ASNR Autorité de sûreté nucléaire et de radioprotection

EXPRI STUDY

EXPOSURE OF THE POPULATION TO IONISING RADIATION DUE TO DIAGNOSTIC MEDICAL IMAGING PROCEDURES

Procedures performed in France in 2022

The French Authority for Nuclear Safety and Radiation Protection (ASNR) is an independent administrative authority established by the French Law of May 21, 2024 on the organisation of nuclear safety and radiation protection governance to meet the challenge of revitalising the nuclear industry. On behalf of the State, ASNR is responsible for overseeing civil nuclear activities in France and its main missions include expertise, research, training, and informing the public.

Abstract

In accordance with its scope as defined by the Public Health Code, ASNR periodically analyses the exposure of the French population to ionising radiation from diagnostic medical imaging examinations. This report, so called ExPRI (Exposure of the Population to Ionising Radiation), has existed since 2003. Once every 5 years, it aims to establish data relating to the exposure of the French population to ionising radiation due to diagnostic medical imaging examinations (conventional, dental and diagnostic interventional radiology, CT scans and diagnostic nuclear medicine) and to analyse changes in this exposure.

This study focuses on exposures in 2022, and, for the first time, it was based on diagnostic imaging procedures extracted from the National Health Data Sample (ESND), which includes 2% of beneficiaries of the French national health insurance system and is representative of the French population.

The main data studied are the frequency of procedures and the contribution of each type of procedure to the average annual effective dose per caput.

Exposure of the French population to diagnostic imaging changed in 2022 compared with 2017: the overall annual frequency of procedures fell by around 8%, from 1,181 to 1,083 procedures per 1,000 beneficiaries.

This general decrease was mainly due to a reduction of around 19% in conventional radiology procedures. In contrast to this general trend, the frequencies of computed tomography (CT scan) procedures and diagnostic nuclear medicine increased by around 11% and 22%, respectively.

The average dose per beneficiary increased very slightly to 1.57 mSv in 2022, compared with 1.53 mSv in 2017.

As for the distribution of the number of procedures and the collective effective dose, although CT scans account for only a small number of procedures (15.6%), they are on the increase and remain by far the modality that contributes most to population exposure in terms of collective effective dose (75.6%). As the second largest contributor to collective effective dose, the share of nuclear medicine is also increasing. It is the modality that has increased most between 2017 and 2022, both in frequency and, consequently, in contribution to the collective effective dose.

In 2022, 42.6% of the population benefited from one or more diagnostic procedures, down slightly from 2017 (45.4%). This percentage falls to 28.9% if dental examinations are not taken into account (32.7% in 2017). Half of this population - the patients - received a cumulative effective dose of 0.1 mSv or less in 2022.

Also, in 2022, 78% of patients received a dose lower than the average dose of 3.7 mSv for all patients.

Given the rapid development of CBCT (cone beam computed tomography), dental radiology was analysed more specifically. The data shows a sharp increase (56%) in the number of dental CBCT procedures between 2017 and 2022, although the frequency of use is comparatively low (around ten procedures per 1,000 beneficiaries) compared to dental panoramic radiography (around one hundred procedures per 1,000 beneficiaries). Dental panoramic radiography is also up by 11%. Conversely, facial CT scans (dentascan), which are rarely used (fewer than 6 procedures per 1,000 beneficiaries), are down 16%.

Over a longer time period, French data from ExPRI reports have also been compared with global data from the latest UNSCEAR report, published in 2022, based on data from 2009-2018. Generally speaking, trends in procedure frequency and doses in France are similar to those observed worldwide.

Glossary

ASN_ **Autorité de sûreté nucléaire** (French Nuclear Safety Authority) (which became ASNR on January 1, 2025)

ASNR_ **Autorité de sûreté nucléaire et de radioprotection** (French Authority for Nuclear Safety and Radiation Protection)

ASSURANCE MALADIE_ **Assurance Maladie** (French national health insurance system)

ATIH_ **Agence technique de l'information sur l'hospitalisation** (Technical Agency for Information on Hospitalisation)

CBCT_ Cone-beam computed tomography

CCAM_ **Classification commune des actes médicaux** (common classification of medical procedures)

CNAM_ **Caisse nationale de l'assurance maladie** (National Health Insurance Fund) (CNAMTS before January 1, 2018)

CNAMTS_ **Caisse nationale d'assurance maladie des travailleurs salariés** (National Health Insurance Fund for salaried workers) (CNAM since January 1, 2018)

CRD_ **Commission radioprotection dentaire** (Dental Radiation Protection Commission)

CT_ Computed tomography

DAP_ Dose-area product

DCIR_ **Datamart de consommation inter-régimes du SNIIRAM** (SNIIRAM inter-regime consumption data mart)

DLP_ Dose-length product

DREES_ **Direction de la recherche et des études statistiques** (Directorate for Research and Statistical Studies)

DRL_ Diagnostic reference levels

EGB_ **Échantillon généraliste des bénéficiaires** (general sample of beneficiaries)

ESND_ **Échantillon du système national des données de santé** (National Health Data System sample)

ExPRI_ **Exposition de la population aux rayonnements ionisants due aux actes d'imagerie médicale diagnostique** (Exposure of the population to ionising radiation from diagnostic medical imaging procedures)

HAS_ **Haute autorité de santé** (French National Authority for Health)

ICRP_ International Commission on Radiological Protection

INSEE_ **Institut national de la statistique et des études économiques** (National Institute of Statistics and Economic Studies)

IRSN_ **Institut de radioprotection et de sûreté nucléaire** (French Institute for Radiation Protection and Nuclear Safety) (which became ASNR on January 1, 2025)

MRI_ Magnetic resonance imaging

NGAP_ General classification of professional procedures dispensed by the French Social Security scheme

PET_ Positron emission tomography

PMSI_ **Programme de médicalisation des systèmes d'information** (Programme for the medicalisation of information systems)

SNDS_ **Système national des données de santé** (National Health Data System)

SNIIRAM_ **Système national d'information interrégimes de l'Assurance maladie** (National inter-regime health insurance information system)

UNSCEAR_ United Nations Scientific Committee on the Effects of Atomic Radiation

Contents

1. INTRODUCTION

Medical imaging is a speciality that provides undeniable benefits when it comes to patient care, and its utility is no longer up for debate. As it employs ionising radiation to a great extent, medical imaging is the main contributor to exposure of the French population to ionising radiation of artificial origin [1]. It is therefore important to estimate and characterise this medical exposure on a regular basis, as the European Union has been requiring since 1997 [2]. This requirement was reinforced in 2013 by European Directive 2013/59/EURATOM [3], which has now been transposed into French law. In this respect, article R. 1333-67 of the French Public Health Code, recently amended by Decree 2024-1240 of December 30, 2024 [4] following the establishment of the French Authority for Nuclear Safety and Radiation Protection states that *"The average exposure of the population to ionising radiation from medical diagnostic procedures, by imaging modality, anatomical region, age, and sex, is estimated and analysed periodically by the French Authority for Nuclear Safety and Radiation Protection and is the subject of a public report that can be consulted on the Authority's website."*

This mission has been performed by the French Institute for Radiation Protection and Nuclear Safety (IRSN) since 2003, the year in which the Institute participated with the InVS (Institute for Health Surveillance, now part of Santé Publique France) in the creation of the national ExPRI system (Exposure of the Population to Ionising Radiation). The aim of this system is to provide the authorities, medical professionals, and the public with up-to-date data on the exposure of the French population to diagnostic medical imaging procedures, in terms of the frequency and types of diagnostic procedures performed in France, the associated radiation doses, and to characterise the exposed population. Since 2010, this system has been fully implemented by IRSN. As of January 1, 2025, the ASNR is now responsible for this mission. Since the national ExPRI system was implemented, four reports have been produced at 5-year intervals (covering the years 2002, 2007, 2012 and 2017) [5], [6], [7], [8], as well as two reports dedicated to exposure of the paediatric population (covering the years 2010 and 2015) [9], [10] and a report dedicated to exposure of children due to CT scans in France for the period 2012-2018 [11].

In addition to meeting regulatory requirements, the ExPRI system is also used to update the data submitted to UNSCEAR as part of its report on the sources and effects of ionising radiation [12].

This ExPRI report analyses the exposure of the population to ionising radiation from diagnostic imaging procedures in France in 2022, using the following indicators:

- the frequency of each type of diagnostic imaging procedure using ionising radiation;
- the proportion of the population actually exposed, i.e. having undergone at least one diagnostic imaging procedure using ionising radiation during this period;
- the contribution of each type of procedure to the average annual effective dose per caput in the population of France as a whole;
- the annual effective dose received by people actually exposed, i.e. having undergone at least one diagnostic procedure using ionising radiation in 2022.

Chapters 2 and 3 of the report cover the methods for selecting diagnostic imaging procedures, estimating the frequency with which they are performed, and the associated doses. The results obtained by imaging modality and by category of examination for the population as a whole are presented in chapter 4, where the results are classified by age and sex. This chapter also includes a Focus feature that compares, in 2017 and 2022, the frequencies of procedures and effective doses delivered for extraoral dental radiology and facial CT scans, especially for children aged 11 to 15. These types of examinations are more frequently prescribed for this age group in the context of orthodontic treatment, in particular.

Chapter 5 is devoted to an analysis of the population actually exposed, using the same indicators. Lastly, changes in the main indicators since 2002 are described in chapter 6, in which two Focus features are devoted to the impact of the Covid-19 epidemic on the number of procedures in 2020 and a comparison of French data with international data.

2. CHOICE OF PROCEDURE TYPES and determining their frequency

The general approach used to select diagnostic imaging medical procedures is similar to that used in the previous ExPRI study for 2017 [8], except that the sample of beneficiaries used has changed: the general sample of beneficiaries (EGB), closed in 2022, has been replaced by the sample from the national health data system (ESND). The main differences between these two samples are detailed in section 2.2 below.

2.1 SELECTION OF DIAGNOSTIC IMAGING PROCEDURES FOR THE STUDY

Only imaging procedures using ionising radiation **for diagnostic purposes** are included, i.e.:

- all conventional radiology procedures, including dental radiology and mammography;
- CT scans[1];
- nuclear medicine procedures exclusively for diagnostic purposes. Therapeutic procedures are therefore excluded from this study (molecular radiotherapy, radioembolisation, etc.);
- interventional radiology procedures exclusively for diagnostic purposes[2]. Therapeutic procedures, diagnostic procedures performed during a therapeutic procedure (such as angiographies performed during coronary angioplasty), and procedures performed in the operating theatre in support of surgery, etc. are therefore excluded from this study.

These procedures are referred to as "**diagnostic procedures**" in the remainder of this report. The full list of procedures included in the study, classified by imaging modality and by examination category, can be consulted in the appendix to this report.

IDENTIFICATION OF PROCEDURES: FRENCH COMMON CLASSIFICATION OF MEDICAL PROCEDURES (CCAM)

The CCAM is a single coded reference system for all technical medical procedures covered by the national health insurance system. Its use has been national and compulsory since December 31, 2005 for all general practitioners and specialists practising either in the outpatient sector (local practices, health clinics, etc.) or in the public or private hospital sector (hospitalisations and outpatient consultations). These codes are used for pricing and activity descriptions.

The CCAM ensures that diagnostic procedures are unambiguously identified from one another. Each type of procedure is identified by a complete description and a code composed of four letters and three digits: for example, the CCAM code ZBQK002 corresponds to the description “Chest radiograph”. For the purposes of this study, the list of relevant CCAM codes was obtained via a keyword search on version 73.10 of the CCAM followed by a comparison with the list of CCAM codes selected for the 2017 study [8]: 404 codes were selected, including 3 new codes compared to the 2017 study (angiomammography and two virtual colonoscopy CT scan procedures).

It is important to take note that 91.3% of procedures performed by dentists are coded using the CCAM nomenclature. The remaining proportion of dental radiology procedures not associated with a CCAM code (8.7%) is identified by means of a special service reference (see section 2.2 below for further details).

1 Biopsies with radiological guidance were not included in the study because these procedures are highly dependent on the operator and the difficulty of the procedure for which representative dosimetric data are rare.
2 As with CT scans, guided biopsies are not included.

2. CHOICE OF PROCEDURE TYPES and determining their frequency

GROUPING OF PROCEDURES

The procedures selected for this study were grouped into two categories:

a. By imaging modality:

- conventional radiology (excluding dental) including mammography;
- dental radiology;
- computed tomography;
- diagnostic nuclear medicine;
- diagnostic interventional radiology.

b. By examination category:
The categories of diagnostic examinations defined in this study are based on medical practice criteria and generally group together procedures relating to the same anatomical area *(head and neck, limbs, etc.)* or the same functional system of the human body *(digestive tract, nervous system, etc.)* when this is more relevant, particularly in nuclear medicine. In a few cases, the grouping is based on the type of imaging equipment used when this is very specific *(mammography, bone mineral densitometry, PET)*. Lastly, dental radiology procedures are divided into two categories depending on whether the image receptor is located outside the patient's mouth *(extraoral group including dental panoramic, cone-beam CT, teleradiography of the skull)* or inside the patient's mouth *(intraoral group including periapical, bitewing and occlusal radiographs)*. It should be noted that dental CT scan (CCAM code LAQK013 "facial CT scan") is classified in the "CT scan" modality and not "dental radiology".

Imaging modality / Examination category	Number of CCAM codes
CONVENTIONAL RADIOLOGY	**124**
Limbs	35
Spine	19
Urogenital system	13
Digestive tract	12
Pelvis	11
Chest	9
Head and neck	8
Mammography	6
Other	4
Skeletal system	4
Bone mineral densitometry	3
DENTAL RADIOLOGY	**23**
Intraoral	18
Extraoral	5
COMPUTED TOMOGRAPHY	**51**
Head and neck	14
Limbs	10
Abdomen and/or pelvis	9
Spine	7
Multiple areas	5
Chest and heart	3
Other	2
Breast	1
NUCLEAR MEDICINE	**80**
Circulatory system	12
Digestive system	11
Osteoarticular and muscular system	11
Endocrine system	10
Urogenital system	10
Immune and haematopoietic systems	8
Respiratory system	7
Nervous system	6
PET and oncology	4
Other	1
DIAG. INTERVENTIONAL RADIOLOGY	**78**
Vascular	50
Neurological	11
Cardiac	10
Biliary tract	7
TOTAL	**356**

Table I. Number of CCAM codes actually used for this study on 2022 data, by imaging modality and examination category (*i.e.* codes for which at least one procedure is present in 2022 in the ESND).

Table I above shows the examination categories taken into account for each imaging modality, as well as the number of CCAM codes effectively used for this study (codes counting at least one procedure in 2022 on the sample population considered), i.e. 356 codes out of the 404 selected. The full list of CCAM codes included in this study can be consulted in the appendix to this report.

2.2 ESTIMATE OF THE FREQUENCY OF DIAGNOSTIC IMAGING PROCEDURES

The study's estimate of the frequency of procedures for "whole of France" population is based on the frequency observed in the population included in the National Health Data System sample (ESND) which is included in the SNDS, *i.e.* the pseudonymised database managed by the CNAM containing billing information for healthcare procedures.

NATIONAL HEALTH DATA SYSTEM SAMPLE (ESND)

The SNIIRAM order of June 20, 2005 made it possible to create a national sample representing 1/97th of state health insurance beneficiaries, known as the general sample of beneficiaries (EGB), on which the majority of previous ExPRI studies were based. This was a sample of national health insurance beneficiaries linking their administrative and socio-demographic characteristics to their "consumption" of care over time. Since 2016, the affiliation schemes included in this sample have covered 95.6% of beneficiaries.

This sample was closed in 2022 and replaced by the National Health Data System Sample (ESND), on which the ExPRI study is based for 2022. This new sample compiles the procedures of 2% of the population present in the main SNDS database, who have consumed at least one session of care in local practices or private clinics since 2006, all schemes combined [1].

To date, there are no published studies on the representativeness of the ESND in relation to the general population that are as comprehensive as those conducted in the past for the EGB. However, the national health insurance system [13] states that the ESND is representative of the French population according to:
- age (using age groups 0-14, 15-34, 35-54, 55-64, 65-75 and over 75);
- sex;
- the major affiliation schemes, the patient's region and department (metropolitan France and overseas departments and regions).

Just over 1,500,000 beneficiaries were in the ESND in 2022. The composition of the ESND in 2022 is shown in **Table II** below. The population concerned was studied by 5-year age group, in accordance with the recommendations of European Commission Report No. 154 [14], with the exception of individuals aged 90 and over, who were grouped into a single age bracket for statistical reasons. In accordance with good practice for use of the ESND [13], the procedures selected covered a population aged 110 years at maximum.

Age (in 2022)	Men	Women	TOTAL
0-4 years	37,617	36,108	**73,725**
5-9 years	42,956	41,214	**84,170**
10-14 years	46,267	44,531	**90,798**
15-19 years	46,617	44,022	**90,639**
20-24 years	48,288	45,313	**93,601**
25-29 years	47,909	46,880	**94,789**
30-34 years	49,208	48,618	**97,826**
35-39 years	48,919	48,286	**97,205**
40-44 years	49,028	48,561	**97,589**
45-49 years	47,912	46,485	**94,397**
50-55 years	50,103	49,232	**99,335**
55-59 years	47,896	48,095	**95,991**
60-64 years	43,940	45,610	**89,550**
65-69 years	39,761	43,108	**82,869**
70-74 years	37,638	41,683	**79,321**
75-79 years	27,728	32,186	**59,914**
80-84 years	17,992	22,781	**40,773**
85-89 years	12,884	19,593	**32,477**
90-110 years	10,954	22,728	**33,682**
TOTAL	**753,617**	**775,034**	**1,528,651**

Table II. Composition of the national health data system sample (ESND) by sex and age group.

1 Except the French National Assembly and Senate

2. CHOICE OF PROCEDURE TYPES and determining their frequency

COUNTING PROCEDURES

The healthcare consumption of each beneficiary in the sample is periodically entered into the ESND using a) billing data from the SNIIRAM, which includes reimbursement data for healthcare services (private hospital and local practice) and b) public hospital data from the Programme for the Medicalisation of Information Systems (PMSI) of Technical Agency for Information on Hospitalisation (ATIH). The CCAM is used to code the procedures performed. As each beneficiary included in the ESND is identified by a pseudonym, it is possible to reconstruct the care pathway, while respecting the anonymity of patients, regardless of whether procedures were performed by a professional practising in the private or public sector, or if they took place in a local practice or hospital. The ESND can therefore be used to count all diagnostic procedures using ionising radiation performed on beneficiaries in the sample.

The data extracted from the ESND for the ExPRI study can be considered sufficiently complete to describe the exposure of the population due to diagnostic procedures carried out in the private sector or during inpatient or outpatient care in the public hospital sector.

As the ESND is a sample of around 2% of the French population, certain infrequent procedures may only be present in very small numbers in the sample, or even not at all. Extrapolation to the entire population then becomes uncertain because of the sharp increase in statistical uncertainty.

EXTRACTION OF PARAMETERS OF INTEREST FOR THE STUDY

Queries were executed using the SAS Enterprise Guide 8.3 software on the sample databases of SNIIRAM and PMSI to extract all diagnostic procedures of the ESND performed from January 1 to December 31, 2022, as well as data relating to the beneficiaries (sex and age at the time of the procedure).

The diagnostic procedures extracted include:

- procedures performed in the private sector, i.e. procedures performed in private practices and private health establishments (during stays or outpatient care), including dental care when coded in the CCAM;
- procedures performed in public health establishments, during hospital stays or outpatient treatment, including dental treatment;
- procedures carried out by dentists not coded in the CCAM, in the private sector (i.e. coded in the NGAP, the general classification of treatments dispensed by the French Social Security scheme).

For each of these procedures, the parameters of interest for the study were:

- the beneficiary's demographic characteristics: pseudonymised identifier, sex, month and year of birth;
- the characteristics of the procedure:
  - type of reference service [1],
  - the care sector (private, non-CCAM dental, public inpatient and outpatient);
  - CCAM code (or type of service for the part of dental radiology coded in the NGAP and not in the CCAM) and procedure description, for all procedures,
  - the month and year it was performed.

The analysis focused on:

- the frequency with which each type of diagnostic procedure was performed in 2022 according to the imaging modalities and examination categories (classifications defined above), and according to the age and sex of beneficiaries;
- the proportion of the population actually exposed in 2022, i.e. having undergone at least one diagnostic procedure during the year, characterised by age and sex.

COMPARISON OF ESND TO THE EGB ON 2017 DATA

Between the previous ExPRI study based on 2017 data and the current study based on 2022 data, the ESND beneficiary sample replaced the EGB following its closure. As a result, the extraction queries on SAS EG had to be modified. In order to check the consistency and validity of these new queries, the data obtained between the EGB and the ESND were compared for the year 2017. This year's data on the EGB is available as a result of the previous ExPRI report, and can be found on the SNDS portal for the ESND via query extraction. This comparison ensures that the results are correctly transposed between the samples, particularly in view of the differences in representativeness (92.5% for the EGB, compared with the inclusion of all schemes for the ESND).

1 The type of reference service is a variable defining the type of care provided in the DCIR sample for procedures in the private sector. There are 10 values for this variable associated with radiology procedures. In practice, in 2022, only 4 codes returned a non-zero number of procedures (by decreasing number of procedures): code 1351 (CCAM imaging procedures [excluding ultrasound]), code 1331 (radiology procedures), code 9423 (oral health prevention - radiography 4 views) and code 9422 (oral health prevention - radiography 2 views). Code 1351 is used for all radiological procedures coded in the CCAM, including dental procedures. Codes 1331, 9422, and 9423 are used exclusively for dental radiology procedures not coded in the CCAM.

