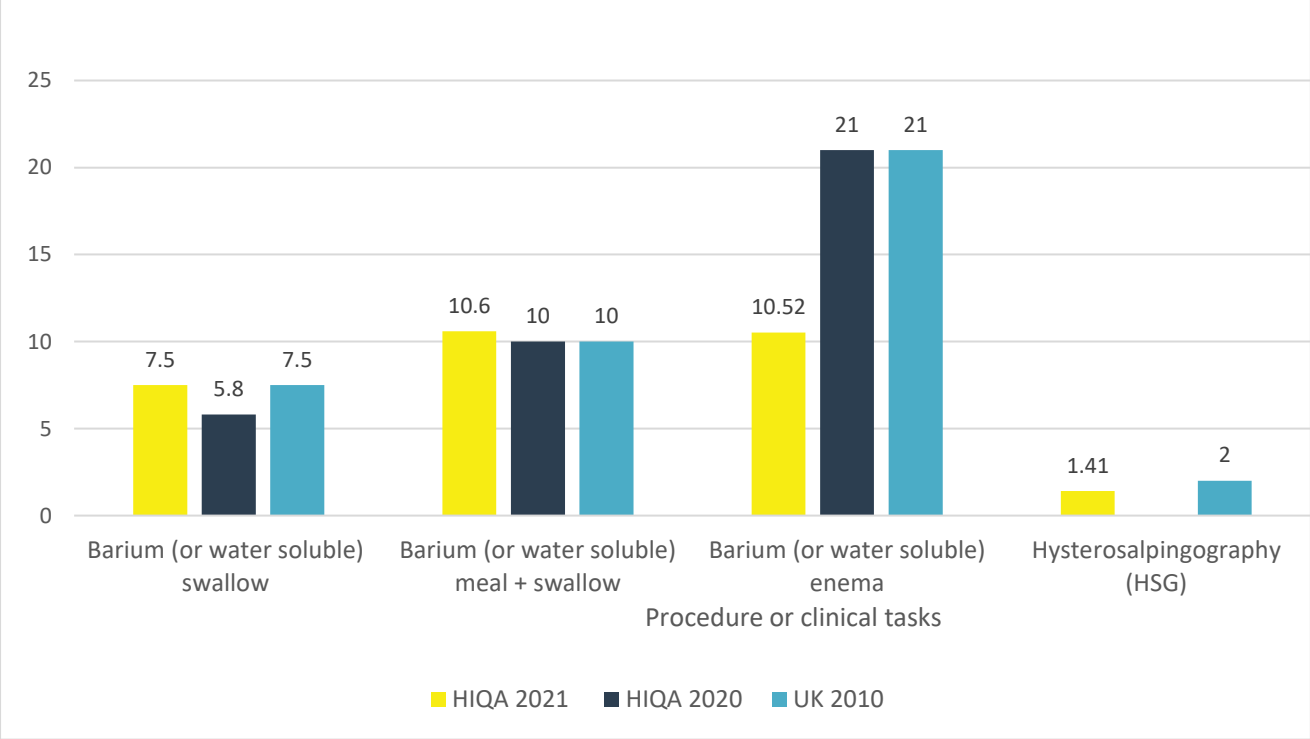


Figure 6. DRL comparison of cardiac adult national DRLs