Age group (in 2017)	Sex	Number of individuals in the ESND in 2017	As a proportion of the total	Number of individuals in the EGB in 2017	As a proportion of the total	ESND/EGB ratio of proportions
0-4 years		40,274	2.76%	19,812	2.82%	0.98
5-9 years		44,812	3.07%	21,852	3.11%	0.99
10-14 years		44,480	3.04%	21,667	3.08%	0.99
15-19 years		45,075	3.08%	20,834	2.96%	1.04
20-24 years		44,612	3.05%	18,174	2.58%	**1.18**
25-29 years		46,228	3.16%	22,214	3.16%	1.00
30-34 years		46,746	3.20%	22,341	3.18%	1.01
35-39 years		47,652	3.26%	23,686	3.37%	0.97
40-44 years		47,072	3.22%	23,227	3.30%	0.98
45-49 years	**Men**	49,827	3.41%	24,804	3.53%	0.97
50-54 years		48,100	3.29%	23,953	3.41%	0.97
55-59 years		44,759	3.06%	21,798	3.10%	0.99
60-64 years		41,314	2.83%	20,131	2.86%	0.99
65-69 years		40,095	2.74%	19,368	2.75%	1.00
70-74 years		30,550	2.09%	14,752	2.10%	1.00
75-79 years		21,096	1.44%	9,848	1.40%	1.03
80-84 years		17,233	1.18%	8,148	1.16%	1.02
85-89 years		11,633	0.80%	5,294	0.75%	**1.06**
90-110 years		7,296	0.50%	3,201	0.46%	**1.1**
0-4 years		38,546	2.64%	18,682	2.66%	0.99
5-9 years		43,032	2.95%	20,991	2.98%	0.99
10-14 years		42,476	2.91%	20,742	2.95%	0.99
15-19 years		42,327	2.90%	19,424	2.76%	**1.05**
20-24 years		43,274	2.96%	17,375	2.47%	**1.2**
25-29 years		45,714	3.13%	22,332	3.18%	0.99
30-34 years		46,163	3.16%	22,654	3.22%	0.98
35-39 years		47,205	3.23%	23,121	3.29%	0.98
40-44 years		45,608	3.12%	22,774	3.24%	0.96
45-49 years	**Women**	48,731	3.34%	24,124	3.43%	0.97
50-54 years		47,892	3.28%	23,543	3.35%	0.98
55-59 years		45,780	3.13%	22,770	3.24%	0.97
60-64 years		43,523	2.98%	21,547	3.06%	0.97
65-69 years		42,681	2.92%	20,957	2.98%	0.98
70-74 years		33,681	2.31%	16,462	2.34%	0.98
75-79 years		24,968	1.71%	12,070	1.72%	1.00
80-84 years		23,591	1.61%	11,453	1.63%	0.99
85-89 years		19,558	1.34%	9,250	1.32%	1.02
90-110 years		17,515	1.20%	7,886	1.12%	**1.07**
TOTAL		**1,461,119**		**703,261**		

Table III. Number of individuals by sex and age group, and proportion of the total for both the EGB and ESND samples, as well as the ratio of proportions between these two samples (ratios differing by +/- 5% are underlined in bold).

2. CHOICE OF PROCEDURE TYPES and determining their frequency

Number of beneficiaries and distribution by age, for both sexes
With regard to beneficiaries, it should be noted that the age distribution is slightly different between the two samples. **Table III** above shows the distribution of beneficiaries by 5-year age bracket, for men and women, in the two samples, for the same year 2017.

We can see that the two samples differ, mainly in the 15-19 and 20-24 age groups, and in the oldest ages for men, from 85 onwards, and for women, after 90.

The 15-24 age group includes many students. They are proportionately higher in the ESND than in the EGB, given that all student health insurance schemes are now included.

Beneficiaries of advanced age (75 and over) are proportionately higher in the ESND than in the EGB. The origin of this difference could not be determined with certainty.

In any event, these differences between the two samples must be taken into consideration when comparing data from the two samples. While these differences are minimal, on the whole, they must still be taken into consideration when comparing the data from 2017 (EGB) and 2022 (ESND) for these categories of the population.

Frequency of procedures
Overall for 2017, the frequency of procedures per 1,000 beneficiaries was 1,181 with the ESND (new sample) compared with 1,187 with the EGB (old sample) for the same year. This corresponds to a loss of 0.5% in procedure frequency due to the change in sample.

Age group	Frequency of procedures EGB in 2017	Frequency of procedures ESND in 2017	ESND/EGB ratio	Frequency of procedures EGB in 2017	Frequency of procedures ESND in 2017	ESND/EGB ratio
	Men			Women		
0-4 years	294	299	1.02	284	271	**0.95**
5-9 years	503	504	1.00	522	522	1.00
10-14 years	944	938	0.99	1,029	1,013	0.98
15-19 years	825	804	0.97	816	804	0.98
20-24 years	685	633	**0.92**	729	663	**0.91**
25-29 years	731	739	1.01	780	759	0.97
30-34 years	785	802	1.02	838	863	1.03
35-39 years	853	862	1.01	985	989	1.00
40-44 years	914	953	1.04	1,252	1,285	1.03
45-49 years	990	1,029	1.04	1,434	1,455	1.01
50-54 years	1,139	1,178	1.03	1,775	1,804	1.02
55-59 years	1,339	1,337	1.00	1,881	1,888	1.00
60-64 years	1,430	1,498	**1.05**	1,975	2,019	1.02
65-69 years	1,683	1,631	0.97	2,236	2,136	0.96
70-74 years	1,847	1,741	**0.94**	2,317	2,215	0.96
75-79 years	2,017	1,933	0.96	2,191	2,212	1.01
80-84 years	2,026	1,912	**0.94**	2,058	2,045	0.99
85-89 years	1,890	1,683	**0.89**	1,917	1,848	0.96
90-110 years	1,335	1,242	**0.93**	1,298	1,291	**0.99**

Table IV. Procedure frequencies by sex and age group, for the EGB and ESND samples in 2017, and ratio between the two (ratio values differing by +/- 5% are underlined in bold).

Looking at **Table IV** above, the frequencies of procedures as a function of age, for men on the one hand and women on the other, we can see differences between samples, in particular among older beneficiaries, especially men, and among students.

If we consider the frequency of procedures by modality, we find that the number of procedures per 1,000 beneficiaries between the ESND and the EGB for 2017 is identical for all modalities, except dental radiology, where a decrease of 1.4% was observed in the ESND (i.e. 5 fewer procedures in the ESND out of 351 procedures per 1,000 beneficiaries), as shown in **Figure 1** below.

With regard to the percentage distribution of the number of procedures by modality, the two samples are in agreement, with a maximum difference of 0.3 points for dental radiology, as shown in **Figure 2** below.

Distribution of doses by modality

In terms of the distribution of doses among the different modalities, the two samples are also in agreement, with a maximum difference of 0.2 points, as shown in **Figure 3** below.

Doses per caput (beneficiary and patient)

The doses per beneficiary and per exposed patient (*i.e.* beneficiary having received at least 1 procedure in 2017) are identical between the two samples. The average dose per beneficiary was 1.53 mSv for both samples in 2017. Similarly, the average dose per patient was 3.40 mSv for both samples.

Proportion of beneficiaries who received at least one treatment

Similarly, the proportion of 'patients' among beneficiaries is in line with the two samples (45%).

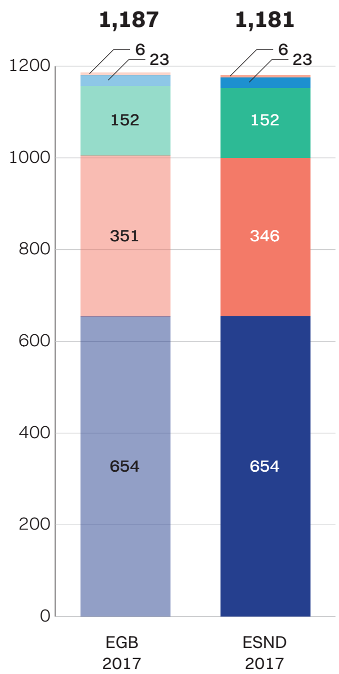


Figure 1. Total procedure frequency and by imaging modality (per 1,000 beneficiaries), for both the EGB and ESND samples, for 2017 data.

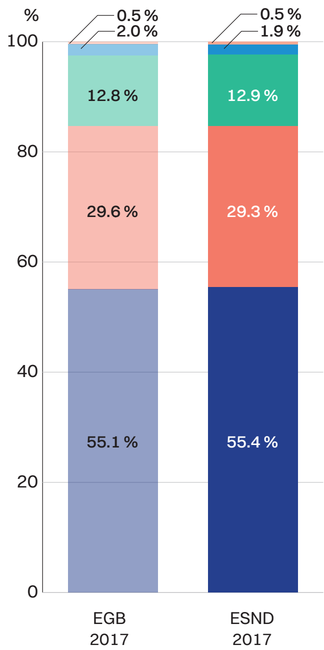


Figure 2. Proportion of total number of procedures by imaging modality, for both the EGB and ESND samples, for 2017 data.

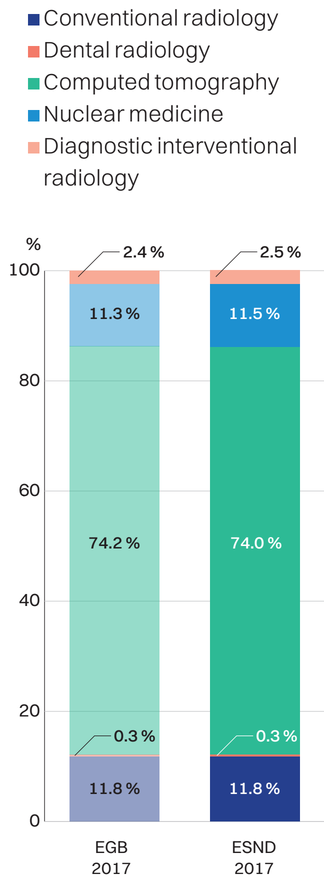


Figure 3. Contribution to annual effective dose by imaging modality, for the EGB and ESND samples, for 2017 data.

2. CHOICE OF PROCEDURE TYPES and determining their frequency

Men

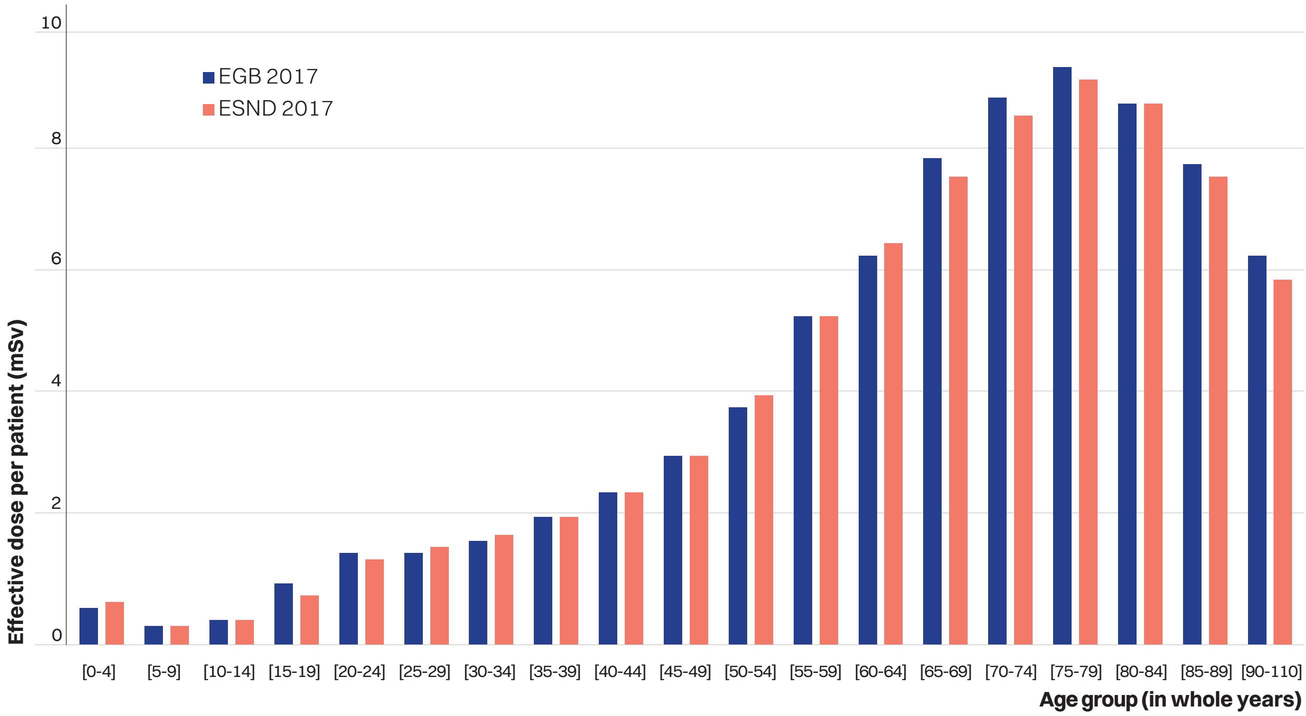


Figure 4. Distribution of cumulative effective doses per patient, by age category, for men.

Women

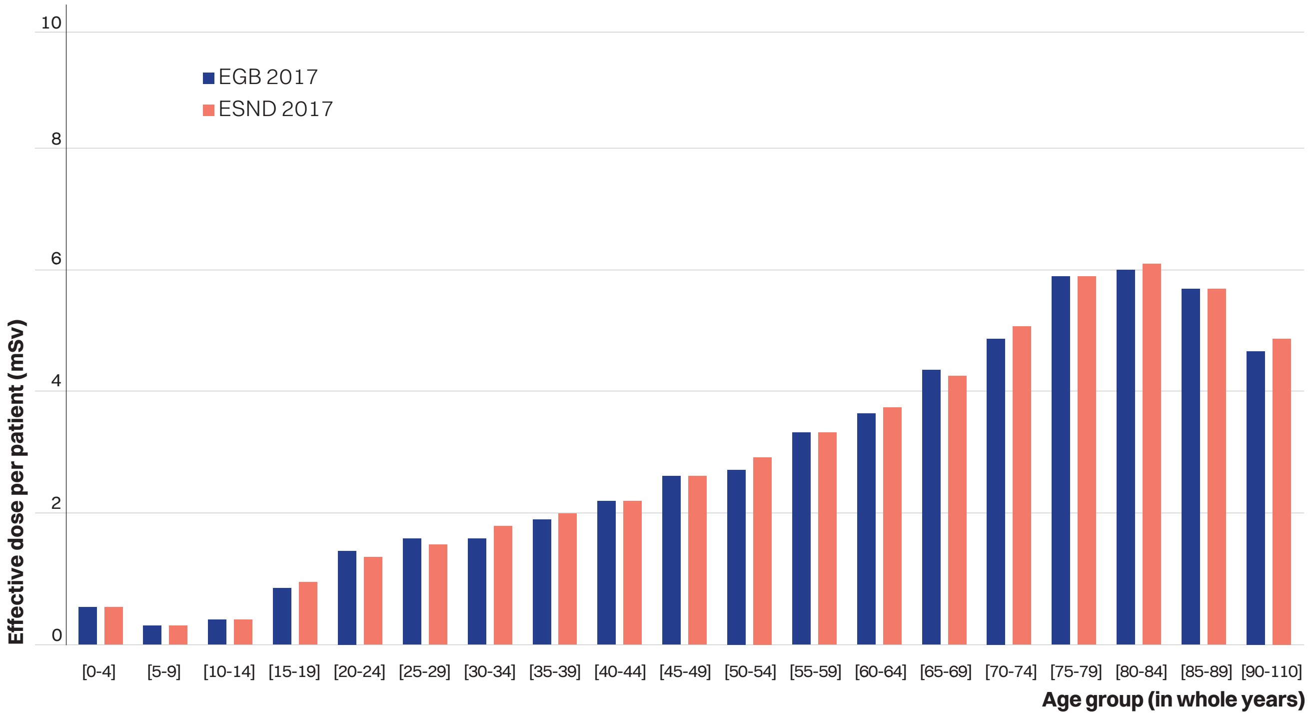


Figure 5. Distribution of cumulative effective doses per patient, by age category, for women.

Cumulative dose per patient according to age
Figures 4 and 5 above show the dose per patient as a function of age, for men and women respectively.

For men, particularly of advanced age, agreement between cumulative doses per patient is not as good as for women. The maximum difference concerns men over 65 and is around 0.2-0.4 mSv for doses of approximately 8-9 mSv.

For women, this difference is less significant, at a maximum of around 0.1-0.2 mSv for doses of approximately 5-6 mSv above the age of 65.

To make a comparison over time, it is therefore necessary to take into account this difference due to the sample.

EXTRAPOLATION TO THE FRENCH POPULATION

In the previous ExPRI study for 2017, extrapolation to the French population took two aspects into consideration:
- the EGB represented 1/97th of national health insurance beneficiaries;
- not all schemes were covered, with a proportion of 95.6% of beneficiaries.

This is no longer applicable to the ESND, since the sampling method is very different from that of the EGB. In fact, extrapolation can no longer be carried out simply by applying the 2/100 sampling factor, given that this is not strictly a 2% sample as explained above (*i.e.* the ESND contains 2% of beneficiaries consuming in the private sector since 2006).

To carry out this extrapolation, the beneficiaries present in the ESND in 2022 must first be counted. A selection was made as follows:
- beneficiaries integrated before January 1, 2023, i.e. those integrated before 2022 and those integrated during 2022;
- beneficiaries living throughout 2022 or who died during the year;
- beneficiaries aged up to 110 years old;
- the usual corrections to sex codes and beneficiary identifiers as recommended by the national health insurance system.

Secondly, it was decided to use the French population provided by INSEE, i.e. 67,926,558 people as of January 1, 2022[1]. The ratio between the number of beneficiaries counted in the ESND (1,528,651) and the aforementioned INSEE population then provides the extrapolation factor of approximately 2.3/100.

It should be remembered that, unlike the EGB which used a unique beneficiary identifier, the ESND is built on the same basis as the SNDS with respect to identifiers, i.e. several types of identifier exist for beneficiaries and there is no single, constant identifier for a single beneficiary. In addition, changing the beneficiary's pseudonym during his or her lifetime can result in the beneficiary being counted twice, as well as missing dates of death.

It should also be noted that the total number of national health insurance beneficiaries does not correspond perfectly to the French population (as defined by INSEE). In other words:
- the population covered by a compulsory French health insurance scheme, known as the beneficiary population, is affiliated to one of the health insurance schemes but does not have to be a resident of France (e.g. French expatriates).
- the French population as defined by INSEE are residents of France but may not be affiliated to a French health insurance scheme (e.g. people with a provisional social security number).

Thus, extrapolation using a factor based on ESND beneficiaries on the one hand, and on the INSEE population on the other, is accompanied by uncertainties due to this difference in population.

As indicated above, the uncertainty associated with this extrapolation method increases sharply when the number of people in the ESND is low. This is why the procedure frequencies and contributions to the average annual effective dose are not shown in the annexed tables for CCAM codes with fewer than 50 procedures in 2022.

Given the uncertainties caused by the extrapolation method chosen, the extrapolated numbers between two extrapolation methods based on different samples (ESND vs EGB) should not be compared in the graphs below. In addition, the extrapolated number of procedures should not be considered to the nearest unit, but as orders of magnitude of the number of procedures.

1 It would also have been possible to choose the number for the population as of January 1, 2023, given that this study covers the whole of 2022. The difference between 2022 and 2023 is small, around 0.03% (or 200,000 people).

3. ESTIMATION OF DOSES ASSOCIATED with diagnostic imaging procedures

3.1 DOSIMETRIC INDICATOR: EFFECTIVE DOSE

In accordance with the recommendations of European reports 154 [14] and 180 [15] and international reports [12], [16], the dosimetric indicator used in this study to assess the exposure of individuals to ionising radiation from diagnostic procedures is the effective dose (expressed in millisieverts, mSv). The effective dose is an indicator of the risk of long-term health damage (potential cause of cancers and heritable effects) linked to exposure to ionising radiation (stochastic effects). This indicator is a tool for assessing the overall risk to the whole organism, whether or not it is fully exposed, taking into account the type of radiation (nature and energy) and the specific radiosensitivity of each exposed organ [17]. Calculated on the basis of weighting factors defined for the general population, all ages and sexes combined, **effective dose must not be used to quantify an absolute risk for a specific population, *or, a fortiori*, to estimate individual risk [1]. Furthermore, the low effective doses associated with examinations involving only a small part of the body, such as dental radiography or mammography for example, should not mask the fact that local exposure, to the salivary glands or the mammary gland in the case of the aforementioned examples, can be relatively high.**

Nevertheless, effective dose is a practical tool recognised by the International Commission on Radiological Protection (ICRP) for estimating the relative radiological risks associated with imaging examinations involving different anatomical areas, or those associated with different imaging modalities for the same anatomical area. As it is a standardised indicator, it can also be used to study changes over time in the exposure of the population resulting from all medical procedures using ionising radiation or, more specifically, from a particular examination method, as well as to make comparisons between different countries.

Average effective doses by type of diagnostic procedure were calculated using the tissue weighting factors defined in publication 103 of the International Commission on Radiological Protection (ICRP) [17], except for nuclear medicine for which the most recent reference publication [18] still refers to the tissue weighting factors defined in ICRP publication 60 [19]. The annual effective dose per caput is obtained by summing the effective doses associated with the various procedures performed on the same patient over the period of interest.

Various sources of data were used to estimate these average effective doses by type of procedure to be as representative as possible of French radiology and nuclear medicine practice in 2022.

The average effective doses by type of procedure are detailed in the appendix to this report, classified by imaging modality, examination category, and CCAM code. Overall, they have decreased compared with 2017 [8], in line with the fall in dosimetric indicators already noted in the IRSN report published in June 2023 on the analysis of data relating to the updating of diagnostic reference levels for the years 2019 to 2021 [20].

3.2 ESTIMATE OF AVERAGE EFFECTIVE DOSES ASSOCIATED WITH EACH TYPE OF PROCEDURE

In the absence of individual dosimetric data, and despite the sometimes wide dispersion of doses for the same type of procedure [20], population exposure is estimated by associating an average effective dose with each type of procedure, defined by its CCAM code. These average effective doses are calculated for an adult patient of standard morphology, and are considered constant regardless of the patient's age and sex, in accordance with the method

1 ICRP Publication 103 [17] - *"The effective dose for protection purposes is based on the mean doses in organs or tissues of the human body. [...] This quantity provides a value which takes account of the given exposure conditions but not of the characteristics of a specific individual. In particular, the tissue weighting factors are mean values representing an average over many individuals of both sexes."*

recommended at the European level [15]. Unless explicitly stated otherwise in the description of the CCAM code, the effective doses used in this study correspond to a complete procedure, as recommended in the aforementioned European Commission report RP 154. A complete procedure is defined as *"one or a series of exposures of one anatomical region/organ/organ system, using a single imaging modality (i.e. radiography/fluoroscopy or CT), needed to answer a specific diagnostic problem or clinical question, during one visit to the radiology department"*. For example, a CT scan of the chest with intravenous injection of contrast (code ZBQH001) is a complete procedure which may involve one or more acquisitions. The associated effective dose is therefore calculated by multiplying the dose associated with a single thoracic spiral by the average number of spirals estimated for this procedure.