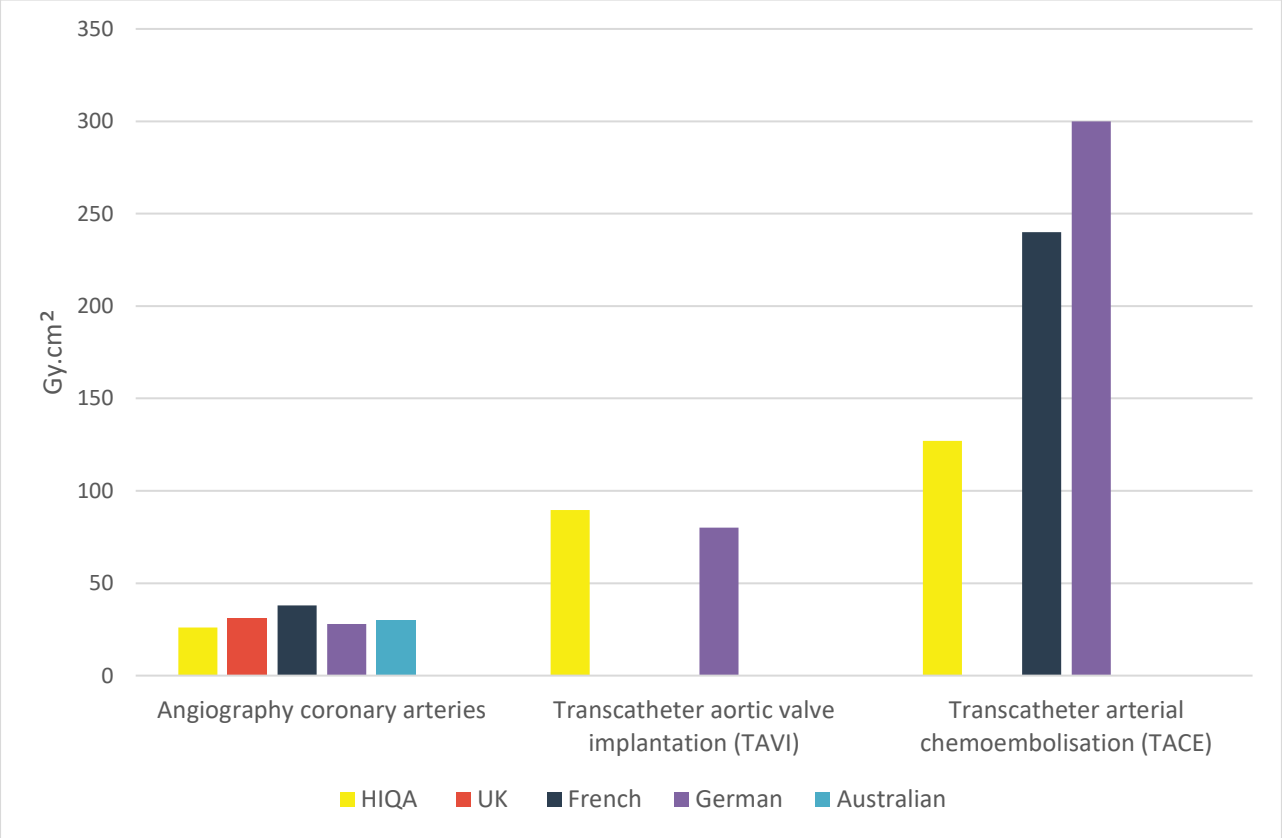
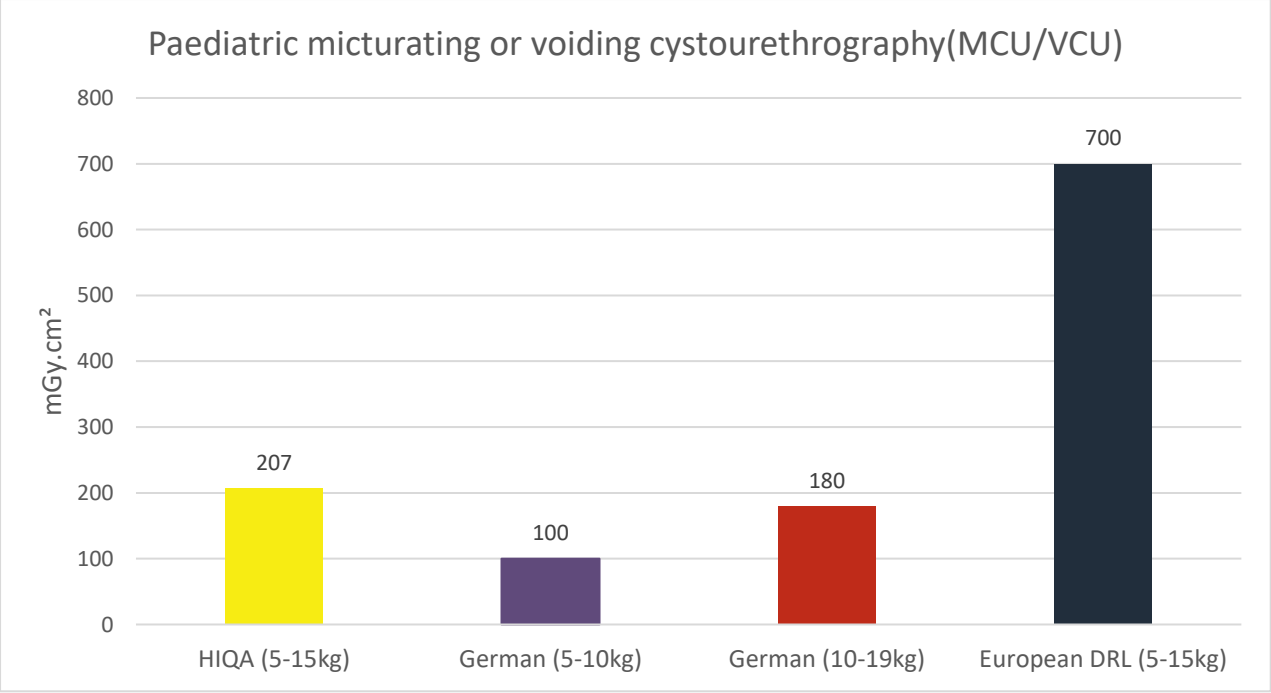


Figure 7. DRL comparison with previously established paediatric national DRL



4. Discussion

This national DRL review satisfies HIQA's regulatory responsibility for the establishment and review of national DRLs for medical procedures using radiation. It also provides undertakings, facilities and service users with important information on representative service user doses which can be used to help keep these doses as low as reasonably achievable nationally.

4.1 Survey response rate

The DRL survey was issued to 64 facilities that provide either a fluoroscopy or FGI service or a combination of these services. All facilities returned a DRL survey which resulted in a response rate of 100%. This response rate resulted in a robust dataset from which HIQA determined representative national DRL values and 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

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 2 and Table 3 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 further promote the optimisation process on a national basis.[13]

While a meaningful comparison to previously established national data is somewhat difficult as previous national DRLs were limited[3] and the national DRLs established by HIQA drew from internationally available DRLs[7,8,9] and peer reviewed literature [10,11] this work represents an extensive national DRL review, based on census patient dose data and therefore should be used as a basis for all ongoing national patient dose reviews in fluoroscopy and FGI.

When comparisons are made with previously established DRL values adopted by HIQA in 2020,[6] all but one of newly established DRLs are below that of previously established figures. The DRL for the barium (or water soluble) meal plus swallow is slightly above that of the previously established figure, and in this case the newly established figure should be the preferred metric for national comparison as it is based on recently established, nationally representative data.

4.3 Equipment age profiles

In this survey, most of the equipment used in Ireland to deliver the fluoroscopic and FGI service was categorised as zero to five years old as displayed in Figure 3. This is

a positive finding as the European Society of Radiology (ESR) states that equipment up to five years old reflects the current stage of technology and the use of such equipment will improve quality and safety in medical imaging. [12]

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. Undertakings may consider best practice guidance such as that produced by the ESR[12] when determining the need for equipment upgrade and prioritising certain equipment for upgrade and replacement. 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.[12] It is important to note that it is not a current regulatory requirement to replace equipment based on age.

4.4 Equipment technology analysis

Most facilities used digital flat panel detector technology to establish local facility DRL data. It is broadly acknowledged that flat panel detector systems have increasingly replaced image intensifier systems in cardiac and angiographic procedures. [19,20,21] Digital flat panel detector systems have been shown to have the capability to reduce patient dose when dose optimisation strategies are maintained and reinforced. [22,23,24]

This survey detailed that facilities use only digital flat panel detector technology in paediatric fluoroscopy and FGI when establishing local facility DRLs. Cardiac services predominantly rely on digital flat panel detector technology to establish local facility DRLS and a similar pattern was seen across many adult gastrointestinal investigations, urology procedures, line insertions and other abdominal FGI. A similar pattern was seen across many adult gastrointestinal investigations, urology procedures, line insertions and other abdominal FGIs such as EVAR, TACE, HSG, IVC filter insertions and percutaneous transhepatic biliary drainages.