Since 2004, all managers of radiological or nuclear medicine facilites have been required to carry out an annual dosimetric assessment for at least two types of procedures routinely performed in the imaging unit, chosen from a list published by order [21]. This dosimetric assessment, which is essential for practioners to assess and optimise their practice, must be sent to the ASNR (formerly the IRSN), which publishes a periodic analysis for France. The latest review presents an analysis of dosimetric indicators collected over the period 2019-2021 [20], particularly in adults:

- the dose-area product (DAP) per exposure, in conventional radiology;
- the dose-length product (PDL) per acquisition, in CT scan;
- the administered activity of a radiopharmaceutical in nuclear medicine.

The average values of these various dosimetric indicators were calculated specifically for the purposes of this study.

The various data sources used in the previous ExPRI study [8] were therefore updated to include the results of studies that are as close as possible to clinical practice in 2022, using data provided by imaging departments as part of the update of diagnostic reference levels.

In conventional radiology, effective dose calculations were performed by multiplying the average DAP for the entire procedure by the conversion factor for the anatomical region under consideration, where available [15], or by simulating the diagnostic procedure using PCXMC V2.0 software [22].

In mammography, the effective dose was calculated by multiplying the average glandular dose for the entire procedure (2 images per breast) [23] by the w_T factor defined for the breasts (or half of this factor for unilateral mammography) in ICRP publication 103 [17].

In CT, the effective dose associated with each type of procedure was calculated by multiplying the average DLP for the entire procedure by the conversion factor for the anatomical region under consideration, where available [15], [24], or using CT Expo software [25].

In nuclear medicine, average effective doses were calculated from the average activity administered by applying the conversion factors updated by the ICRP in 2015 [18] for the main radiopharmaceutical. It should be noted that as these conversion factors are still calculated on the basis of the tissue weighting factors in ICRP Publication 60 [19], the average effective doses per nuclear medicine procedure are not strictly equivalent to the average effective doses per procedure for the other imaging modalities considered here, which are, for their part, based on the tissue weighting factors in ICRP Publication 103 [17].

3.3 UNCERTAINTY OF EFFECTIVE DOSE VALUES

The main sources of uncertainty in the estimation of average effective dose by type of procedure were described and discussed in the 2007 report [6]. They remain valid for the present study and concern:

- the national dispersion of effective doses delivered for a given type of procedure, taking into account differences in practices and equipment;
- the inconsistencies that may persist for certain types of procedures between actual clinical practice and the CCAM classification;
- the rarity of certain types of procedures, which makes the associated dosimetric assessment unreliable.

European Commission Report RP No. 180 [15] gives an estimate of the uncertainty in the average effective doses per type of procedure calculated by each of the countries participating in the Dose Datamed 2 study. The average uncertainty, based on the method proposed by Hart and Wall [26], is within a range of 20-40% for all the procedures taken into account.

The uncertainty in the calculation of average annual effective doses per caput is mainly due to the uncertainty in the average effective doses for the different types of procedures, which is much greater than the uncertainties in the frequency of procedures or the population count.

European Commission Report RP No. 180 [15] also states that the uncertainty in dose estimates for the population is between 12% and 25%, depending on whether the average effective doses for the various types of procedures are calculated on the basis of actual clinical practice or estimated from the literature. As the average effective doses for the various types of procedure mentioned in this study are partly calculated on the basis of real data (data collected under the DRL system or specific studies) and partly extrapolated from the literature, the uncertainty in the average annual effective doses per caput calculated in this study should fall within this range.

4. EXPOSURE OF ENTIRE population in 2022

This chapter describes the results of the study covering the entire ESND population, whether or not they received a diagnostic procedure in 2022. The results are given in:

- number of procedures extrapolated to the French population,
- distribution of the collective effective dose by imaging modality,
- frequency of procedures (number of procedures per 1,000 beneficiaries),
- average annual effective dose per beneficiary.

A total of 1,654,867 diagnostic procedures were performed during 2022 on beneficiaries included in the ESND. Extrapolated to the entire French population covered by the healthcare system, it is estimated that just under 74 million diagnostic procedures were performed in France in 2022. This corresponds to an average of 1,082 procedures per 1,000 beneficiaries (who may or may not be exposed) and an average annual effective dose of 1.57 mSv per beneficiary. These averages provide an indicator of the French population's exposure to ionising radiation from medical sources (excluding therapeutic use), which is useful for international comparisons and for the estimation of French population exposure to ionising radiation, all sources combined, conducted periodically by the ASNR (formerly IRSN) [1]. However, the actual exposure of the French population is extremely heterogeneous, since only a fraction of the beneficiaries in the sample received one or more diagnostic procedures in 2022. The population of patients who are actually exposed is examined in chapter 5 of this report.

4.1 EXPOSURE DISTRIBUTION BY IMAGING MODALITY: FREQUENCY OF PROCEDURES AND AVERAGE EFFECTIVE DOSE PER BENEFICIARY

Table V opposite and **Figure 6** below show the number of imaging procedures and the distribution of the associated collective effective dose for the year 2022, broken down by imaging modality.

Conventional radiology accounts for the majority of procedures performed, with around 36 million procedures, and is the third largest contributor to collective effective dose after CT scans and nuclear medicine. Nearly 24 million dental radiology procedures are recorded, this makes dental radiology the second highest contributor in terms of number of procedures, but the lowest in terms of collective effective dose.

Imaging modality	Number of procedures	Procedures %	Coll. effective dose %
Conventional radiology	36,122,193	49.1	8.9
Dental radiology	23,606,291	32.1	0.3
Computed tomography	11,450,368	15.6	75.6
Nuclear Medicine	1,907,543	2.6	13.1
Diagnostic interventional radiology	467,896	0.6	2.1
TOTAL	**73,554,291**	**100**	**100**

Table V. Number of diagnostic imaging procedures and percentage of associated collective effective doses.
Rounded values, extrapolated for the whole of France, 2022.

Conversely, computed tomography is only the third most frequent modality, with just over 11 million procedures, well behind dental radiology, but it contributes almost 76% of the collective effective dose attributable to the diagnostic medical imaging sector.

Nuclear medicine, which accounts for only a small percentage of procedures (2.6%), is now the 2nd largest contributor to collective effective dose, with just over 13%.

Finally, diagnostic interventional radiology, which is very poorly represented in this study in terms of the number of procedures, contributes about 2% of the collective dose.

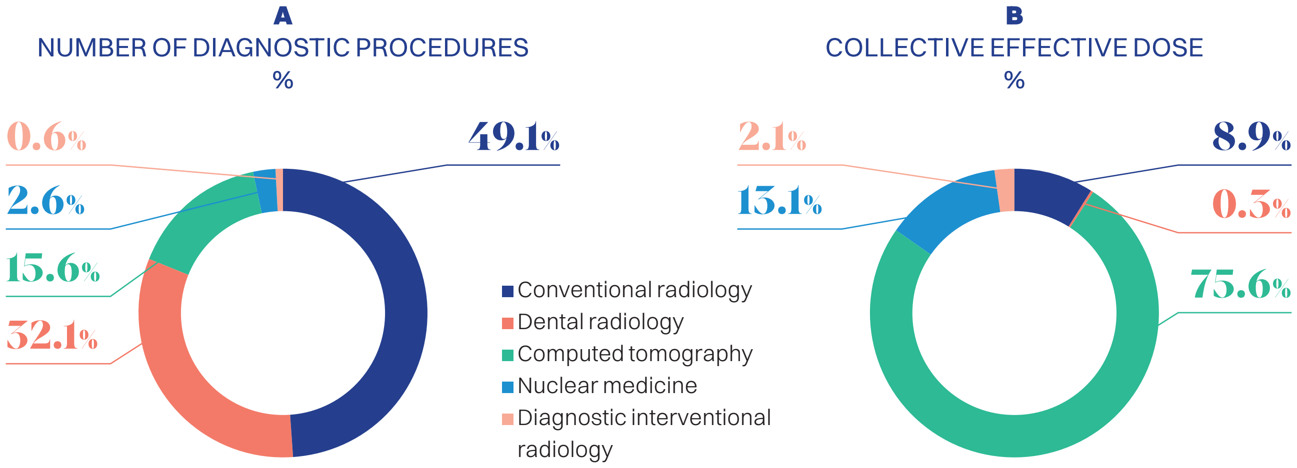


Figure 6. Distribution by imaging modality of diagnostic procedures and collective effective dose.

FREQUENCY OF PROCEDURES BY IMAGING MODALITY ACCORDING TO AGE AND SEX

In addition to the distribution of the number of procedures, it is useful to calculate the frequency with which procedures are performed, i.e. the annual number of diagnostic procedures performed on patients of a given age and sex, in relation to the population of that age and sex. These frequencies differ significantly according to the age of the individuals and, to a lesser extent, according to their sex, as can be seen in **Figure 7** below, which presents them by age group and sex, in terms of the number of procedures per 1,000 beneficiaries of a given sex and age group.

An increase in the frequency of procedures with the age of individuals is observed up to the age category 70-74 for women and 75-79 for men. A peak, already observed in previous studies in the general and paediatric populations [5], [6], [7], [8], [9], [10], is observed for children 10-14 years old, as well as for adolescents 15-19 years old. Over the age of 85, the frequency of procedures decreases sharply.

There is also a clear difference between men and women: the frequency of procedures is higher for women in practically all age groups. The differences are particularly marked in the 40 to 74 age group. Overall, taking all ages together, the frequency of procedures is 1,215 procedures per 1,000 women, compared with 946 procedures per 1,000 men, as shown in **Table VI** below.

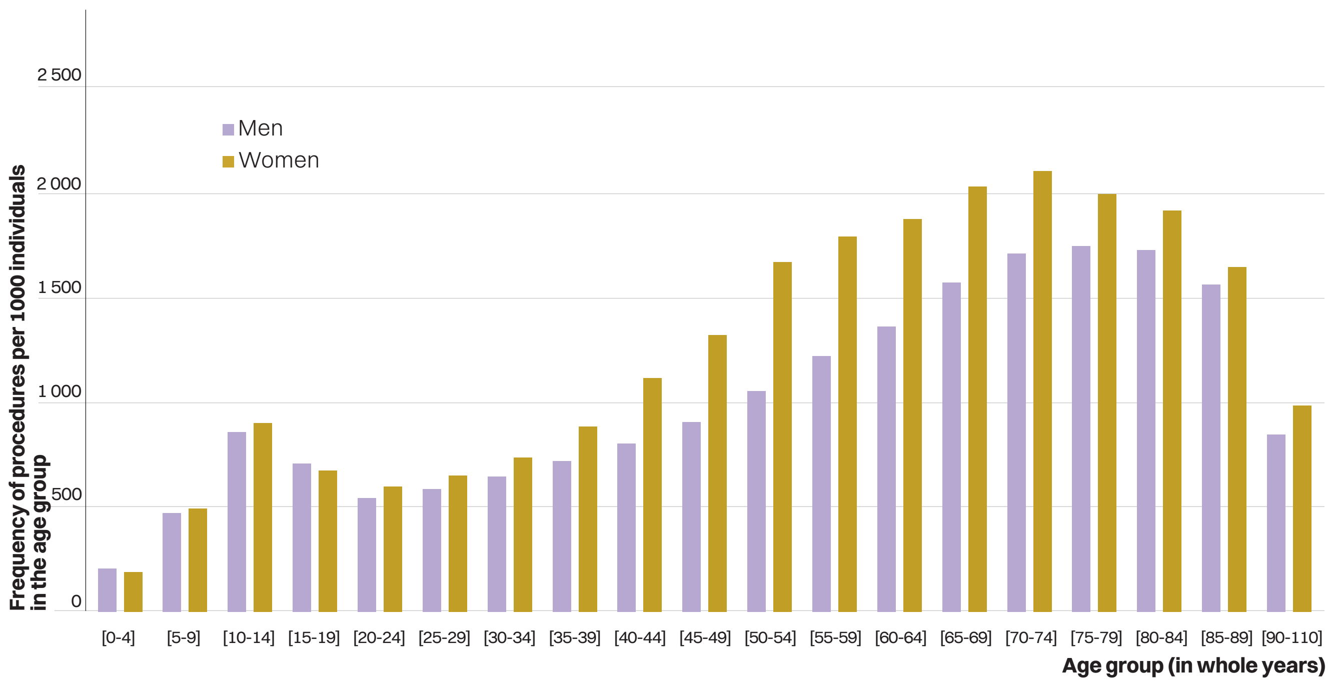


Figure 7. Frequency of procedures performed (all modalities) by age group and sex (expressed as number of procedures per 1000 beneficiaries).

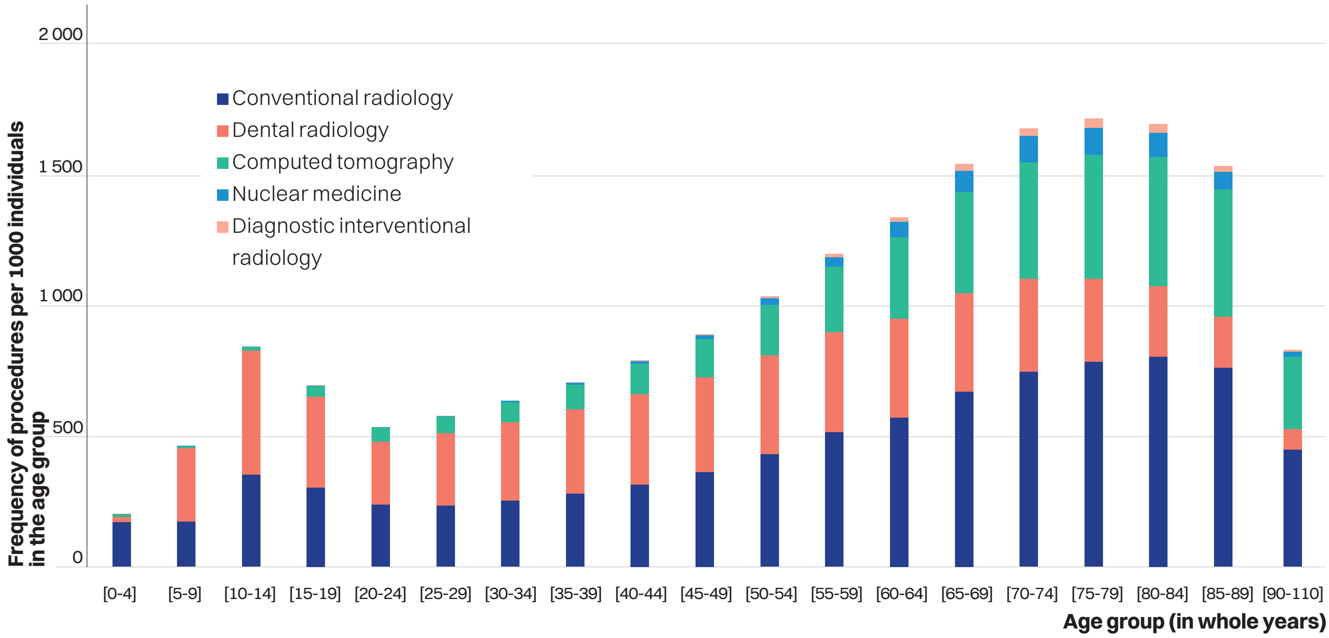
Imaging modality	Men		Women		OVERALL	
	/1000 indiv.	%	/1000 indiv.	%	**/1000 indiv.**	**%**
Conventional radiology	409.1	43.2	650.8	53.5	**531.8**	**49.1**
Dental radiology	325.5	34.4	368.8	30.3	**347.5**	**32.1**
Computed tomography	174.9	18.5	162.3	13.4	**168.6**	**15.6**
Nuclear Medicine	27.5	2.9	28.7	2.4	**28.1**	**2.6**
Diagnostic interventional radiology	9.0	0.9	4.9	0.4	**6.9**	**0.6**
ALL MODALITIES	**946.0**	**100.0**	**1,215.5**	**100.0**	**1,082.9**	**100.0**

Table VI. Frequency of procedures by sex and imaging modality.

Figure 8 below shows the distribution of examinations by age and sex, in addition to **Table VI** above:

- The use of conventional radiology is significantly higher in women between the ages of 40 and 90 than in men in the same age group. The use of mammography explains most of this difference, as will be discussed below.
- Dental radiology is noticeably more frequent among women, in almost all age groups.
- The frequency of CT scans is perceptibly higher for men, particularly from the age of 55 onwards. The frequency of CT scans increases steadily for both sexes from adolescence onwards, peaking in the eighties.
- Nuclear medicine, and even more so diagnostic interventional radiology, only reach significant frequencies after the age of 40 or 50, and peak for people in their 70s.

Men



Women

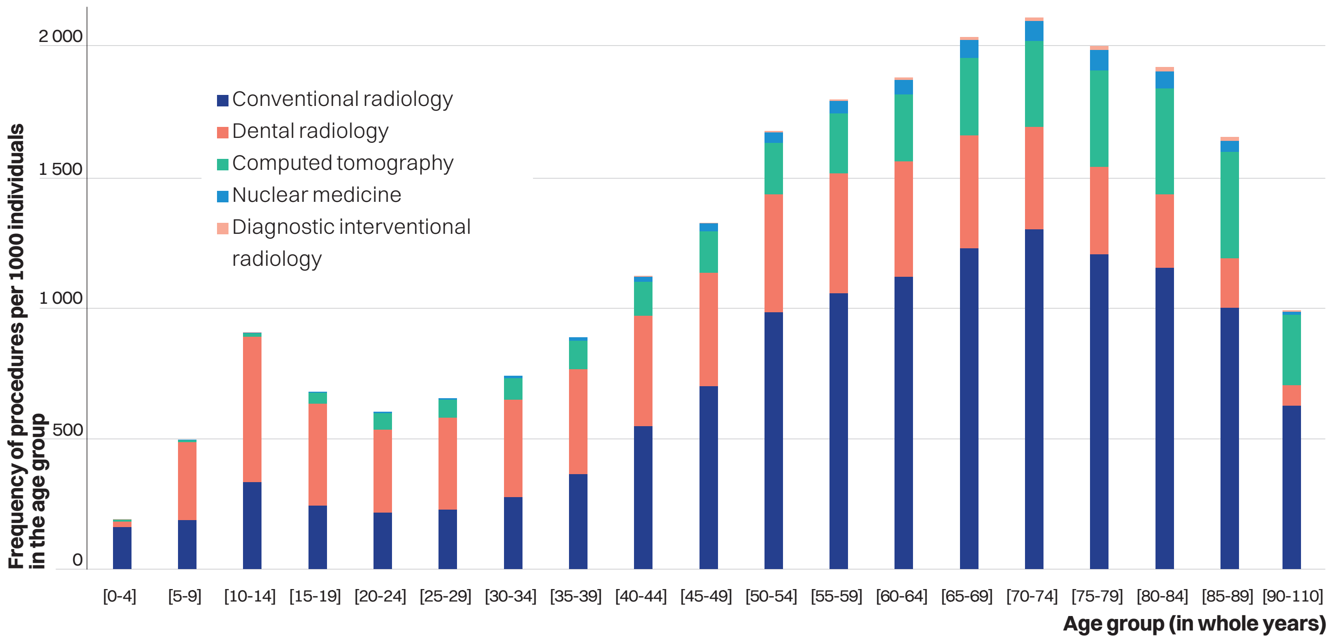


Figure 8. Comparison of procedure frequencies by modality and age group in the male and female populations.

AVERAGE EFFECTIVE DOSE BY IMAGING MODALITY ACCORDING TO AGE AND SEX

This section looks at the distribution of effective dose according to the age and sex of individuals. This is the average annual effective dose per beneficiary, i.e. the sum of the effective doses corresponding to diagnostic procedures performed on patients of a given age and sex, divided by the population of that age and sex.

This quantity is an indicator of the exposure of the French population as a whole, without distinguishing between the population exposed or not to medical radiation. The average effective dose received by only those individuals actually exposed will be studied in Chapter 5 of this report.

Figure 9 below shows the average annual effective dose per beneficiary, expressed in mSv, by age group and sex, per beneficiary, expressed in mSv.

Doses vary widely depending on the age of the individual: from less than 0.1 mSv per year for children under 10 to more than 5 mSv per year for men aged 75 to 85. Overall, the dose increases more rapidly with age, reaching a maximum in the 75-79 age group for men and 80-84 for women, and then decreases fairly rapidly.

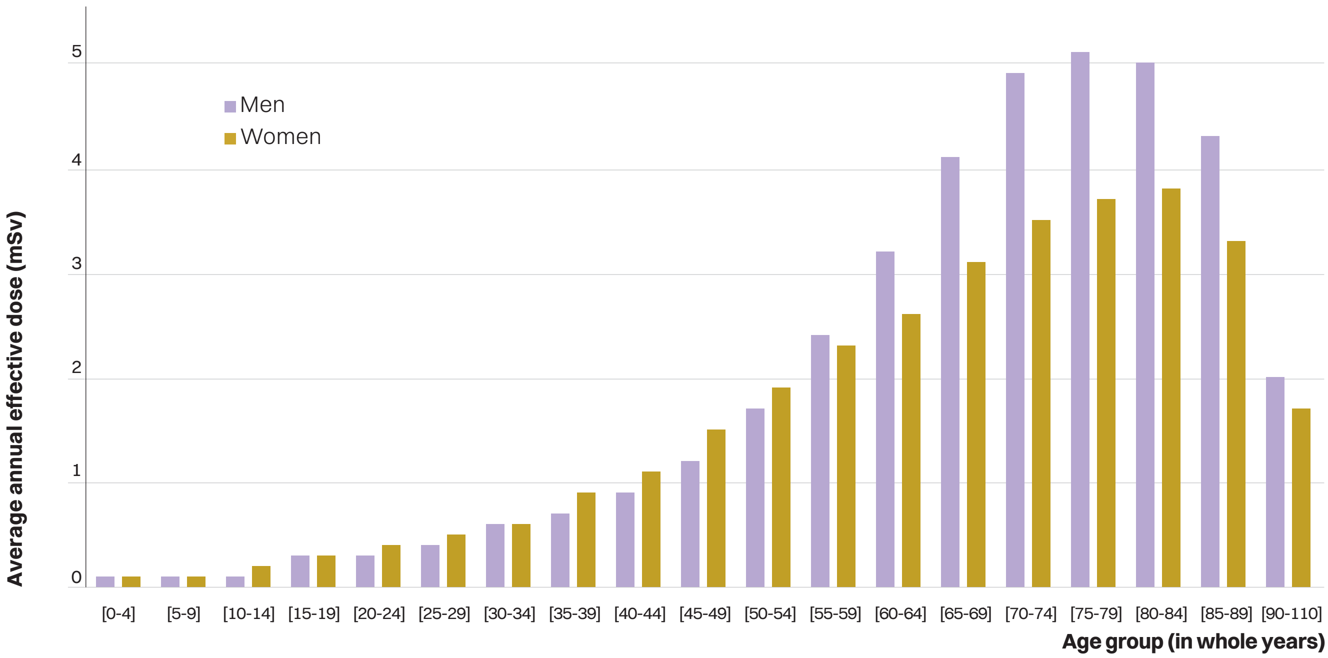
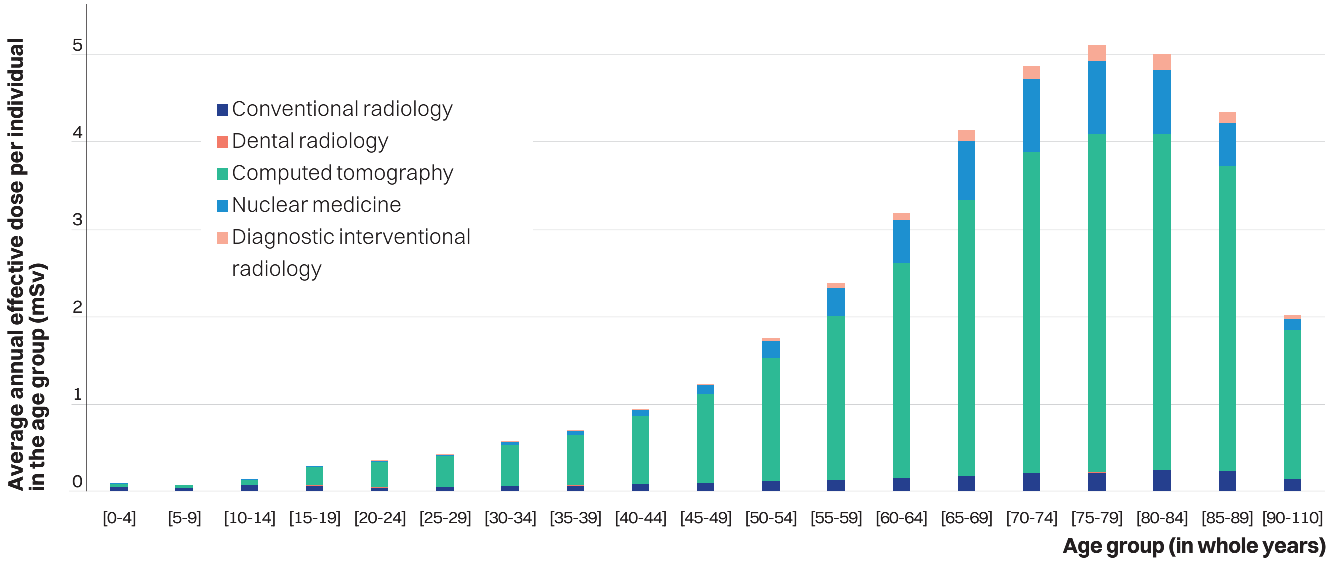


Figure 9. Average annual effective dose per beneficiary by age group and sex.

In contrast to what is observed for procedure frequencies, the male population over the age of 60 receives a noticeably higher average effective dose than the female population, as can be clearly seen in **Figure 10** below. Overall, taking all ages together, the average annual effective dose is around 1.6 mSv per man, compared with 1.5 mSv per woman, as shown in **Table VII** below. We can see that this difference is mainly due to CT scans, which as indicated in the previous section are more frequent among men, and to a lesser extent, nuclear medicine and diagnostic interventional radiology.

On the other hand, the contribution of conventional radiology is much higher for women than for men because of mammography examinations, as shown in section 4.2.1 below.

Men



Women

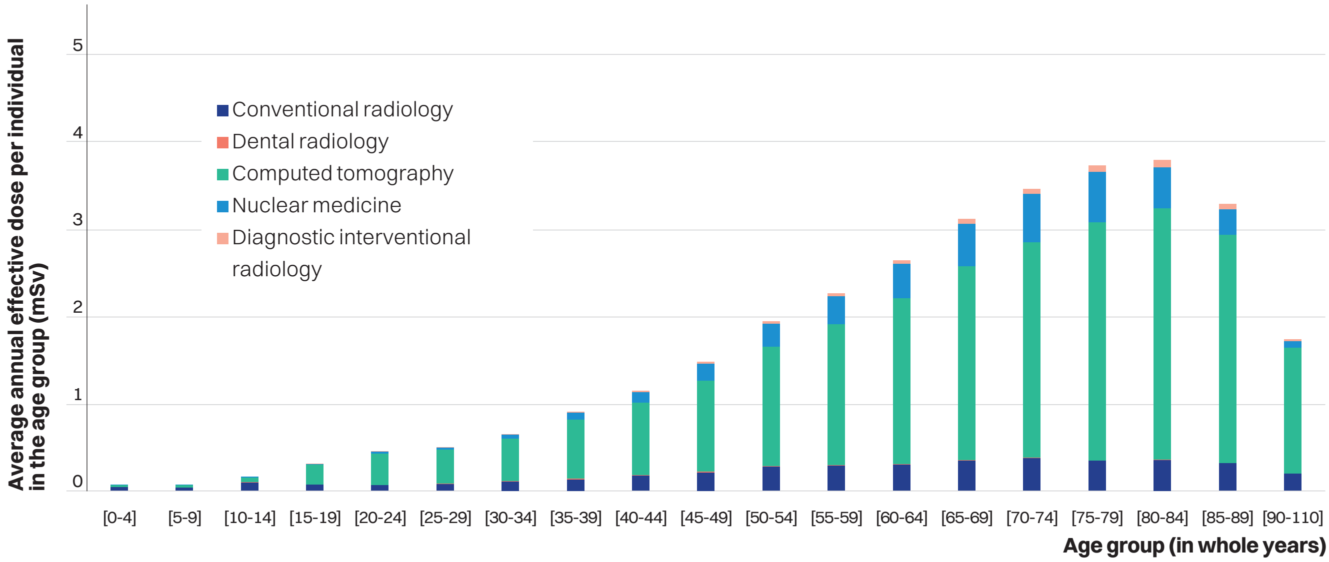


Figure 10. Comparison of average annual effective doses between the male and female populations, by modality and age group.

Figure 10 above shows the contribution of each imaging modality according to age and sex, in addition to **Table VII** below:

- The increasingly important contribution of CT scans with the age of the individual is very clearly demonstrated: CT scans account for the vast majority of the collective effective dose for all age groups from 15 upwards and for both sexes. However, the contribution of CT scans is much more marked in men from around the age of 55.
- The dose attributable to conventional radiology is higher in women from the age of 10. The biggest differences between men and women are in the 45-84 age bracket.
- Dental radiology does not contribute significantly to the average effective dose for any age group. This is due to the characteristics of diagnostic procedures of this modality (very localised exposure of an area with few radiosensitive organs). This should not obscure the fact that local exposure, particularly of the salivary glands, may be relatively high; these results should therefore be interpreted with care.
- Nuclear medicine makes a significant contribution to the average effective dose from the age of 45, particularly in men, where it is the second largest contributor to the dose, ahead of conventional radiology.
- Diagnostic interventional radiology makes a fairly significant contribution to the average effective dose from the age of 55-60, more pronounced for men than women.

Imaging modality	Men		Women		OVERALL	
	µSv/indiv.	%	µSv/indiv.	%	µSv/indiv.	%
Conventional radiology	92	5.7	186	12.2	**140**	**8.9**
Dental radiology	4	0.3	5	0.3	**5**	**0.3**
Computed tomography	1,268	78.0	1,112	73.0	**1,189**	**75.6**
Nuclear medicine	216	13.3	196	12.9	**206**	**13.1**
Diagnostic interventional radiology	44	2.7	24	1.6	**34**	**2.2**
ALL MODALITIES	**1,625**	**100.0**	**1,523**	**100.0**	**1,574**	**100.0**

Table VII. Average annual effective dose by sex and imaging modality, all ages combined.

4.2 EXPOSURE DISTRIBUTION BY CATEGORY OF EXAMINATIONS: FREQUENCY OF PROCEDURES AND AVERAGE DOSES PER BENEFICIARY

This chapter deals with the frequency of imaging procedures and the average effective dose per group of procedures. These groups of procedures were defined in Chapter II of this report and correspond to anatomical zones or types of examination when anatomical zones are not relevant. In this chapter, for each imaging modality in turn:

- a table summarising average procedure frequencies and average annual effective doses by procedure group is presented, for the population as a whole and for each sex; procedure groups are ranked by decreasing procedure frequency in the general population,
- two graphs show the frequency of procedures by age group and sex.

CONVENTIONAL RADIOLOGY

Conventional radiology procedures on the limbs are the most frequent, for both men and women: they account for around one third of annual procedures (see **Table VIII** below). They are significantly more frequent in women. However, as the effective doses associated with radiographs of the limbs are very low, due to the absence of organs considered to be radiosensitive in the field exposed to ionising radiation, the contribution of procedures on this anatomical area to the average annual effective dose per beneficiary is extremely low. As with dental radiology, this is linked to the characteristics of these radiographs (very localised exposure of an area with no radiosensitive organs) and should not mask the fact that local exposure can be relatively high.

The second most frequent group of conventional radiology procedures overall are chest radiographs (2nd group for men and 3rd group for women, after limb radiographs and mammography). Their contribution to the average annual effective dose per beneficiary is much higher than that of procedures on the limbs, but remains very moderate compared with other anatomical areas such as the pelvis or spine.

Mammography is the 2nd most frequent group of conventional radiology procedures performed on women, with an average annual frequency of 137 procedures per 1,000 beneficiaries. Logically, this frequency varies greatly according to the age of the women, as shown in **Figure 11** below. Mammography is also the 2nd highest contributor to the average annual effective dose per woman in conventional radiology, at just over 47 µSv. The characteristics of these examinations (localised exposure of a single radiosensitive organ) are one of the causes. This should not obscure the fact that exposure of the mammary gland can be relatively high.

Procedures involving the pelvis represent the 3rd most frequent group of conventional radiology procedures for men and the 4th most frequent for women, although they are significantly more frequent for women than for men. They account for the largest proportion of the average annual effective dose attributable to conventional radiology, comparable to that from spinal procedures.

Spinal procedures are the 4th and 5th most frequent conventional radiology group for men and women respectively, although they are noticeably more frequent for women. Together with procedures on the pelvis, they represent the two groups with the greatest impact on the average annual effective dose per beneficiary.

Bone mineral densitometry is the 6th most frequent group overall. It is seven times more frequent in women than in men. These examinations are the smallest contributors to the average annual effective dose per beneficiary.

Procedures involving the digestive tract, which represent the 7th most frequent group overall, are nevertheless the 4th highest contributor to the average annual effective dose per beneficiary in conventional radiology, due to the relatively high effective doses associated with this type of radiography.

Procedures on other anatomical areas are both infrequent and make only a small contribution to the average annual effective dose per beneficiary.

Examination category	Procedure frequency (/1000 indiv.)			Average annual effective dose (µSv/indiv)		
	Men	**Women**	**OVERALL**	**Men**	**Women**	**OVERALL**
Limbs	165.3	212.3	**189.2**	0.23	0.31	**0.27**
Chest	127.4	119.5	**123.4**	5.68	5.01	**5.34**
Mammography	0.5	136.5	**69.5**	0.17	47.3	**24.07**
Pelvis	52.8	83.5	**68.4**	35.41	56.85	**46.29**
Spine	41.2	62.5	**52**	29.66	44.25	**37.07**
Bone mineral densitometry	2.5	17.6	**10.2**	<0.01	0.02	**0.01**
Digestive tract	6.8	7.6	**7.2**	13.86	22.88	**18.44**
Head and neck	5.3	3.9	**4.6**	0.95	0.98	**0.96**
Other	4.8	2.8	**3.8**	2.34	1.37	**1.85**
Skeletal system	1.6	2.1	**1.8**	1.59	2.18	**1.89**
Urogenital system	1.1	2.5	**1.8**	2.52	4.79	**3.67**
TOTAL	**409.3**	**650.8**	**531.9**	**92.4**	**185.9**	**139.9**

Table VIII. Distribution of exposure by category of examination in conventional radiology: frequency of procedures and average effective dose per beneficiary.

Figure 11 below shows very significant variations in the distribution of locations of conventional radiology procedures according to age, as well as certain sex-related specificities:

- Radiographs of the limbs are very frequent in children aged between 10 and 14, then become less frequent in adulthood before increasing again, particularly in women, reaching a peak around the age of 75.
- Chest radiographs are increasingly frequent as people get older, becoming the most common group of procedures for men aged 65 and over. Children under the age of 5 are a special case, since the majority of procedures are performed on the chest.
- The frequency of procedures on the pelvis also increases markedly with age. These procedures are more frequent among women in all age groups.
- Mammography is a special group, since they almost exclusively concern women and the vast majority of procedures are concentrated in the 40 to 84 year age group, given that the age of organised breast cancer screening in the year under review was between 50 and 74 years old.

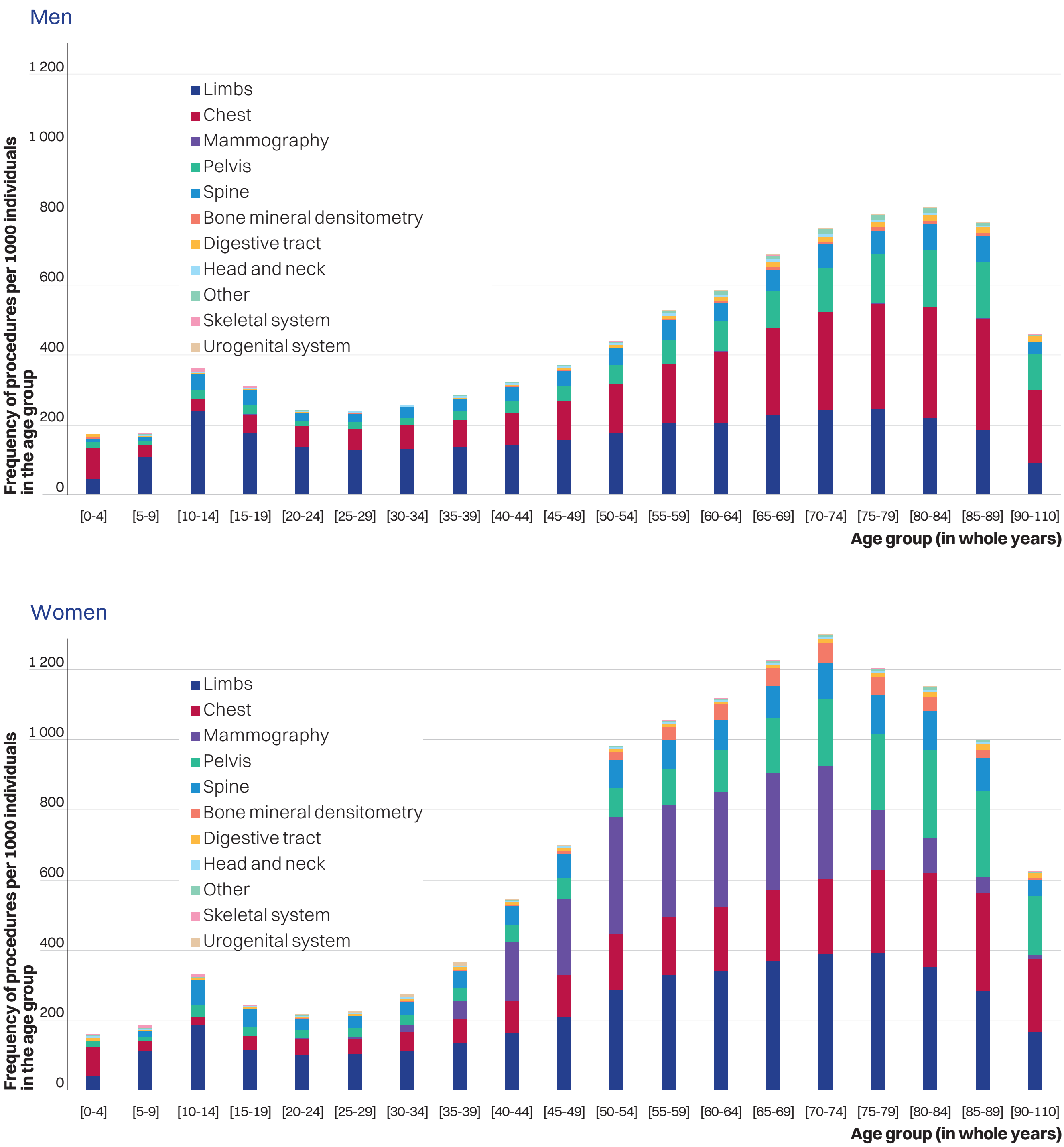


Figure 11. Comparison of frequencies of conventional radiology procedures by examination category and age group in the male and female populations.

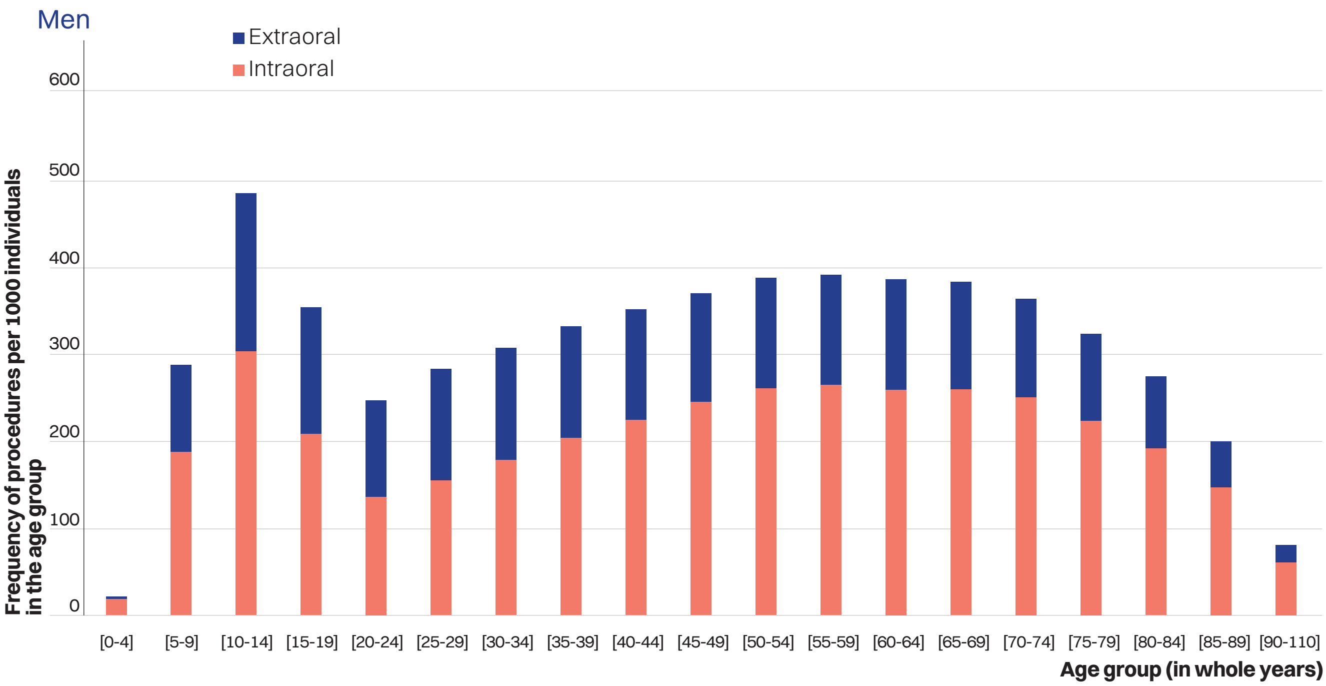
DENTAL RADIOLOGY

Dental radiology procedures are divided into two groups in **Table IX** below: intraoral radiographs, which account for around two-thirds of procedures, and extraoral radiographs, which include dental panoramic, cone-beam CT and teleradiographs of the skull, for the remaining third. In each of these groups, the frequency of procedures is markedly higher among women. As a result, the average annual effective dose per woman from dental radiology is around 15-20% higher than for men. The extraoral radiography group accounts for about two-thirds of the average annual effective dose, which in total represents only an extremely small proportion of the collective effective dose from diagnostic medical imaging (0.3%, see section 4.1 of this report).

The age distribution of the two groups of dental radiology procedures is shown in **Figure 12** below. The frequency of procedures is highest in the 10-14 age group, for both groups of procedures and for both sexes. It then decreases until the age of 20-24. The frequency of extraoral radiography then remains relatively stable, at around 130 procedures per 1,000 men and 150 procedures per 1,000 women, until around the age of 70, before declining very rapidly. The frequency of intraoral radiography increases progressively from the age of 25 until 55-59, when it reaches 264 procedures per 1,000 men and 298 procedures per 1,000 women. This frequency decreases slowly, and then very rapidly after the age of 75.

Examination category	Frequency of procedures (/1000 indiv.)			Average annual eff. dose (µSv/indiv)		
	Men	**Women**	**OVERALL**	**Men**	**Women**	**OVERALL**
Intraoral	208.2	233.0	**220.8**	1.4	1.6	**1.5**
Extraoral	117.3	135.8	**126.7**	3.1	3.7	**3.4**
TOTAL	**325.5**	**368.8**	**347**	**4.5**	**5.3**	**4.9**

Table IX. Exposure distribution by examination category in dental radiology: frequency of procedures and average effective dose per beneficiary.