In contrast, image intensifier technology or a combination of both image intensifier technology and digital flat panel detector were relied upon more frequently in establishing local facility DRLs for orthopaedic procedures, arthrography and joint injections as well as ERCP procedures.

4.5 Annual procedure numbers

Nationally, previous work on population dose published in 2014, which considers both procedure frequency and average dose did not publish procedure numbers for

fluoroscopy and FGI. [25] The Radiological Protection Institute of Ireland (RPII) published a report [14] which estimated the number of procedures carried out in Ireland in 2005 and included the Barium Enema, Angiocardiography and Percutaneous Transluminal Coronary Angioplasty (PTCA) annual procedure numbers. This report published estimated procedure frequencies and when compared to actual 2021 data, a marked decrease in the use of the Barium Enema procedure is noted. Also of note is a smaller increase in the use of coronary angiography and a decrease in the use of percutaneous coronary interventions (PCI). However, annual procedure frequency data comparisons should acknowledge changes in intervening practice and methodology between the two surveys.

Therefore, there is no definitive baseline for annual procedure numbers in fluoroscopy and FGI nationally and this work represents the establishment of this data. Annually there are over 120,000 adult fluoroscopy and FGI completed in Ireland each year. Paediatric procedure numbers are considerably less at just over 3,300. Given the increased radiosensitivity of this population[26] this is seen as a positive finding.

The most common procedures nationally are;

1. adult angiogram of the coronary arteries,
2. arthrography - spinal injection,
3. orthopaedic extremity (excluding intramedullary nail),
4. peripherally inserted central venous catheter (PICC).

These four procedures account for more than half of all fluoroscopy and FGI completed annually.

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 are used as a benchmark to optimise patient radiation dose, while maintaining the required diagnostic information. 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 fluoroscopy and FGI imaging, also referred to as interventional radiology. 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.

This survey has produced a large range of procedures and clinical tasks not previously established nationally. 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 were compared to those adopted by HIQA in 2020, large dose reductions were noted across the vast majority of procedures and clinical tasks, where comparisons could be made.

The age of equipment used to supply this service nationally was found to be predominantly newer equipment which was less than 5 years old. This has important safety implications for service users as this equipment is considered relatively new and is often associated with advanced technology and potential dose reducing features.

The frequency data obtained has also established annual procedure numbers for many previously unavailable fluoroscopy and FGI procedures. Procedure numbers in the field of paediatric fluoroscopy and FGI were found to be very low when compared to that in the adult population. As this service can be associated with potentially high patient doses and the paediatric population is particularly sensitive to the risks of exposure to ionising radiation, this was seen as a positive finding.

In light of this new set of national DRLs in fluoroscopy and FGI, undertakings should continue to review DRLs having regard to this updated and extensive national DRL procedure and clinical task list. To drive further improvements, undertakings can also compare local facility DRLs with the national median (50^{th} percentile) doses produced in this report to further optimise patient doses.

In the coming years, HIQA will continue to establish national DRLs in other areas of imaging and treatment including nuclear medicine. 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 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 undertakings. 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 fluoroscopy and FGI in Ireland.

6. Glossary

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

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.

Digital flat panel detector: Digital flat panel detector fluoroscopy systems produce a digital electronic signal representing the pattern of x-ray radiation transmitted through the patient.

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.

Fluoroscopically guided intervention (FGI): procedures that use fluoroscopy equipment to obtain real-time imaging to help introduce and guide devices and equipment used for diagnostic or treatment purposes.

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

Image intensifier: A very large vacuum tube that captures the pattern of x-ray radiation transmitted through the patient and converts it into a light image of sufficient brightness to be seen on the television camera.

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.

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 (facilities) 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.

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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[††] If not already cited, all online references were accessed at the time of preparing this handbook. Please note that online addresses may change over time.