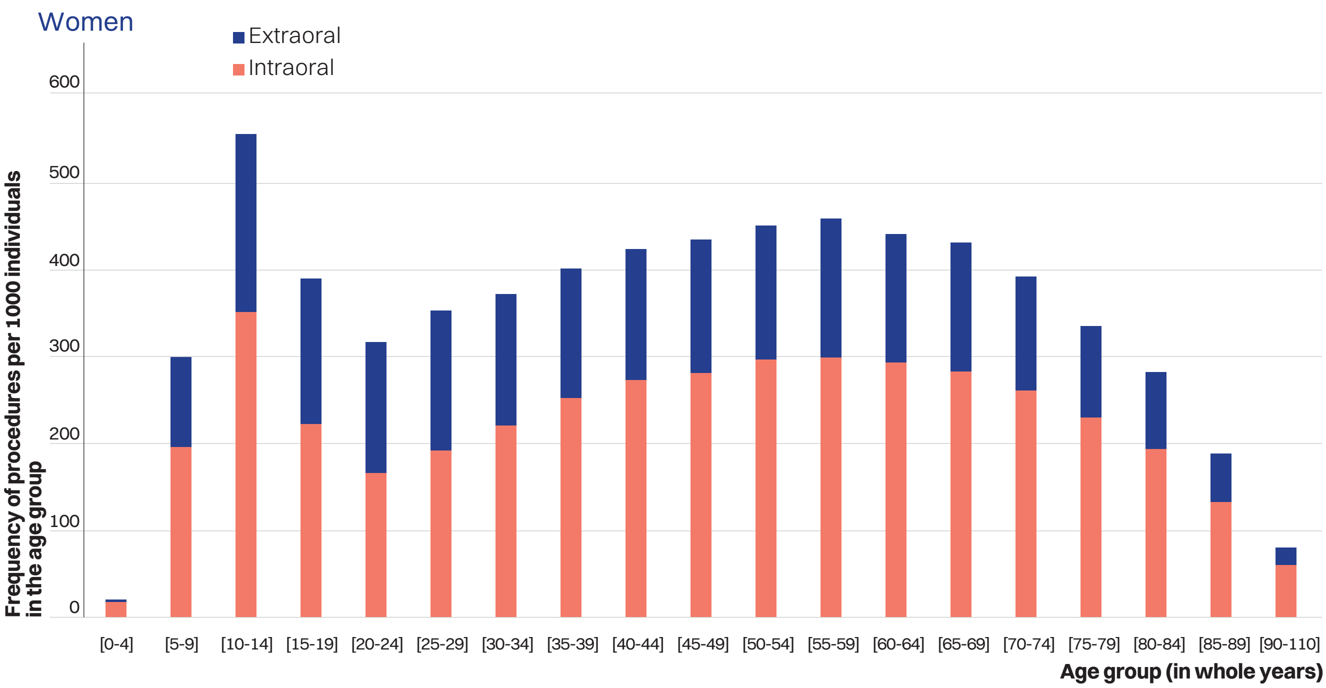


Figure 12. Comparison of the frequency of dental radiology procedures by examination category and by age group in the male and female populations.

Focus

Comparison of procedure frequencies and effective doses delivered in extraoral dental radiology and facial CT scans in 2017 and 2022, particularly in children aged 11 to 15

Given the rapid development of cone beam computed tomography (CBCT) in the dental field, particularly since the last ExPRI report on 2017 data, it seemed useful to assess the impact of its development on procedure frequencies and effective doses delivered in extraoral dental radiology, i.e. orthopantomography (more commonly known as dental panoramic) and CBCT, as well as for CT scans of the face (dentascan).

This analysis is of particular interest for children aged 11 to 15, for whom this type of examination is more commonly prescribed as part of orthodontic treatment in particular.

Procedure frequencies were calculated for the years 2017 and 2022 for three groups of patients: the general population of ESND beneficiaries, children aged 15 and under, and children aged 11 to 15.

The results are presented in **Tables X, XI and XII**.

Code	Title	2017 frequency of procedures per 1,000 beneficiaries	2022 frequency of procedures per 1,000 beneficiaries	Absolute difference	Relative difference
HBQK002	**Panoramic dental-maxillary radiograph**	97.7	108.5	10.9	11.1%
LAQK027	**CBCT of the maxilla, mandible and/or dental arch**	7.8	12.2	4.4	56.2%
LAQK013	**CT scan of the face**	6.1	5.1	-1.0	-15.8%

Table X. Frequency of extraoral procedures and facial CT scans in the general population of ESND beneficiaries for the years 2017 and 2022.

Code	Title	2017 frequency of procedures per 1,000 beneficiaries aged 15 and under	2022 frequency of procedures per 1,000 beneficiaries aged 15 and under	Absolute difference	Relative difference
HBQK002	**Panoramic dental-maxillary radiograph**	69.2	81.5	12.3	17.7%
LAQK027	**CBCT of the maxilla, mandible and/or dental arch**	2.4	4.1	1.6	68.1%
LAQK013	**CT scan of the face**	1.4	0.9	-0.5	-36.8%

Table XI. Frequency of extraoral procedures and facial CT scans in children aged 15 and under for the years 2017 and 2022.

These results show that, overall, fewer of these procedures are performed on children aged 15 and under than on the general population. However, this is not the case for the specific category of children aged 11 to 15, for whom the frequency of panoramic procedures is higher (139 procedures per 1,000 beneficiaries in this age group) than for the general population (109 procedures per 1,000 beneficiaries) in 2022. This difference may be linked in particular to orthodontic treatment, which is often carried out on beneficiaries in this age group and for which one or more panoramic examinations may be necessary [27].

For the three populations considered, the same trends are observed between 2017 and 2022:

- an increase in the frequency of panoramic examinations (from 10 to 18% depending on the population considered);
- a more marked increase in the frequency of CBCT procedures (from 56% to 68%);
- a reduction in the frequency of facial CT scans (from 15% to 50%).

In this context, in April 2021, the ASN and the Dental radiation protection commission (CRD) reminded dental surgery professionals of the importance of individual justification for the prescription of panoramic radiography and compliance with its clinical indications [27], in particular that:

- panoramic radiographs should only be performed in the presence of specific clinical signs and symptoms,
- there is no justification for panoramic radiographs to be performed at regular intervals or on a systematic basis.

The results seem to suggest, particularly in children aged 11 to 15 years, a shift from facial CT scans to dental CBCT examinations, which produce lower effective doses. This type of substitution is positive from the point of view of patient radiation protection. However, it is important to remain vigilant about the appropriate use of this technique, for which the appropriation of indications and the justification for its use are still recent, especially in children.

Code	Title	2017 frequency of procedures per 1000 beneficiaries aged 11 to 15	2022 frequency of procedures per 1000 beneficiaries aged 11 to 15	Absolute difference	Relative difference
HBQK002	**Panoramic dental-maxillary radiograph**	126.8	139.4	12.6	9.9%
LAQK027	**CBCT of the maxilla, mandible and/or dental arch**	5.3	8.8	3.5	64.7%
LAQK013	**CT scan of the face**	3.0	1.5	-1.5	-50.4%

Table XII. Frequency of extraoral procedures and facial CT scans in children aged 11 to 15 for the years 2017 and 2022.

Focus

Comparison of procedure frequencies and effective doses delivered in extraoral dental radiology and facial CT scans in 2017 and 2022, with particular reference to children aged 11 to 15

Changes in effective doses delivered to children aged 11 to 15 specifically

An analysis was also carried out to assess the impact of these changes on the effective doses relating to these examinations in children aged 11 to 15 specifically.

The detailed results of this analysis for panoramic examinations, dental CBCT and facial CT scans are presented in **Table XIII** below.

In 2017, effective doses from panoramic examinations, dental CBCT, and facial CT scans accounted for 2.2% of the effective dose from all examinations combined received by children aged 11 to 15, representing a 13.1% share in terms of procedure frequency. By 2022, this proportion in terms of effective dose rose slightly to 2.6%, with a share in terms of procedure frequency of 16.1%.

In 2017, the average effective dose per beneficiary from facial CT scans was fairly close to that from dental panoramic scans (1.9 µSv vs. 2.4 µSv respectively). In 2022, the effective dose contribution from facial CT scans fell compared with 2017 and is equivalent to around a third of that from dental panoramic procedures. By way of comparison, it should be noted that, generally speaking, between 2017 and 2022 the overall effective dose per beneficiary for all examinations combined for children aged 11 to 15 fell by around 20%.

In addition, **Figures 13 and 14** below show, specifically for children ages 11 to 15, the distribution of procedure frequencies and effective doses for panoramic examinations, dental CBCT, and facial CT scans in 2017 and 2022. Dental panoramic examinations deliver the lowest dose (per procedure) of the three examinations considered.

As a result, by 2022, dental panoramic procedures will account for 93% of all procedures, but only 59% of the effective dose relating to these procedures. Facial CT scans, which account for only 1% of the dental procedures considered in this Focus, but which are the examinations with the highest dose, represent 21% of the effective dose delivered. Finally, although CBCT examinations account for only 6% of procedures, they contribute 20% of effective doses from extraoral examinations and facial CT scans. These figures should be compared with the distribution for 2017, when dental CBCT examinations accounted for only 4% of procedures and 11% of the effective dose for the three types of examination considered here.

The decrease in the frequency of facial CT scans somewhat limits the effect of the increase in frequency of CBCT and dental panoramic procedures on the doses delivered to children aged 11 to 15.

Code	Title	% effective dose in 2017 compared to dose of all procedures combined	% effective dose in 2022 compared to dose of all procedures combined
HBQK002	**Panoramic dental-maxillary radiograph**	1.1	1.5
LAQK027	**CBCT of the maxilla, mandible and/or dental arch**	0.2	0.5
LAQK013	**CT scan of the face**	0.9	0.5
	TOTAL	**2.2**	**2.6**

Table XIII. Percentage of effective dose for extraoral examinations and facial CT scans compared with the effective dose for all procedures combined in children aged 11 to 15 for the years 2017 and 2022.

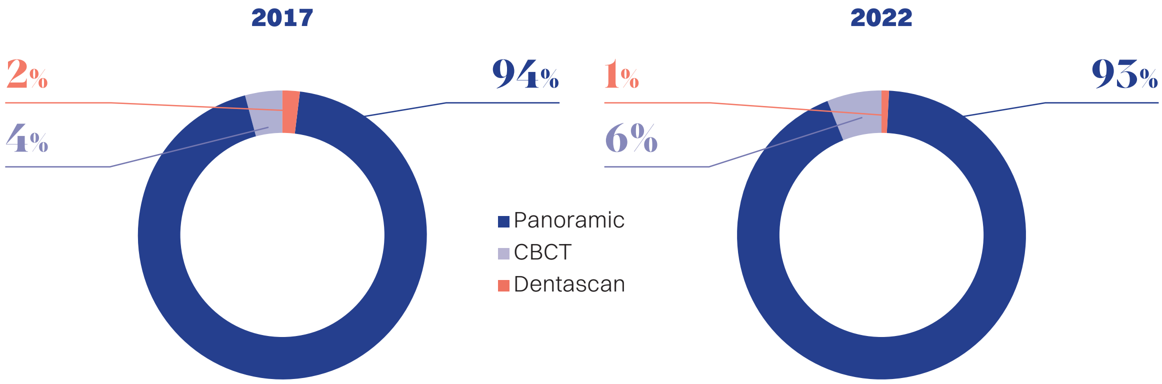


Figure 13. Distribution of frequencies for panoramic procedures, dental CBCT, and facial CT scans in children aged 11 to 15 in 2017 and 2022.

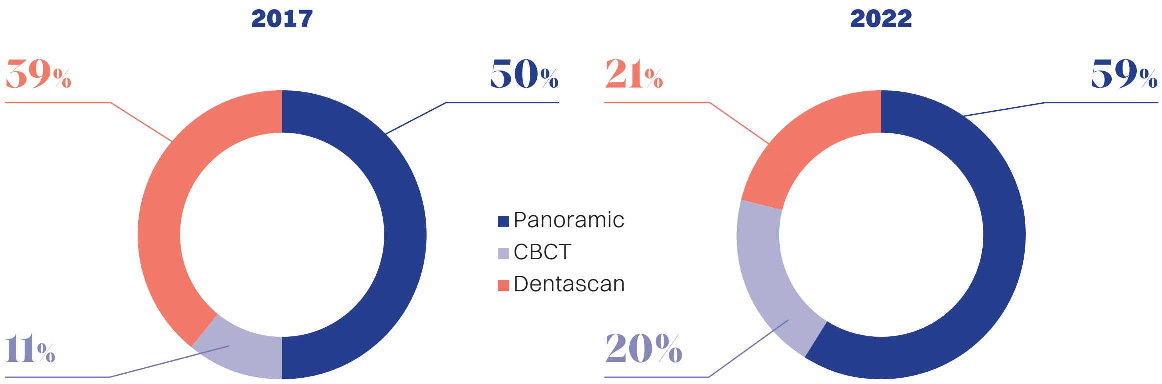


Figure 14. Distribution of effective doses for panoramic procedures, dental CBCT, and facial CT scans in children aged 11 to 15 in 2017 and 2022.

COMPUTED TOMOGRAPHY

As **Table XIV** below shows, the anatomical areas that most frequently undergo CT scan are the abdominal-pelvic region, the chest and heart region, and the head and neck region, with roughly equivalent frequencies in men and women. However, the abdominal-pelvic region contributes around six times more to the average annual effective dose per beneficiary than the head and neck region, and slightly more so for men.

CT scans covering multiple areas take fourth place. For this group, the frequency of procedures is higher for men than for women, with a significant difference in average annual effective doses between men and women, of around 100 µSv per beneficiary.

Spine CT scans are the only group for which both the frequency of procedures and the average annual effective dose are higher in women than in men.

CT scans of the limbs are both relatively infrequent and make only a small contribution to the average annual effective dose per beneficiary. It should be noted that CT scans of the "head and neck" region, although the third most frequent procedure, also contribute little to the average annual effective dose per beneficiary.

Anatomical area	Frequency of procedures (/1000 indiv.)			Average annual eff. dose (µSv/indiv)		
	Men	Women	OVERALL	Men	Women	OVERALL
Abdomen and/or pelvis	40.9	38.4	**39.6**	353.2	321.0	**337.0**
Chest and heart	42.6	36.6	**39.6**	228.8	196.1	**212.3**
Head and neck	33.7	33.6	**33.6**	60.6	57.6	**59.1**
Multiple areas	29.6	23.3	**26.4**	430.6	339.2	**384.3**
Spine	14.2	17.9	**16.1**	125.3	157.2	**141.5**
Limbs	14.0	12.5	**13.2**	69.7	40.5	**54.9**
Other	<0.1	<0.1	**<0.1**	<0.1	0.2	**0.1**
TOTAL	**174.9**	**162.3**	**168.5**	**1,268.2**	**1,111.7**	**1,189.2**

Table XIV. Exposure distribution by examination category in CT scans: frequency of procedures and average effective dose per beneficiary.

Figure 15 below shows that the change in procedure frequencies with the age of individuals is relatively similar for all groups of CT scan procedures. Extremely low before the age of 15, they increase progressively with age, peaking between the ages of 70 and 90, depending on the anatomical area and the sex. Over the age of 90, they fall sharply. Taking all categories of examination together, the frequency of procedures for men and women is fairly similar in adults aged 20 to 50, but the difference in favour of men widens sharply after the age of 55.

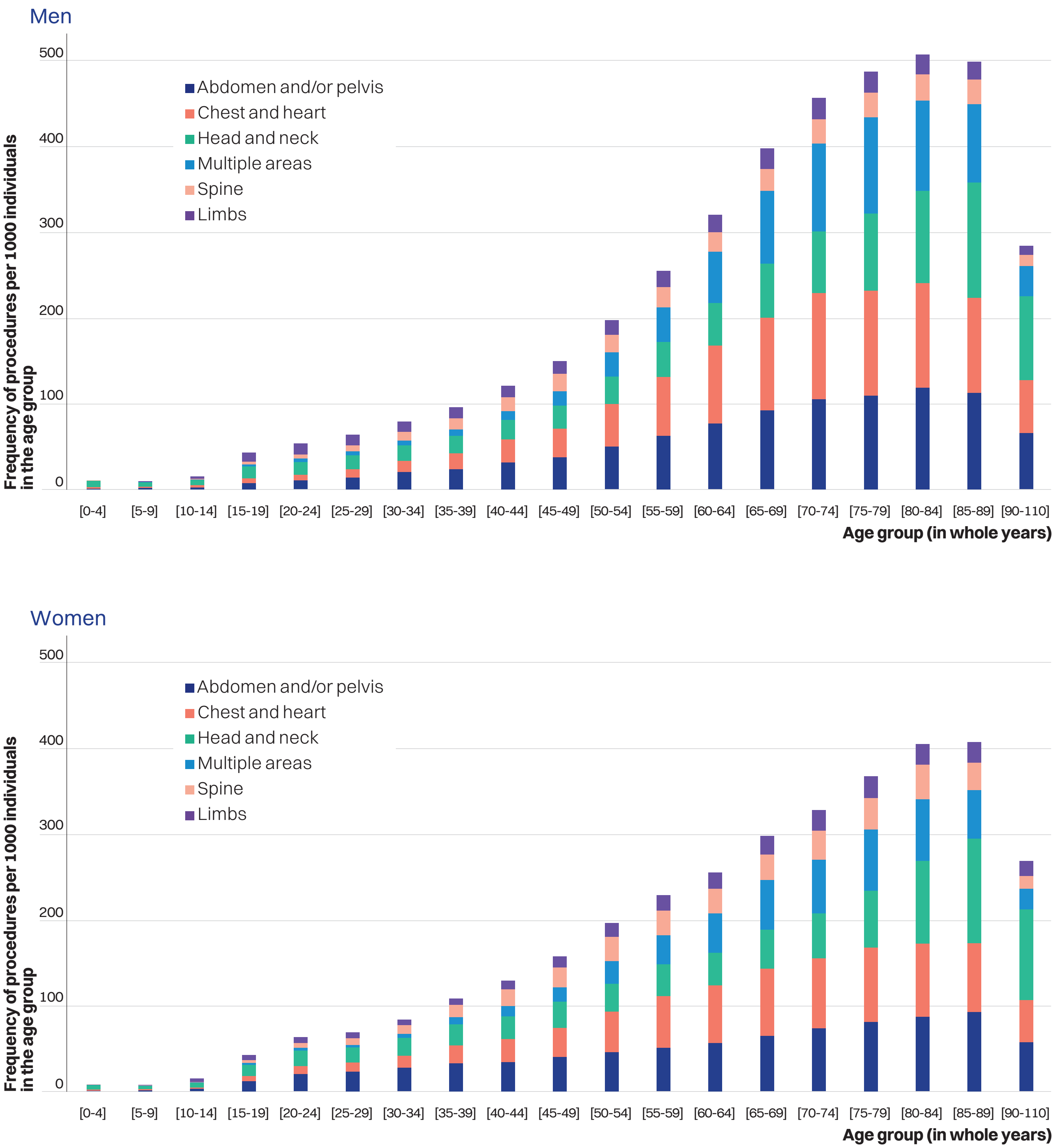


Figure 15. Comparison of the frequency of CT scans by examination category and by age group in the male and female populations.

NUCLEAR MEDICINE

The frequencies of nuclear medicine procedures (**Table XV** below) are high for three main categories of procedures: PET and oncology in first place, followed by the circulatory system and then the osteoarticular and muscular systems. These three groups are also the biggest contributors to the average annual effective dose per beneficiary.

Procedures concerning the endocrine system rank 4th in terms of procedure frequency and average annual effective dose. The other categories follow with very low frequencies.

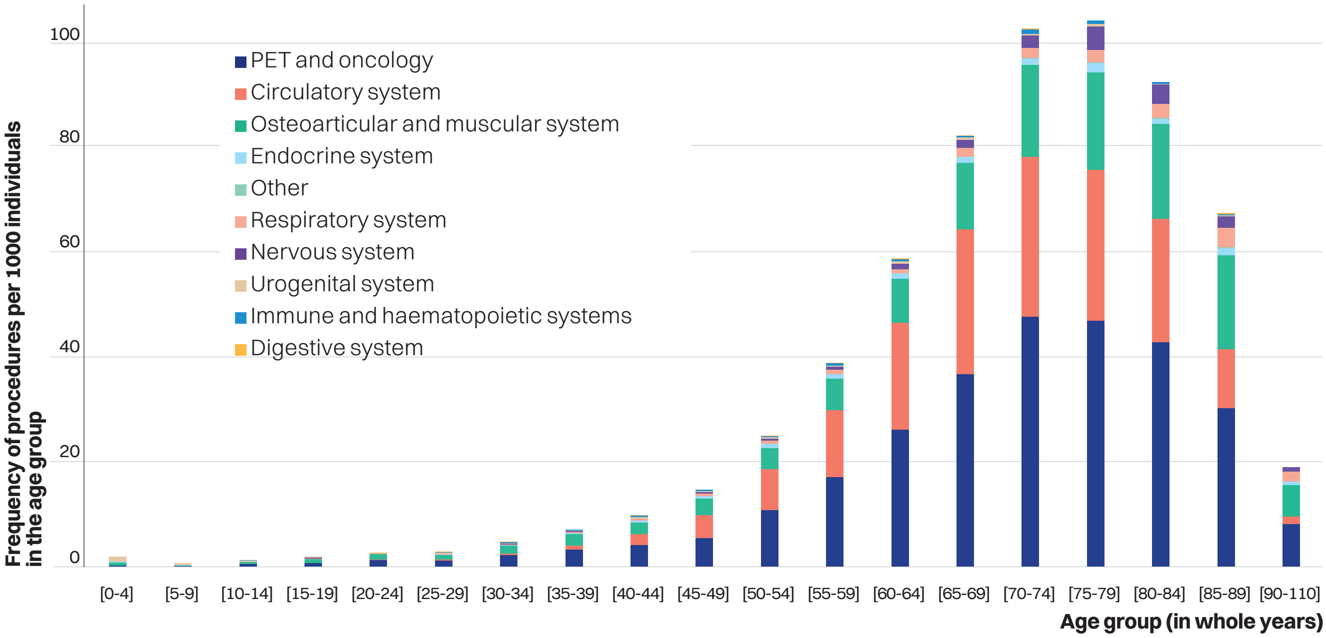
The procedure frequencies for women are higher than those for men for the majority of procedure groups, with the notable exception of procedures involving the circulatory system, for which men have around 50% more examinations, which largely contributes to the fact that the average annual effective dose per beneficiary is higher overall for men than for women for all nuclear medicine procedures.

Anatomical area	Frequency of procedures (/1000 indiv.)			Average annual eff. dose (µSv/indiv)		
	Men	Women	OVERALL	Men	Women	OVERALL
PET and oncology	12.2	13.7	**13.0**	132.8	136.5	**134.7**
Circulatory system	7.9	4.9	**6.4**	60.1	33.5	**46.6**
Osteoarticular and muscular system	5.0	5.1	**5.0**	15.5	15.7	**15.6**
Endocrine system	0.5	1.3	**0.9**	1.5	3.6	**2.6**
Other	<0.1	1.5	**0.8**	<0.1	0.5	**0.2**
Respiratory system	0.6	0.8	**0.7**	1.6	2.1	**1.9**
Nervous system	0.7	0.5	**0.6**	4.0	3.1	**3.5**
Urogenital system	0.3	0.3	**0.3**	0.3	0.4	**0.3**
Immune and haematopoietic systems	0.2	0.3	**0.3**	0.5	0.5	**0.5**
Digestive system	0.1	0.1	**0.1**	0.1	0.1	**0.1**
TOTAL	**27.5**	**28.5**	**28.1**	**216.4**	**196.0**	**206.0**

Table XV. Exposure distribution by category of nuclear medicine examination: frequency of procedures and average effective dose per beneficiary.

Figure 16 below shows that the frequency of nuclear medicine procedures for men is very closely distributed around the 65-85 age group, whereas this distribution is more widespread for women. For the three main categories of examination, the frequency of procedures increases sharply between the ages of 45 and 70 and decreases rapidly between the ages of 75 and 80, depending on sex.

Men



Women

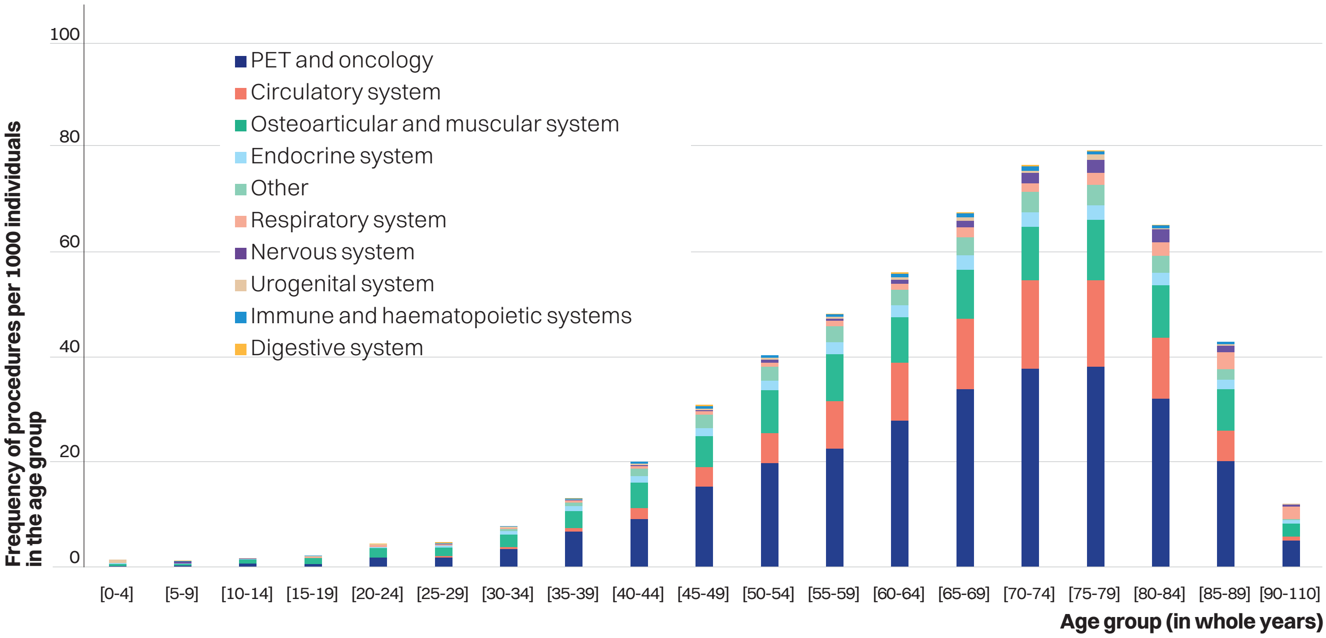


Figure 16. Comparison of the frequency of nuclear medicine procedures by examination category and by age group in the male and female populations.

DIAGNOSTIC INTERVENTIONAL RADIOLOGY

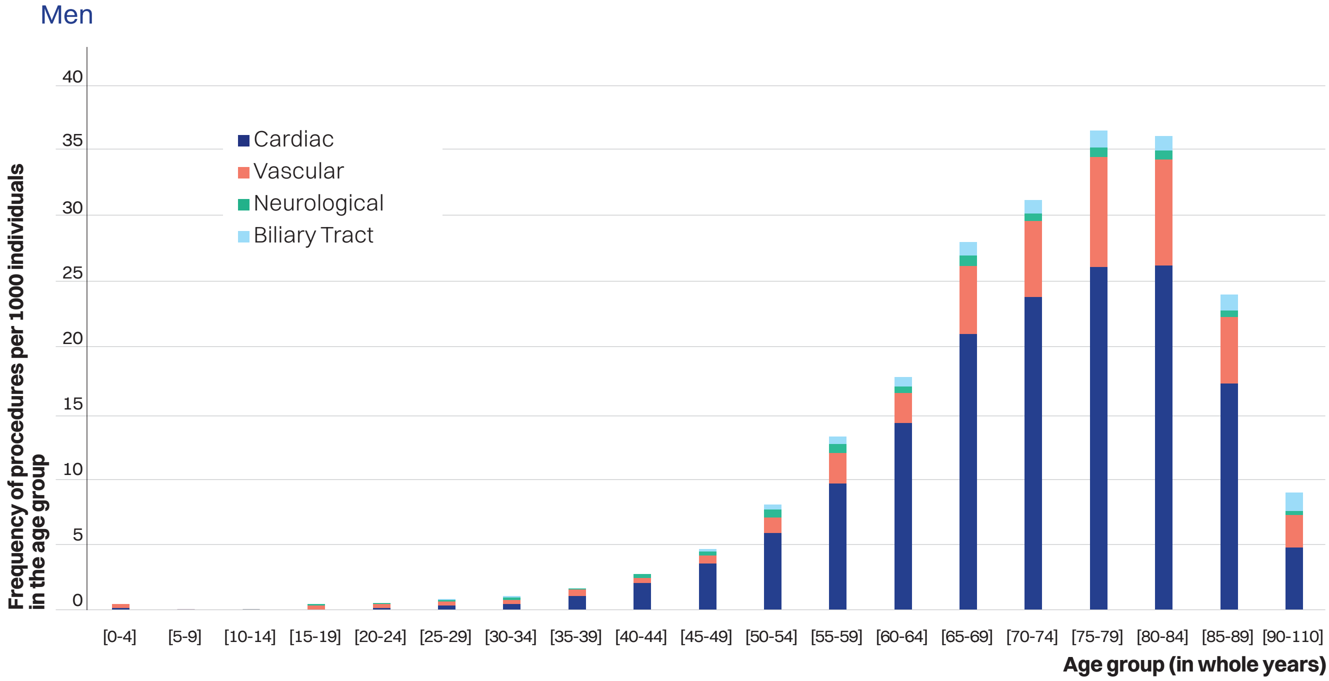
Table XVI below shows that the vast majority of diagnostic interventional radiology procedures are cardiology procedures, which explains why this category is the main contributor to the average annual effective dose associated with this imaging modality. Procedures on the vascular system come second, and are about three times less frequent than cardiac procedures. The neurological and biliary tract categories follow with very low frequencies and very moderate contributions to the average annual effective dose. The frequency of procedures for the vascular and, even more so, cardiac groups is much higher for men than for women. The same applies to the associated average annual effective doses per beneficiary.

It should be remembered here that diagnostic interventional radiology procedures are very frequently associated with therapeutic procedures and, as a result, are not systematically subject to specific CCAM coding. It is likely that a very large number of diagnostic procedures are therefore not taken into account in this study. The figures presented here should not be considered as representative of clinical practice as a whole.

Examination category	Frequency of procedures (/1000 indiv.)			Average annual eff. dose (µSv/indiv)		
	Men	Women	OVERALL	Men	Women	OVERALL
Cardiac	6.5	2.8	**4.7**	26.8	11.4	**19.0**
Vascular	1.7	1.2	**1.5**	13.9	8.7	**11.3**
Neurological	0.3	0.5	**0.4**	2.9	3.2	**3.1**
Biliary tract	0.4	0.3	**0.3**	0.6	0.5	**0.5**
TOTAL	**9.0**	**4.9**	**6.9**	**44.1**	**23.8**	**33.8**

Table XVI. Exposure distribution by examination category in diagnostic interventional radiology: frequency of procedures and average effective dose per beneficiary.

Figure 17 below shows that the frequency of cardiology procedures is extremely low up to the age of 35-40, then rises very quickly in men and more slowly in women, reaching a peak between the ages of 75 and 84. This trend according to age is more or less the same for the other categories of diagnostic interventional radiology procedures, although the small numbers of procedures observed make interpretation uncertain, particularly for the neurological and biliary groups.



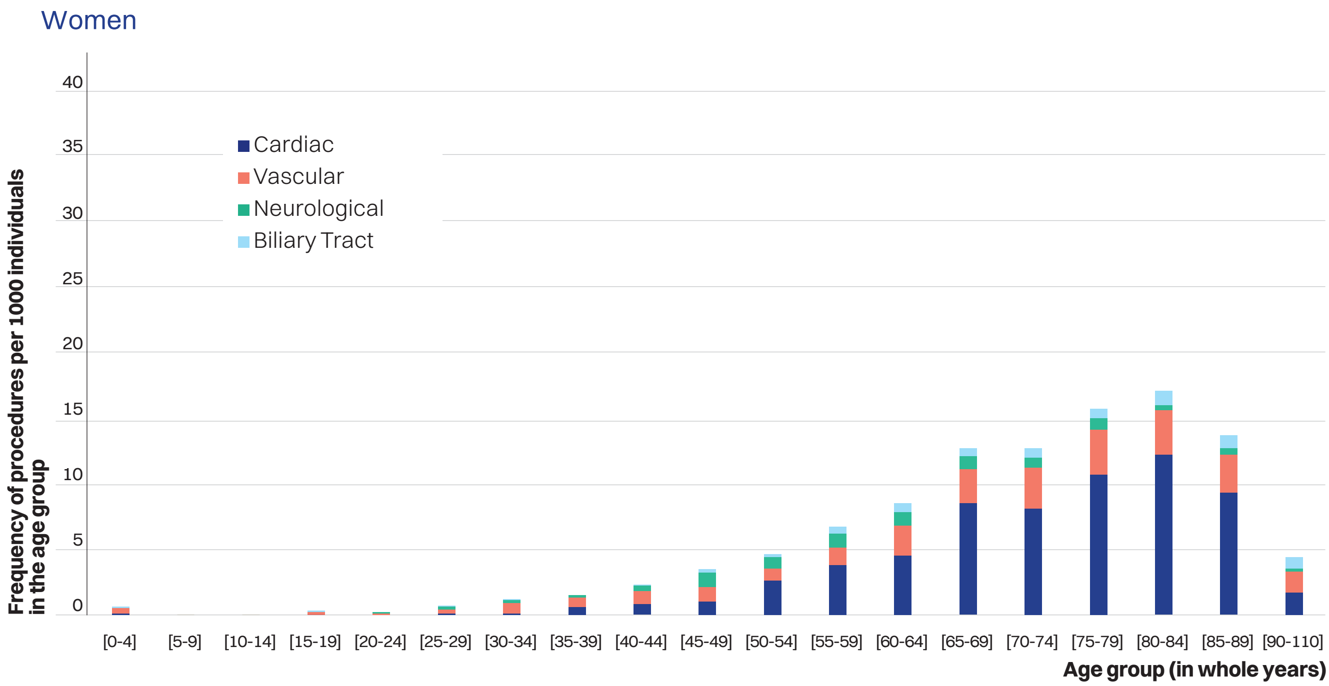


Figure 17. Comparison of frequencies of diagnostic interventional radiology procedures by examination category and by age group in the male and female populations.

5. POPULATION ACTUALLY EXPOSED in 2022

As the ESND is based on both the SNIIRAM for the private sector and the PMSI for hospital stays and outpatient care in the public sector, it is possible to determine the proportion of the population studied that was actually exposed during the year, i.e. having undergone at least one diagnostic imaging procedure using ionising radiation. **This chapter is devoted to the population actually exposed in 2022. The exposed individuals who make up this group will subsequently be referred to as patients.** Patient exposure will be characterised in terms of the number and nature of procedures, as well as annual effective dose per caput.

5.1 CHARACTERISATION OF THE EXPOSED POPULATION

PROPORTION OF INDIVIDUALS ACTUALLY EXPOSED (PATIENTS) AMONG THE COVERED POPULATION

Of the 1,528,651 beneficiaries in the ESND in 2022, 42.6% received one or more diagnostic procedures. As **Table XVII** below shows, these proportions vary widely according to the sex of the individual: the proportion of women exposed is much higher than that of men (47.3% compared with 37.8%). However, this gap is halved if mammography is excluded from the diagnostic procedures taken into account. Even without considering this almost exclusively female examination[1] the difference is around five points. Furthermore, if we exclude dental radiology procedures, which contribute very little to the collective effective dose, the proportion of exposed individuals in the population falls to 28.9%. In 2022, just under one in three French people had at least one diagnostic procedure, excluding dental radiology.

	Men (%)	**Women** (%)	**OVERALL** (%)
All imaging modalities	37.8	47.3	**42.6**
Dental radiology excluded	23.7	33.9	**28.9**
Mammography excluded	37.8	42.6	**40.3**

Table XVII. Proportion of the ESND having undergone at least one diagnostic imaging procedure in 2022.

The proportion of exposed individuals in the population also depends strongly on age, as shown in **Figure 18** below. The fraction of the population having received at least one diagnostic procedure is represented, by age category, as a percentage of the male and female population respectively.

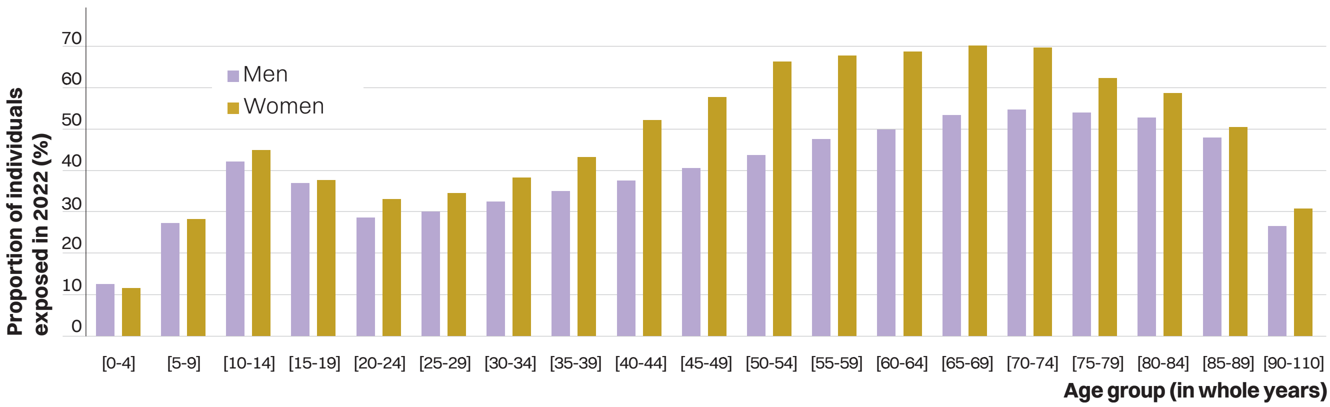


Figure 18. Proportion of individuals exposed in 2022 by age.

1 389 mammography procedures were performed for men, compared with 105,796 for women in the ESND in 2022, i.e. 0.36% of mammography procedures.

It should be noted that the proportion of women exposed is higher than the proportion of men in all age categories. This discrepancy is particularly marked in women aged 35 to 79, which is largely related to mammography examinations, as shown in **Figure 19B** below, in which this type of examination is not taken into account. The exception is children under 5, where the proportion of boys exposed is higher than the proportion of girls. This is in line with what was already observed in the report dedicated to the paediatric population [10] and is due to the higher perinatal mortality of boys compared with girls.

The proportion of exposed individuals in the population increases with age, from around 12% for the youngest children to around 70% for women aged 65 to 74 and around 55% for men aged 65 to 84. Among people under 25, a higher proportion of children and adolescents aged 10 to 19 are exposed, as was also observed in the above-mentioned report [10].

Figure 19A below shows the proportion of individuals exposed to at least one imaging procedure, excluding dental radiology. It should be noted that the general fall in the proportion of individuals exposed modifies only slightly the appearance of the age distribution, with the notable exception of the years corresponding to children and adolescents aged 5 to 19, for whom the proportion is roughly halved. This category of the population is characterised by a high level of use of dental radiology, as indicated in the previous chapter of this report.

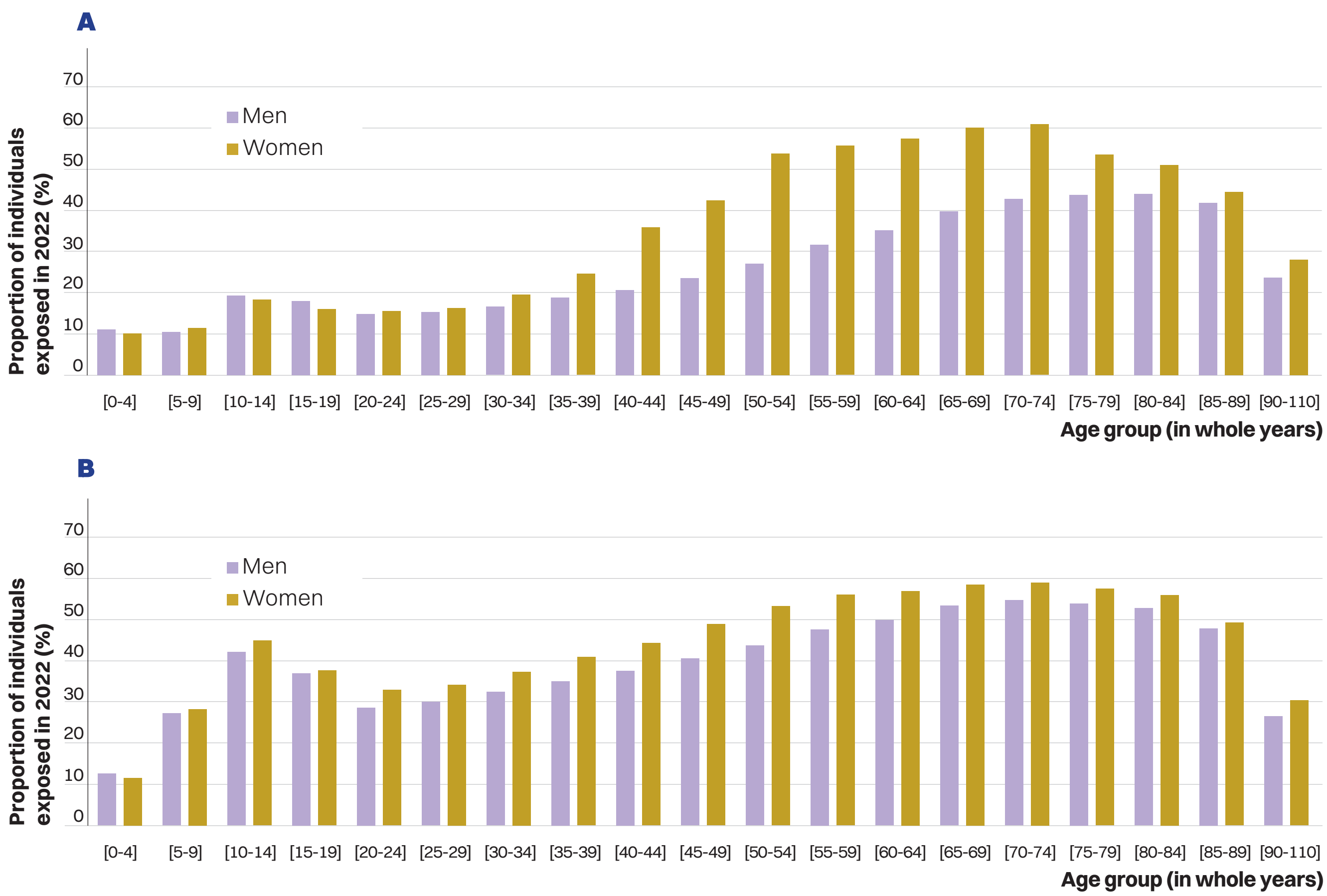


Figure 19. Proportion of individuals exposed in 2022 by sex and year of birth, excluding dental radiology or mammography. **/ A** Dental radiology excluded **/ B** Mammography excluded.

5. POPULATION ACTUALLY EXPOSED in 2022

NUMBER OF PROCEDURES PER PATIENT

The 651,580 people in the ESND exposed to at least one imaging procedure in 2022 underwent 1,654,867 imaging procedures, which represents an average of 2.54 procedures per patient. **Table XVIII** opposite details the various statistics on the annual number of procedures performed on patients. On average, female patients undergo slightly more examinations than male patients (3% more). The distribution of the number of procedures is highly asymmetric, as shown by the different percentiles presented in **Table XVIII**: 50% of patients received one or two procedures in 2022, three-quarters received one to three procedures, and 5% received more than 7 diagnostic procedures in 2022. The maximum number of procedures recorded in the ESND for a single patient was 132.

Number of procedures per patient	Men	Women	OVERALL
Average	2.50	2.57	**2.54**
25th percentile	1	1	**1**
Median	2	2	**2**
75th percentile	3	3	**3**
95th percentile	7	7	**7**
MAXIMUM			**132**

Table XVIII. Statistics on the number of annual procedures per patient, by sex for the year 2022.

The distribution of the average number of diagnostic procedures depends on the patient's age, as shown in **Figure 20** below: young children (aged < 10 years) received fewer than 2 procedures per year on average, while older adults (aged ≥ 75 years) received an average of around 3.4. The increase in the average number of procedures appears to be close to linear with age, with the exception of the 10-14 age group and, to a lesser extent, the 15-39 age groups for men, where an increase in procedures can be observed. Over the age of 75, the average number of procedures performed stabilises for both men and women.