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Appendix 1 – Membership of Expert Advisory Group in place in 2020

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 2 – Sample DRL survey template

Section A. Undertaking details	
Undertaking **name**	
Undertaking **address**	
Undertaking **email address**	
Undertaking **contact number**	
Medical radiological **installation ID** (OSV number)	
Medical radiological **installation name**	
Designated manager **name**	
Designated manager **email address**	
Designated manager **contact number**	

A1. Information on services provided						
Please select **Yes** for the services that you provide and **No** for the services that you do not provide and complete the sections as outlined. Note, if you provide multiple services please complete the multiple relevant sections.						
1.	Do you provide a **Fluoroscopy or Fluoroscopically Guided Intervention** service for **adults?**	Yes		No		If yes, complete section B1 and the appropriate procedures/clinical tasks in section B2
2.	Do you provide a **Fluoroscopy or Fluoroscopically Guided Intervention** service for **paediatrics?**	Yes		No		If yes, complete section B1 and the appropriate procedures/clinical tasks in section B3
4.	Do you provide a **Cardiac Fluoroscopy or Fluoroscopically Guided Cardiac Intervention** service for **adults?**	Yes		No		If yes, complete section B1 and the appropriate procedures/clinical tasks in section B4
5.	Do you provide a **Cardiac Fluoroscopy or Fluoroscopically Guided Cardiac Intervention** service for **paediatrics?**	Yes		No		If yes, complete section B1 and the appropriate procedures/clinical tasks in section B5

Section B1. Fluoroscopy and Fluoroscopically Guided Interventions			
B1. Fluoroscopy and Fluoroscopically Guided Interventional procedure equipment details			
1.	Total no. of fixed Fluoroscopy units in the facility		
2.	Age profile of fixed Fluoroscopy equipment (select multiple options if relevant)	Age range (years)	No. of units
		0 – 5	
		6 – 10	
		10+	
3.	Total no. of mobile Fluoroscopy units in the facility		
4.	Age profile of mobile Fluoroscopy equipment (select multiple options if relevant)	Age range (years)	No. of units
		0 – 5	
		6 – 10	
		10+	

B2. Fluoroscopy and Fluoroscopically Guided Interventions - Adult						
	Procedure/Clinical task	National DRL	Local facility DRL (Gy.cm²)	Local facility DRL sample size (n)	Annual no. of procedures	Image receptor type used to establish DRL (Digital flat panel detector or image intensifier)
Vascular – Thorax and upper limbs						
	Angiogram bronchial arteries					
	Angiogram + embolisation bronchial arteries					
	Embolisation bronchial arteries					
	Central line/central venous catheter (CVC) insertion - excluding peripherally inserted central venous catheters (PICCs)	3 Gy.cm²				
	Peripherally inserted central venous catheter (PICC)	3 Gy.cm²				
	Thoracic aortic endovascular aneurysm repair (TEVAR)					
	Inferior vena cava (IVC) filter insertion/retrieval					
Vascular – Abdomen and liver						
	Transcatheter arterial chemoembolisation (TACE) liver	300 Gy.cm²				
	Transjugular intrahepatic portosystemic shunt (TIPS)	186 Gy.cm²				
	Aortic endovascular aneurysm repair (EVAR)	159 Gy.cm²				
	Angiogram renal artery					
	Angiogram renal artery + embolisation					
	Renal artery embolisation					
	Angiogram mesenteric arteries					
	Angiogram mesenteric arteries + embolisation					
	Mesenteric artery embolisation					
Vascular – Pelvis and lower limbs						
	Angiogram Iliac arteries					
	Angiogram Iliac arteries + stenting					
	Iliac artery stenting	170 Gy.cm²				
	Angiogram femoropopliteal artery - bilateral					
	Angiogram femoropopliteal artery - unilateral	56 Gy.cm²				
	Femoropopliteal angiogram + stenting					
	Femoropopliteal artery stenting					
	Uterine fibroid embolisation (UFE)					
	Pelvic artery embolization					
Neuroradiology						
	Angiogram cerebral arteries					