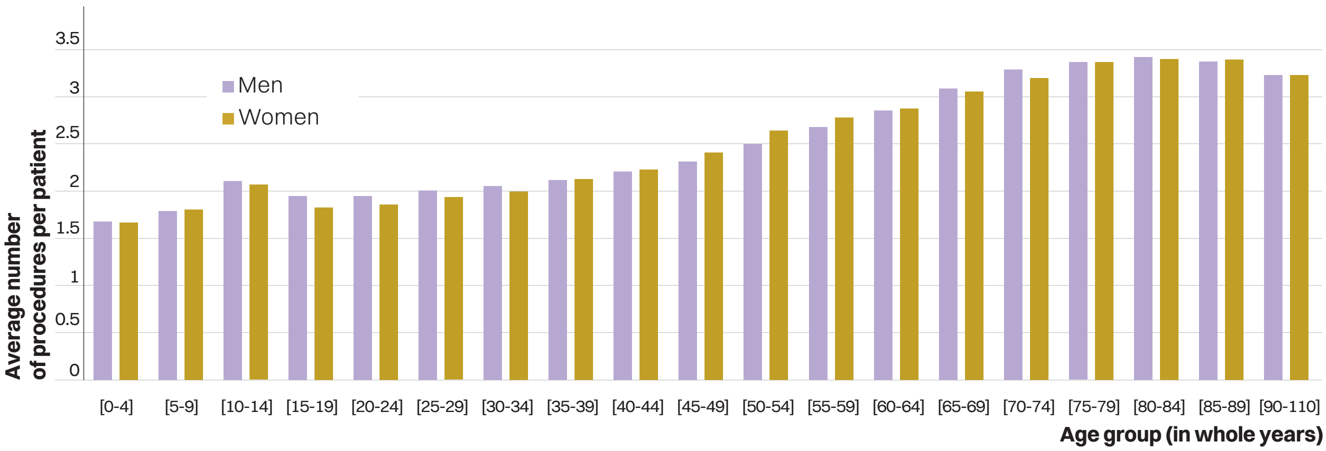


Figure 20. Average number of diagnostic procedures per patient in 2022, by sex and age.

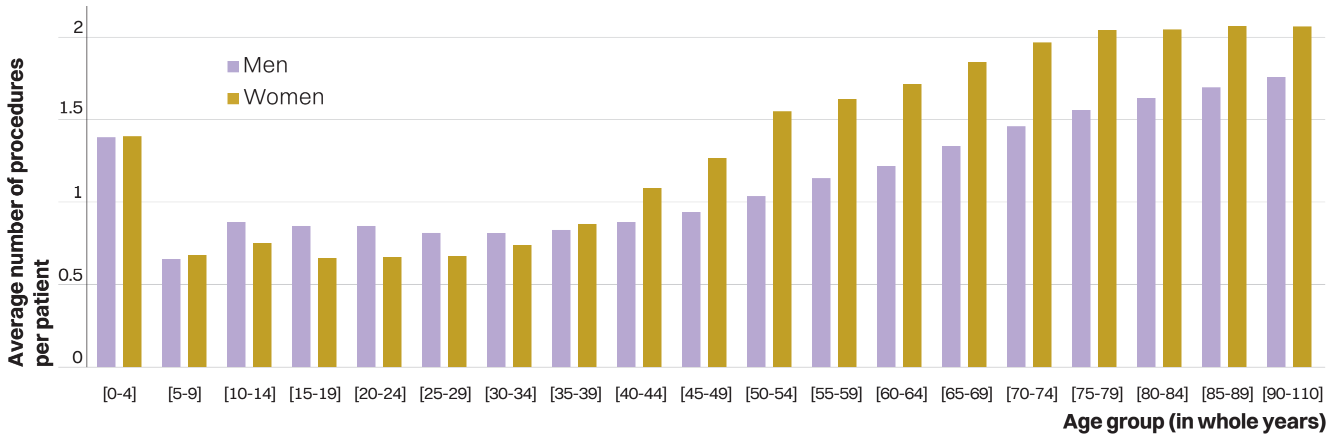
The distribution of the number of procedures by age and sex clearly differs according to the type of imaging performed, as shown in **Figure 21** below for four of them:

- The average number of **conventional radiology** procedures (**Figure 21A**) is relatively high for the youngest children[1] (1.4 per patient for age 5 and under), then stabilises at around 0.7 until the age of 40. In these age ranges, men have more procedures than women[2]. From the age of 40 onwards, the average number of procedures increases almost linearly up to the oldest ages. This increase is more marked for women, who have more annual examinations on average than men across all age groups. This observation is clearly related to mammography linked to breast cancer screening.
- The distribution of the average number of **dental radiology** procedures (**Figure 21B**) follows an inverse trend to that for conventional radiology: the youngest patients (with the exception of children under 5 years of age) have an average of around one dental procedure per year, and this value then falls steadily with age, more sharply still from the age of 85. It should also be noted that younger female patients have slightly more dental radiography examinations on average than younger male patients, with the opposite being true from the age of 35 onwards.
- For **CT scans** (**Figure 21C**), the average number of procedures generally increases with age, and is higher for men. Before the age of 15, the average number of CT scans per patient is very low (around 0.03 to 0.08); it then increases slowly and more sharply to reach a maximum of 0.9 for women and 1.1 for men, for the oldest patients. The difference between men and women is greatest between the ages of 60 and 75: male patients undergo around 1.7 times more CT scans than female patients.
- In **nuclear medicine** (**Figure 21D**), the distribution is also strongly accentuated at older ages. The average number of procedures is very low before the age of 35-40, then increases rapidly, peaking between the ages of 70 and 80 and decreasing rapidly thereafter. The difference between men and women is very significant (a factor of around 1.6) for the over 60 age groups.

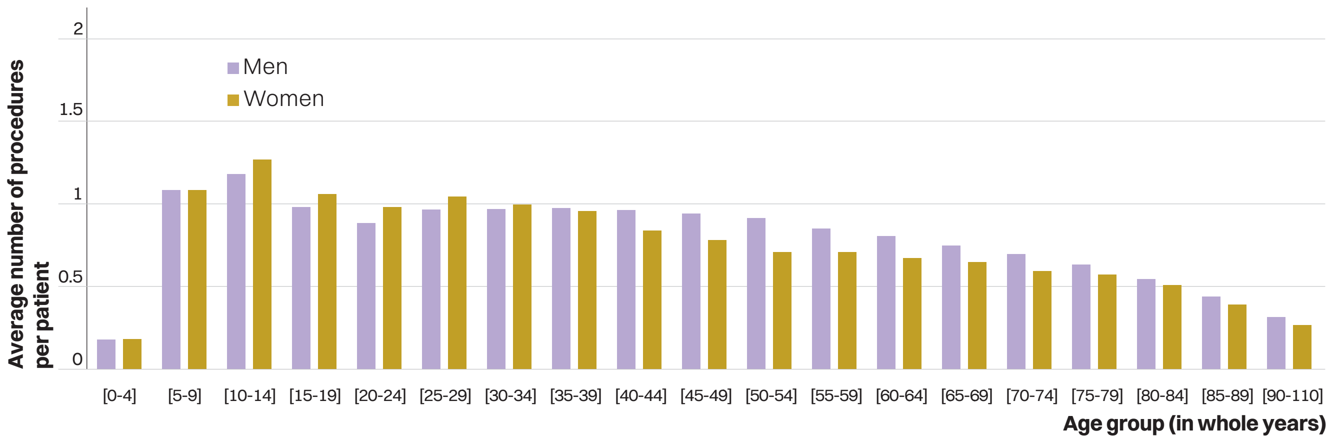
1 Probably linked to chronic pathologies in early childhood (bronchiolitis, etc.).
2 This may be related to the higher frequency of radiographs of the limbs in young men (see Figure 11), probably linked to trauma.

5. POPULATION ACTUALLY EXPOSED in 2022

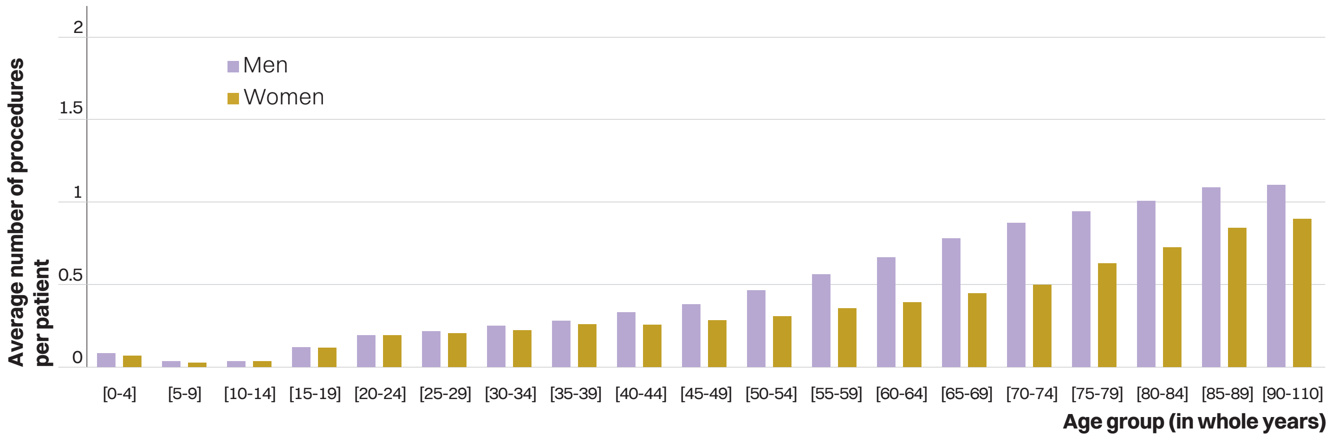
A
CONVENTIONAL RADIOLOGY



B
DENTAL RADIOLOGY



C
CT SCAN



D
NUCLEAR MEDICINE

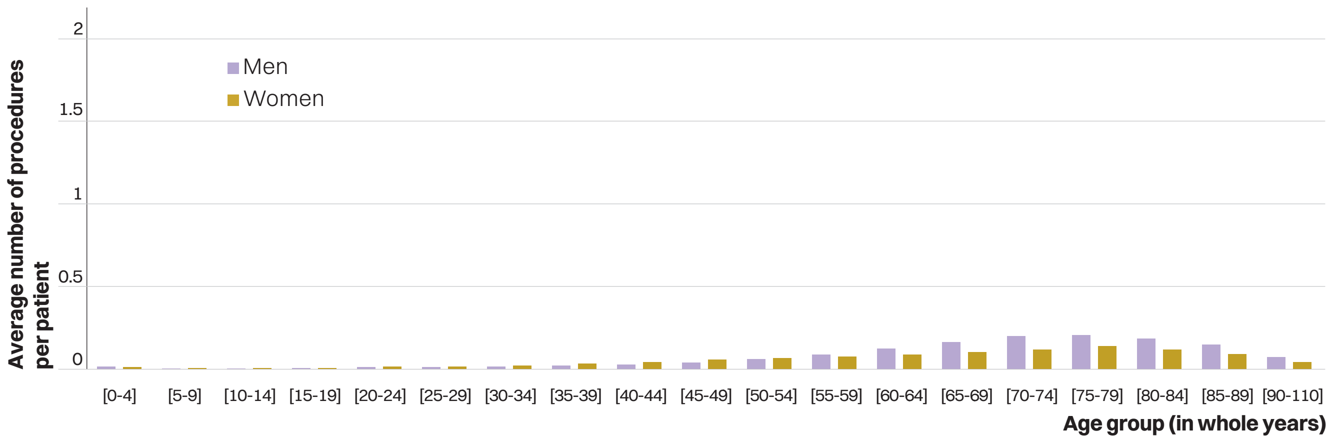


Figure 21. / A to / D. Distribution by age and sex of the average number of procedures per patient, by imaging modality.

For diagnostic interventional radiology, the results obtained are not presented due to the low number of procedures in the ESND.

5.2 EFFECTIVE DOSE PER CAPUT

When the total effective dose calculated for the year 2022 is compared to the number of patients (as a reminder, patients are the beneficiaries actually exposed in the ESND population), the **cumulative average effective dose per caput is approximately 3.7 mSv.** Even more than for the number of procedures, the dose distribution is extremely heterogeneous (see **Table XIX** below): half the patients receive a dose of 0.1 mSv or less, 75% receive 1.9 mSv or less, while the 5% of patients with the highest exposure receive a dose of over 18.6 mSv. The maximum observed in this study was 519 mSv.

Contrary to what was observed in section 5.1 of this report for the number of procedures, a very clear difference between men and women is observed in **Table XIX** below in terms of cumulative effective dose per caput: in 2022, men received on average about 1 mSv more than women. Analysis of the different percentiles confirms that the effective dose distribution for men is clearly shifted towards higher doses than for women. This finding should be seen in relation to the average number of CT scans and nuclear medicine procedures per patient, which is higher for men (see **Figure 21C** and **D above**): as these two imaging modalities are associated with the highest effective doses per examination, it is consistent to observe a higher cumulative effective dose per patient for men than for women.

As dental radiology makes only a very small contribution to the collective effective dose (see chapter 4 of this report), it is useful to characterise the cumulative effective dose per patient by considering all imaging procedures other than dental radiology. The population considered as being exposed is therefore smaller (n = 441,125 instead of 651,580). Within this restricted population, the cumulative average effective dose per caput rose by 47% to around 5.4 mSv. The differences in exposure between men and women that were already observed were confirmed and accentuated, with the difference in cumulative effective dose per patient reaching almost 2.4 mSv.

Annual effective dose per patient (mSv)	Dental included			Dental excluded		
	Men	Women	OVERALL	Men	Women	OVERALL
Average	4.30	3.22	**3.69**	6.85	4.48	**5.44**
25th percentile	0.011	0.019	**0.015**	0.018	0.177	**0.053**
Median	0.04	0.36	**0.10**	1.30	0.38	**0.63**
75th percentile	3.50	1.56	**1.87**	8.90	3.95	**6.50**
95th percentile	22.0	16.0	**18.6**	30.0	19.9	**24.4**
MAXIMUM			**519**			**519**

Table XIX. Statistics on cumulative annual effective doses per patient, by sex, with and without consideration of dental procedures: *"Dental excluded"* means that patients who have only had dental radiology procedures are excluded and that the doses received in dental radiology for patients who have had other procedures are also excluded.

Figure 22 below shows another way of looking at the distribution of cumulative annual effective doses per patient. The percentage of patients who received a cumulative dose within a specified dose range is shown, regardless of sex **(A)** and according to sex **(B)**. Once again, around half (50.4%) of patients received a cumulative of effective dose of less than or equal to 0.1 mSv in 2022. Just under one fifth of patients received a cumulative effective dose between 0.1 and 1 mSv, while another fifth received a dose of between 1 and 10 mSv. Finally, 10% of patients received between 10 and 50 mSv and around 1% received more than 50 mSv. These figures illustrate a fact that simply knowing the average dose per patient tends to hide: the distribution of doses is not symmetrical. Consequently, 78% of patients in 2022 received a dose below the average dose of 3.7 mSv.

In **Figure 22B** below, it should be noted that the distribution of the cumulative effective dose clearly differs according to sex: approximately three times as many women receive a cumulative annual dose between 0.1 and 1 mSv, which corresponds to the dose range for mammography. Above 10 mSv, the proportion of men is higher, due to their more frequent need of CT scans and nuclear medicine.

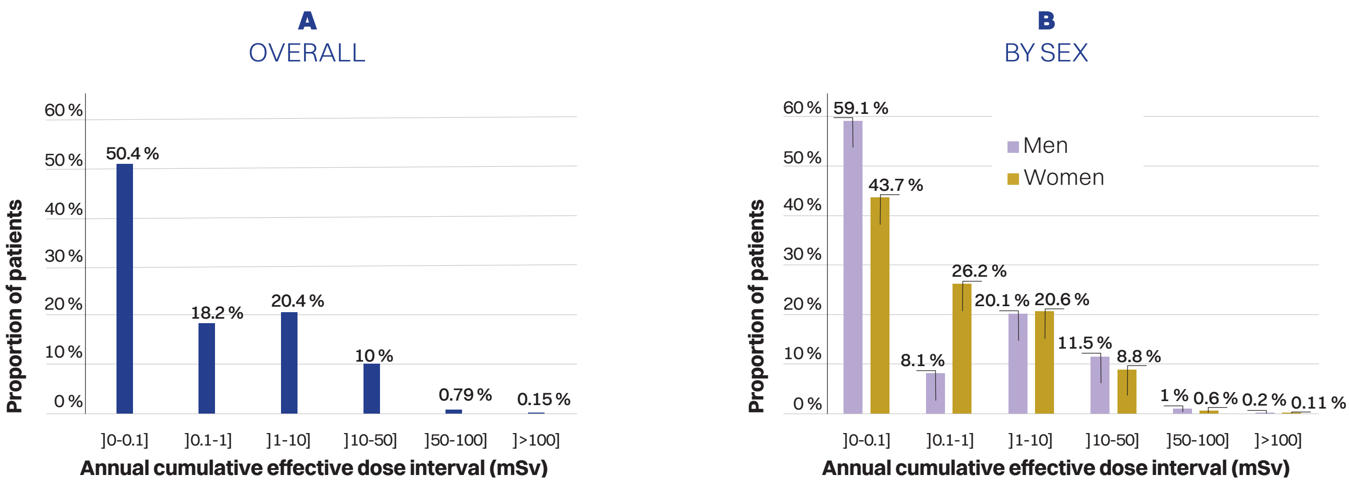


Figure 22. / A and / B. Proportion of patients who received a cumulative annual effective dose within the specified range.

The cumulative average effective dose is also, and even more strongly, correlated to patient age, as shown in **Figure 23** below. The distribution of this dose by age group is shown for both sexes. It varies in a very similar way between men and women up to around the age of 40: less than 1 mSv in children and very young adults (0.7 mSv before the age of 5, around 0.3 mSv between the ages of 5 and 15, 0.9 mSv before the age of 20) and with no marked difference between boys and girls. It increases with age to reach around 2 mSv before the age of 40. Beyond this age, annual exposure becomes significantly higher on average for men than for women (around 9 mSv compared with 5 mSv between the ages of 70 and 74, with a maximum of almost 10 mSv compared with 6.7 mSv between the ages of 80 and 84). This difference can be explained by the results presented in the previous chapter, which show, in particular, that more CT scan and nuclear medicine procedures are performed on men than on women after the age of 45. In fact, the effective doses associated with CT scans and nuclear medicine diagnostic procedures are, for the most part, higher than the effective doses associated with conventional radiology examinations.

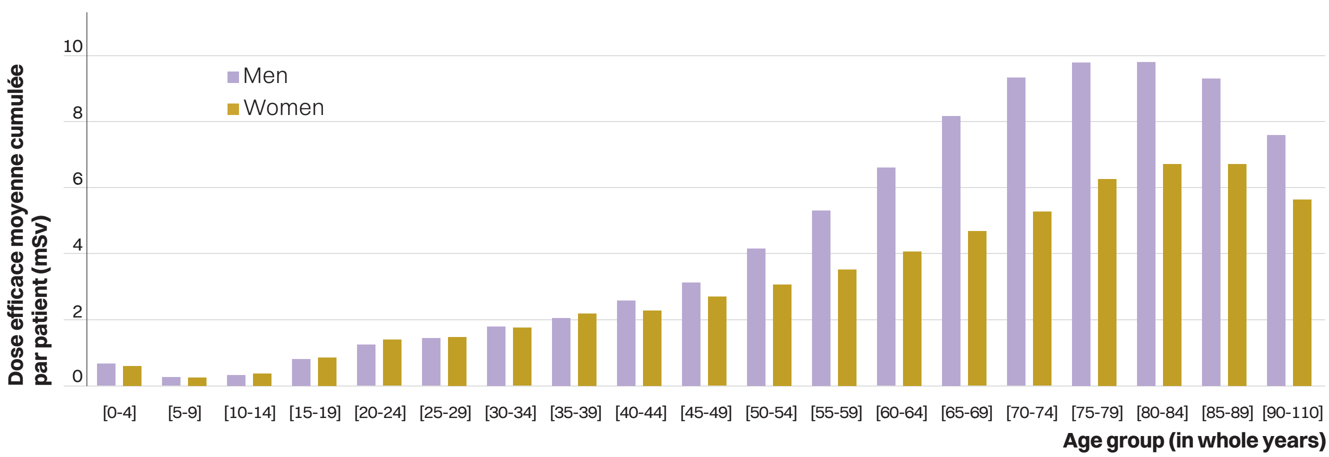


Figure 23. Cumulative average effective dose per patient, by sex and age.

6. CHANGES IN DIAGNOSTIC MEDICAL EXPOSURE of the French population from 2002 to 2022

This study follows on from four previous studies covering the years 2002, 2007, 2012 and 2017 [5], [6], [7], [8]. The method used to estimate the number of diagnostic procedures changed considerably from one study to another.

For 2002, the EGB was not yet available, so the count of procedures was based on multiple sources of data: the national health insurance fund for salaried workers (CNAMTS), the directorate for research and statistical studies (DREES), the regional hospital agency for the Île de France region...

For 2007, the EGB was used for private sector procedures, as public sector data was not yet available in this sample. The data for this sector was extrapolated from a survey of 50 public health establishments. In addition, the data on dental radiology could not be updated and data from 2002, from a survey conducted by the CNAM, was used.

The same method was used for 2012 and 2017. However, the gradual abandonment of NGAP coding for dental radiology procedures in favour of CCAM coding greatly enhanced the reliability of the data collected.

For the year 2022, **the ESND was used rather than the EGB** (see chapter 2 of this report). As the population samples considered in 2017 and 2022 are different, it is difficult to make comparisons between 2022 and previous years in absolute terms. Only the proportions can be commented on.

In the 2022 study, the average effective doses per type of procedure were updated compared with the 2017 study, mainly based on an analysis of the collection of diagnostic reference levels, in order to comply with changes in medical practice (see Chapter 3 of this report).

6.1 CHANGES IN THE AVERAGE NUMBER OF PROCEDURES PER YEAR

The **frequency of procedures fell from 1,181 (ESND) [or 1,187 with the EGB; see chapter 2 of this report] to 1,083 procedures per 1,000 beneficiaries between 2017 and 2022, representing a decrease of 8%**. This general decrease was mainly due to a reduction of around 19% in conventional radiology procedures.

The frequency of CT scans and diagnostic nuclear medicine procedures increased by around +11% and +22% respectively. In addition, the frequency of procedures in 2022, excluding dental radiology, at 735 per 1,000 beneficiaries, is 12% lower than in 2017 [835 with the ESND].