	Angiogram cerebral arteries + embolisation					
	Cerebral artery embolisation	62 Gy.cm²				
	Cerebral mechanical thrombectomy					
	Angiogram carotid arteries					
	Angiogram carotid arteries + stenting					
	Carotid artery stenting					
	Lumbar puncture under fluoroscopy					
Gastrointestinal (GI)						
	Barium (or water soluble) swallow	7.5 Gy.cm²				
	Barium (or water soluble) meal	12 Gy.cm²				
	Barium (or water soluble) meal + swallow	10 Gy.cm²				
	Barium (or water soluble) follow through	8.4 Gy.cm²				
	Barium (or water soluble) enema	21 Gy.cm²				
	Barium swallow (Video)/speech and language therapy investigation	3.4 Gy.cm²				
	Oesophageal stenting					
	Endoscopic retrograde cholangio-pancreatography (ERCP)					
	ERCP + drain placement					
	Percutaneous transhepatic biliary drainage					

Urology						
	Nephrostography - unilateral	9 Gy.cm²				
	Nephrostography + ureteric stent insertion - unilateral					
	Nephrostography - bilateral					
	Nephrostography + ureteric stent insertion - bilateral					
	Nephrostomy - unilateral	13 Gy.cm²				
	Nephrostomy - bilateral					
	Micturating or voiding cystourethrography (MCU/VCU)					
Gynaecological						
	Hysterosalpingography (HSG)					
	Fallopian tube recanalisation					
Musculoskeletal						
	Arthrography - spinal injection	6 Gy.cm²				
	Arthrography - pelvic injection					
	Arthrography - extremity injection					
	Vertebroplasty					
	Orthopaedic - spinal					

	Orthopaedic - upper and lower extremities excluding intramedullary (IM) nail procedures					
	Orthopaedic - pelvis					
	Orthopaedic - IM nail femur					
	Orthopaedic - IM nail tibia					
	Orthopaedic - IM nail humerus					

B3. Fluoroscopy and Fluoroscopically Guided Interventions - Paediatric

	Procedure/Clinical task		National DRL	Local facility DRL (mGy.cm²)	Local facility DRL sample size (n)	Annual no. of procedures	Image receptor type used to establish DRL (Digital flat panel detector or image intensifier)
	Urinary tract, micturating or voiding cystourethrography (MCU/VCU)	< 5 kg	300 mGy.cm²				
		5 to < 15 kg	700 mGy.cm²				
		15 to < 30 kg	800 mGy.cm²				
		30 to < 50 kg	750 mGy.cm²				
		50 to < 80 kg					
	Gastro-intestinal (GI) tract - upper GI examinations	< 5 kg					
		5 to < 15 kg					
		15 to < 30 kg					
		30 to < 50 kg					
		50 to < 80 kg					
	GI tract - contrast enema	< 5 kg					
		5 to < 15 kg					
		15 to < 30 kg					
		30 to < 50 kg					
		50 to < 80 kg					
	GI intervention	< 5 kg					
		5 to < 15 kg					
		15 to < 30 kg					
		30 to < 50 kg					
		50 to < 80 kg					
		< 5 kg					
	Nasogastric (NG)/ nasojejunal (NJ) tube placement	5 to < 15 kg					
		15 to < 30 kg					
		30 to < 50 kg					
		50 to < 80 kg					
	Endoscopic Retrograde Cholangio-Pancreatography (ERCP)	< 5 kg					
		5 to < 15 kg					
		15 to < 30 kg					
		30 to < 50 kg					
		50 to < 80 kg					
	Biliary or percutaneous transhepatic cholangiography	< 5 kg					
		5 to < 15 kg					
		15 to < 30 kg					
		30 to < 50 kg					
		50 to < 80 kg					
	Peripherally inserted central venous catheter (PICC) line	< 5 kg					
		5 to < 15 kg					
		15 to < 30 kg					
		30 to < 50 kg					
		50 to < 80 kg					
	Central line/central venous catheter (CVC) insertion - excluding PICCs	< 5 kg					
		5 to < 15 kg					
		15 to < 30 kg					
		30 to < 50 kg					
		50 to < 80 kg					

B4. Cardiac Fluoroscopy and Fluoroscopically Guided Cardiac Interventions - 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 (Digital flat panel detector or image intensifier)
Coronary Arteries						
	Angiography coronary arteries (CA)	55 $Gy.cm^2$				
	CA + angiography coronary artery grafts					
	CA + Percutaneous coronary intervention (PCI) – single vessel					
	CA + PCI – multivessel					
	PCI – single vessel	75 $Gy.cm^2$				
	PCI – multivessel					
	PCI – chronic total occlusion (CTO)	350 $Gy.cm^2$				
Pacemaker Devices						
	Pacemaker insertion – single chamber	12 $Gy.cm^2$				
	Pacemaker insertion – dual chamber					
	Pacemaker insertion – cardiac resynchronisation therapy pacemaker (CRT)					
	Implantable cardioverter defibrillator (ICD) insertion – single chamber					

	ICD insertion – dual chamber					
Cardiac Pressure Studies						
	Right heart study	12 Gy.cm²				
	Right + left heart catheterisation					
	Angiography coronary arteries (CA) + right + left heart catheterisation					
	Endomyocardial cardiac biopsy ± right heart catheterisation					
Structural and Cardiac Valves						
	Transcatheter aortic valve implantation (TAVI)	130 Gy.cm²				
	Transcatheter mitral valve implantation					
	Mitraclip percutaneous mitral valve repair					
	Transcatheter tricuspid valve repair					
	Transcatheter tricuspid valve replacement					
	Transcatheter pulmonary valve replacement					
	Mitral valvuloplasty					
	Aortic valvuloplasty					
	Pulmonic valvuloplasty					

Cardiac Electrophysiological (EP) Study (without ablation)						
	Supraventricular tachycardia (SVT)/atrial tachycardia (AT)/atrial flutter	12 Gy.cm²				
	Premature ventricular contractions (PVC)					
	Ventricular tachycardia (VT) substrate modification					
Cardiac Ablation (±EP Study)						
	Atrial Flutter					
	Atrial fibrillations – de novo					
	Atrial fibrillations – redo					
	Atrioventricular re-entrant tachycardia (AVRT)					
	Atrial tachycardia (AT)					
	Premature ventricular contractions (PVC)					
	Ventricular tachycardia (VT)					

B5. Cardiac Fluoroscopy and Fluoroscopically Guided Cardiac Interventions - Paediatric							
	Procedure/Clinical task		National DRL	Local facility DRL (mGy.cm²)	Local facility DRL sample size (n)	Annual no. of procedures	Image receptor type used to establish DRL (Digital flat panel detector or image intensifier)
	Patent ductus arteriosus (PDA) closure	< 5 kg					
		5 to < 15 kg					
		15 to < 30 kg					
		30 to < 50 kg					
		50 to < 80 kg					
	Atrial septal defect (ASD) closure	< 5 kg					
		5 to < 15 kg					
		15 to < 30 kg					
		30 to < 50 kg					
		50 to < 80 kg					
	Patent foramen ovale (PFO) closure	< 5 kg					
		5 to < 15 kg					
		15 to < 30 kg					
		30 to < 50 kg					
		50 to < 80 kg					
	Ventricular septal defect (VSD) closure	< 5 kg					
		5 to < 15 kg					
		15 to < 30 kg					
		30 to < 50 kg					
		50 to < 80 kg					
	Pulmonary valve dilation	< 5 kg					
		5 to < 15 kg					
		15 to < 30 kg					
		30 to < 50 kg					
		50 to < 80 kg					

	Procedure/Clinical task		National DRL	Local facility DRL (mGy.cm²)	Local facility DRL sample size (n)	Annual no. of procedures	Image receptor type used to establish DRL (Digital flat panel detector or image intensifier)
	Diagnostic cardiac catheterization right heart	< 5 kg					
		5 to < 15 kg					
		15 to < 30 kg					
		30 to < 50 kg					
		50 to < 80 kg					
	Diagnostic cardiac catheterization left heart	< 5 kg					
		5 to < 15 kg					
		15 to < 30 kg					
		30 to < 50 kg					
		50 to < 80 kg					
	Diagnostic cardiac catheterization right + left heart	< 5 kg					
		5 to < 15 kg					
		15 to < 30 kg					
		30 to < 50 kg					
		50 to < 80 kg					
	EP + Ablation	< 5 kg					
		5 to < 15 kg					
		15 to < 30 kg					
		30 to < 50 kg					
		50 to < 80 kg					

8. Version History

Publication Date	Version	Summary of Changes
October 2022	1.0	Original publication
November 2024	1.1	DRL quantity units in dose ranges updated in Table 3

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