Changes since 2002 are detailed for each imaging modality in **Figure 24**. The decline in conventional radiology is most marked between 2017 and 2022.

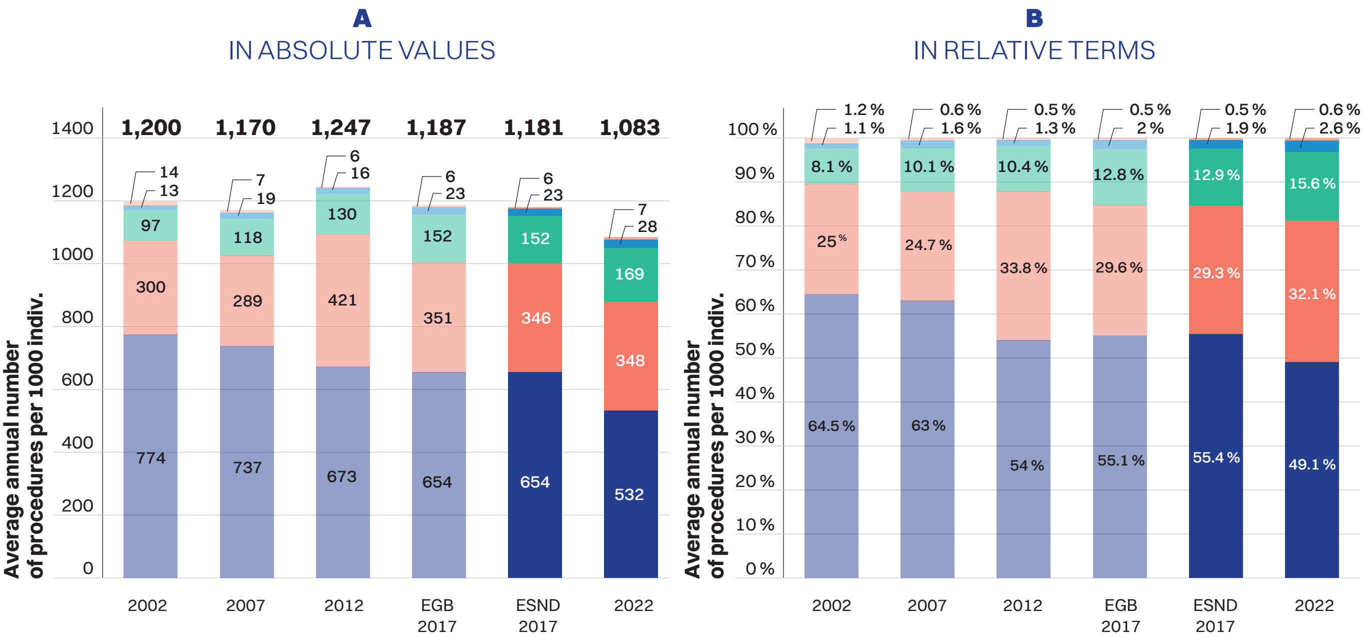


Figure 24. Change in the annual number of diagnostic procedures between 2002 and 2022, by imaging modality. The year 2017 is represented twice: once with the EGB and once with the ESND to illustrate the effect of the change of sample from the EGB [or other data source in 2002] (transparent bars) to the ESND (see chapter 2 of this report).

It is useful to compare this trend with the trend mentioned in the French Court of Audit report on social security in October 2022, chapter 4 entitled "*Medical imaging: developments under way, essential reforms*" [28].

The decline in the relative share of conventional radiology in favour of CT and nuclear medicine examinations is also observed for the period 2019-2021: *"Looking at the period 2019-2021, the total number of procedures has only increased by 0.7% [note: this increase, highlighted by the Court of Audit, takes MRI procedures into account], with the 4.8% decrease in radiology procedures offsetting the increase in CT scan and scintigraphy procedures."*.

6.2 CHANGES IN THE AVERAGE ANNUAL EFFECTIVE DOSES PER BENEFICIARY

As shown in **Figure 25** below, **the average annual effective dose per beneficiary increased very slightly (+2.6%) between 2017 and 2022, from 1.53 to 1.57 mSv**. **Figure 26** below shows that this increase is mainly due to CT scans and nuclear medicine, which generate higher doses, and for which the proportion increased over the period compared with conventional radiology, whose contribution to the annual effective dose continues to fall.

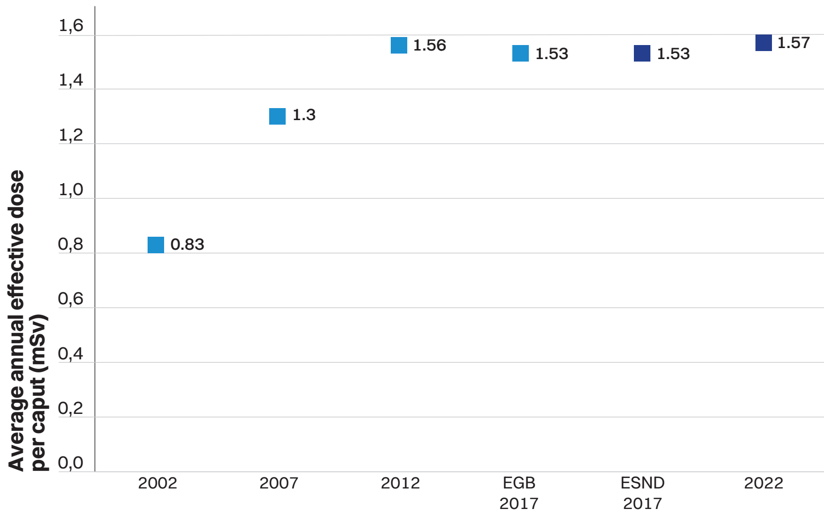


Figure 25. Change in average annual effective dose per beneficiary between 2002 and 2022. The year 2017 is represented twice: once with the EGB and once with the ESND to illustrate the effect of the change of sample with the transition from the EGB [or other data source in 2002] (light blue) to the ESND (dark blue) (see chapter 2 below).

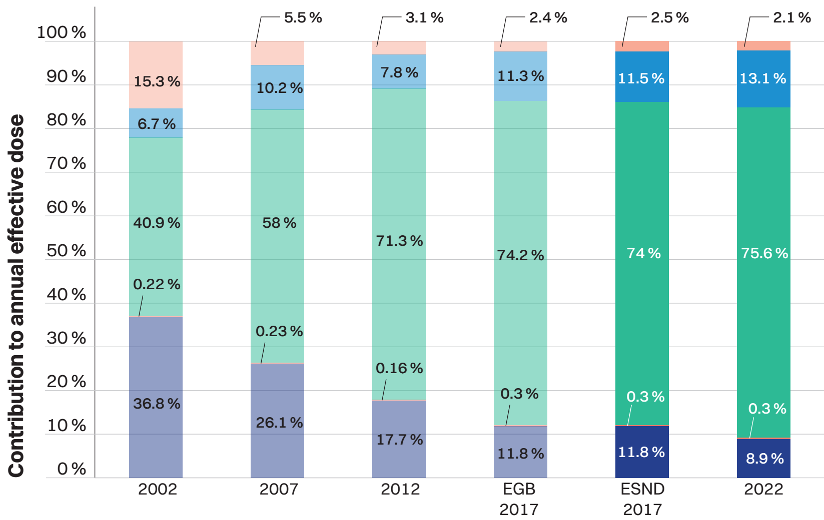


Figure 26. Change of the distribution of the average annual effective dose per beneficiary by imaging modality between 2002 and 2022. 2017 is represented twice: once with the EGB and once with the ESND to illustrate the effect of the change of sample from the EGB [or other data source in 2002] (transparent bars) to the ESND (see chapter 2 of this report).

- Conventional radiology
- Dental radiology
- Computed tomography
- Nuclear medicine
- Diagnostic interventional radiology

6.3 CHANGES IN THE DISTRIBUTION OF PROCEDURES BY EXAMINATION CATEGORY

Table XX below shows the distribution of imaging procedures performed in France in 2017 (EGB) and 2022 (ESND). As the results are not based on the same samples, these changes should be treated with caution. However, as the comparison of the EGB 2017 results with the ESND 2017 (see chapter 2 of this report) revealed little difference in the proportions, comparison of procedure distribution between the EGB 2017 and the ESND 2022 was considered possible.

With regard to **conventional radiology**, radiography of the limbs is still on the increase (+2 points compared with 2017 [EGB]) and in 2022, as in 2017, was the most frequent category of conventional radiology procedures. It is interesting to note that mammography increased by 2 points from 4th to 3rd most frequent procedure between 2017 and 2022, ahead of pelvic radiography. The other categories of conventional radiology procedures (chest, spine, head and neck, digestive tract) have fallen sharply. It should also be noted that the share of the extraoral category (dental panoramic, cone-beam CT, teleradiography of the skull) sharply rose between 2017 and 2022 (+5 points). This is covered in detail in chapter 4 of this report.

As far as **CT scans** are concerned, the most striking change between 2017 and 2022 is the very sharp increase (+6 points) in procedures involving the chest and heart, which rank first among the most frequent examinations, along with CT scans of the abdomen and/or pelvis.

With regard to **nuclear medicine**, in the context of a sharp increase in frequency of procedures (see 6.1 of this report), there have been very marked changes in distribution. In particular, the share of procedures in the PET and oncology category increased by 10 points between 2017 and 2022 out of total nuclear medicine procedures.

Finally, for **diagnostic interventional radiology**, the proportion of cardiology procedures increased by just over two points. However, this observation needs to be qualified since, as already indicated, many peripheral vascular procedures are often performed with both a diagnostic and a therapeutic objective, and are therefore not included in the study. This data should not be considered as representative of the actual changes for this imaging modality.

	Procedures 2017 (%)	Procedures 2022 (%)
Conventional radiology		
Limbs	33.7	35.6
Chest	26.0	23.2
Mammography	11.3	13.1
Pelvis	11.8	12.9
Spine	10.5	9.8
Bone mineral densitometry	1.4	1.9
Digestive tract	2.4	1.4
Head and neck	1.4	0.9
Other	1.1	1
Urogenital system	0.4	0.3
Dental radiology		
Intraoral	68.1	63.5
Extraoral	31.9	36.5
Computed tomography		
Abdomen and/or pelvis	25	23.5
Chest and heart	17.5	23.5
Head and neck	25	19.9
Multiple areas	13.4	15.7
Spine	11.2	9.5
Limbs	7.9	7.8
Nuclear medicine		
PET and oncology	35.0	46.3
Circulatory system	24.0	22.8
Osteoarticular and muscular system	24.9	17.8
Endocrine system	5.1	3.2
Other	3.1	3.2
Respiratory system	3.2	2.5
Nervous system	2.2	2.1
Urogenital system	1.4	1.1
Immune and haematopoietic systems	1.1	1.1
Diagnostic interventional radiology		
Cardiac	65.8	68.1
Vascular	22.6	21.7
Neurological	5.3	5.8
Biliary tract	6.2	4.3

Table XX. Distribution of diagnostic procedures performed in France in 2017 and 2022.

Focus Impact of the Covid-19 epidemic on the number of procedures in 2020

In the period between the last report on 2017 data [8] and this report on 2022 data, France, like all countries around the world, has been affected by the Covid-19 epidemic. In France, the pandemic resulted in four epidemic waves, in spring and autumn 2020, early 2021, then during the summer of 2021, which led the government to introduce restrictions (see **Figure 27** below). In particular, several lockdowns were decreed in an attempt to contain the pandemic. Between March 17, 2020 and May 11, 2020, an initial lockdown involved restricting travel to what was strictly necessary, closing schools and many businesses, and halting activities that were not essential to the life of the nation. Then, between October 30, 2020 and December 15, 2020, a second lockdown was established. More flexible than the first, this period of restrictions allowed many sectors to continue operating. Other restrictions were also put in place in response to the two waves of 2021.

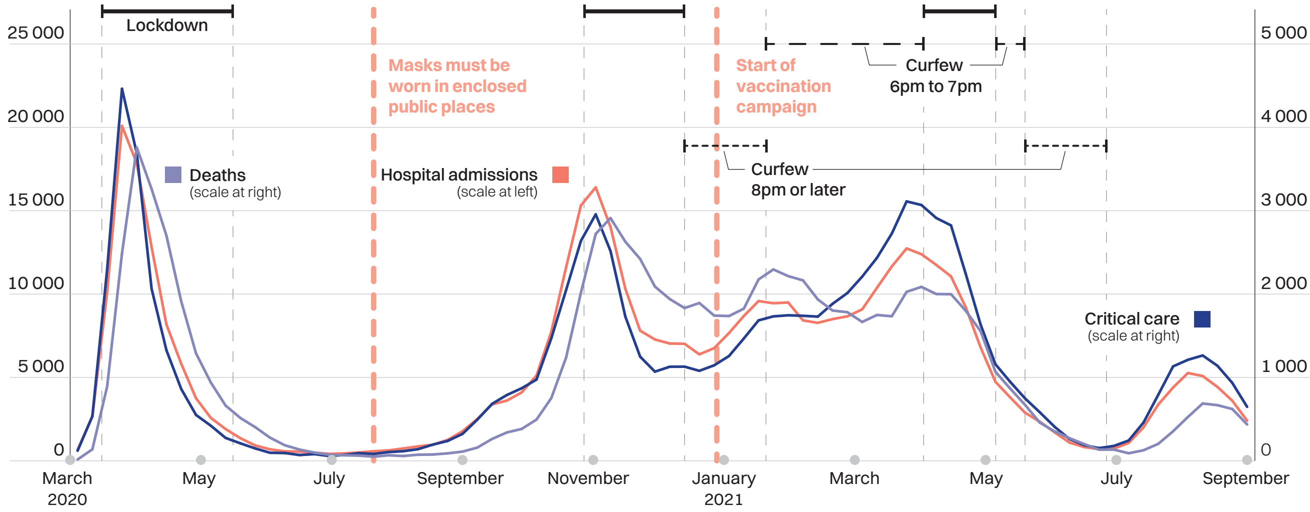


Figure 27. Weekly number of new hospitalisations, admissions to critical care and hospital deaths linked to Covid-19.
- Reading: in the week of November 2, 2020, there were 16,400 new hospitalisations for Covid-19 in France, 3,000 admissions to critical care, and 2,700 deaths in hospital as a result of the disease.
- Scope: France, hospital deaths only (excluding social or medical-social institutions).
- Sources: Information system for victim monitoring (SI-VIC), extracted and processed by DREES for hospitalisations; SI-VIC and Santé publique France information system, processed by Santé publique France for deaths. Graphic: INSEE [29]

IMPACT ON THE NUMBER OF IMAGING PROCEDURES AS A WHOLE

It seemed useful to assess the impact of these events on the number of imaging procedures performed within the ESND and the associated average effective dose. To do this, the number of monthly imaging procedures was evaluated, for all modalities, for the year 2020 and compared with the years 2017 and 2022. An estimate of the number of procedures theoretically expected in 2020, based on the assumption of a linear increase in the number of procedures between 2017 and 2022, was also made and compared with the number of procedures actually recorded in 2020. The results are shown in **Figures 28 and 29** below. The effect of the first lockdown is clearly visible, with around 30-70% fewer procedures than expected, depending on the month. There was a slight "recovery" effect after May 11, 2020 for procedures not carried out during the first lockdown period, particularly in July 2020 (+10% compared with expectations). The effect of the second lockdown (at the end of 2020) is virtually non-existent, with a maximum reduction of 5% compared to the expected level for November 2020. Overall, in 2020, around 10% fewer procedures were performed than expected.

In addition, the average dose per beneficiary calculated for 2020 is 1.44 mSv, compared with the average dose of 1.53 mSv estimated for 2017 and 1.57 mSv for 2022. This represents a dose around 8% lower than the expected exposure in 2020. Beneficiaries were therefore exposed to a relatively lesser extent in this particular year.

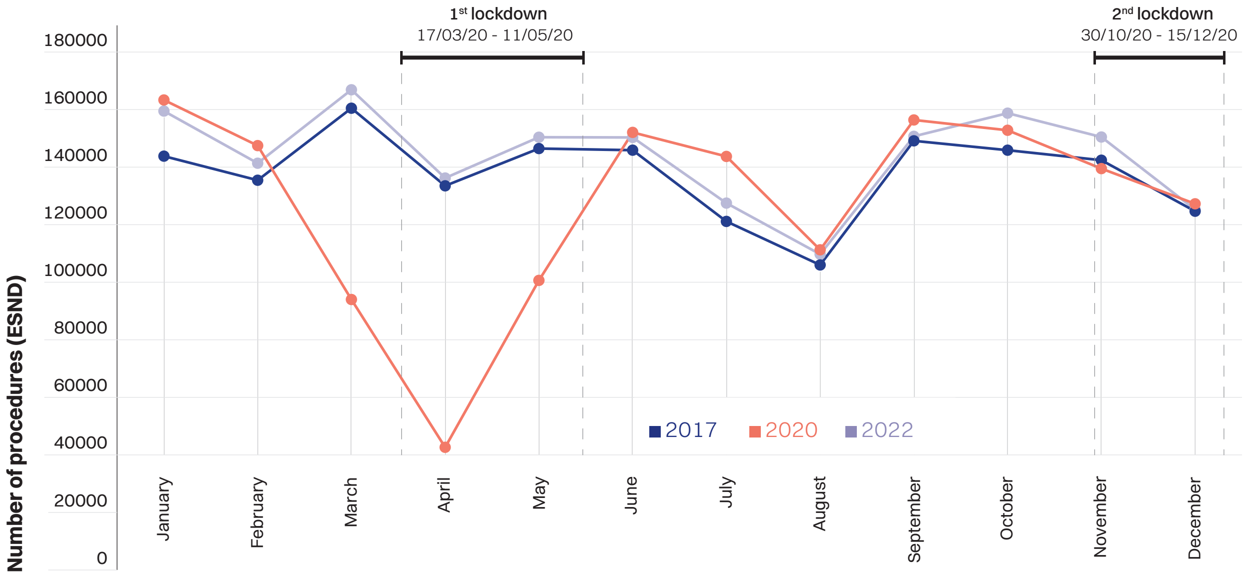


Figure 28. Number of monthly imaging procedures (using ionising radiation) performed on ESND beneficiaries in 2017, 2020, and 2022.

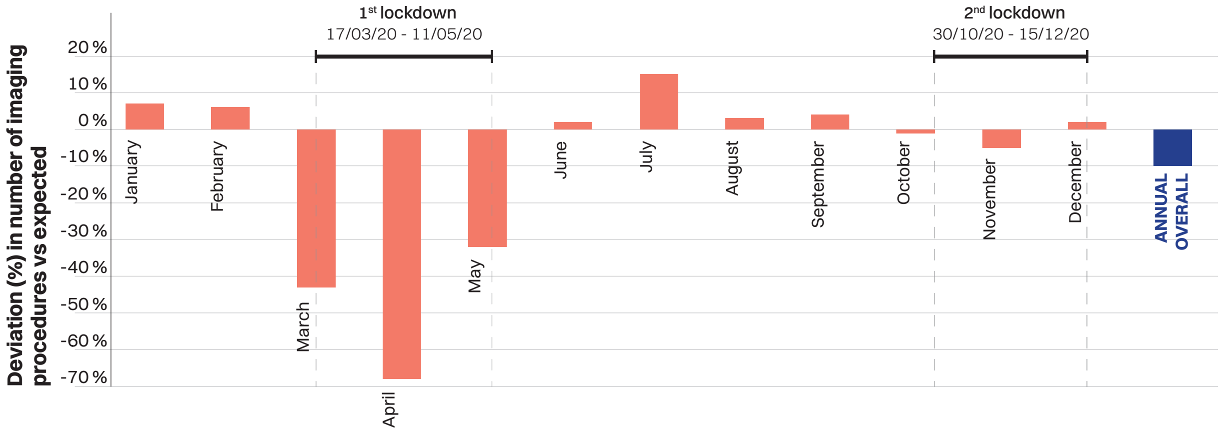


Figure 29. Deviation in the number of monthly imaging procedures (using ionising radiation) performed on ESND beneficiaries in 2020 compared with the number of procedures theoretically expected, assuming a linear trend between 2017 and 2022.

Focus
Impact of the Covid-19 epidemic on the number of procedures in 2020

IMPACT ON THE NUMBER OF IMAGING PROCEDURES OF THE THORACIC REGION AND MAMMOGRAPHY

An additional analysis of the number of monthly procedures over the years 2017, 2020, and 2022 was conducted for certain specific procedures:
• chest radiographs and CT scans of the chest and heart in connection with the diagnosis of Covid-19,
• mammography, to assess the impact of lockdown on examinations conducted, in particular as part of breast cancer screening on asymptomatic women.

Figure 30 below shows the monthly number of chest and heart CT scans for the years 2017, 2020, and 2022. In 2020, this number increased significantly from April onwards (+60% compared with 2017) and remained high during all the following months (+45% to +55% compared with 2017), with a new peak in the autumn (+60% compared with 2017). This effect is mainly due to the fact that the chest CT scan without injection has become the first-line reference examination recommended by learned societies and the HAS [30], [31] for the diagnosis of Covid-19. As a result, the number of chest and heart CT scans was very high in 2020, and increased during the successive waves of Covid in the spring and autumn.

The trend in the number of chest radiographs performed over the years 2017, 2020, and 2022 is shown in **Figure 31** below. There was a marked drop in the number of examinations from March to May 2020, the period corresponding to the first lockdown, with a maximum drop of around 55% in April 2020 compared with April 2017 (and around 40% compared with April 2022). There was also a minor effect from the 2nd lockdown. These findings illustrate the fact that health professionals followed the advice of learned societies and the HAS and did not use chest radiography as the first-line diagnostic tool for Covid-19.

Figure 32 below shows the change in the number of mammography examinations performed in 2017, 2020, and 2022. In 2020, this number was heavily impacted by the first lockdown, with a fall of over 80% in April. There was a slight recovery in July and autumn 2020, as the 2nd lockdown had no marked effect on the number of mammography examinations. In 2020, the number of mammography examinations is therefore 10% lower overall than in 2017 and 2022. On the other hand, the number of mammography examinations performed in 2017 and 2022 is roughly equivalent, with curves that follow the same shape: a maximum number of examinations in March and a minimum number of procedures in August. Mammography, for example, is not affected by the general fall in the number of conventional radiology procedures between 2017 and 2022 (see chapter 6 of this report), particularly as a result of efforts linked to the breast cancer screening campaign.

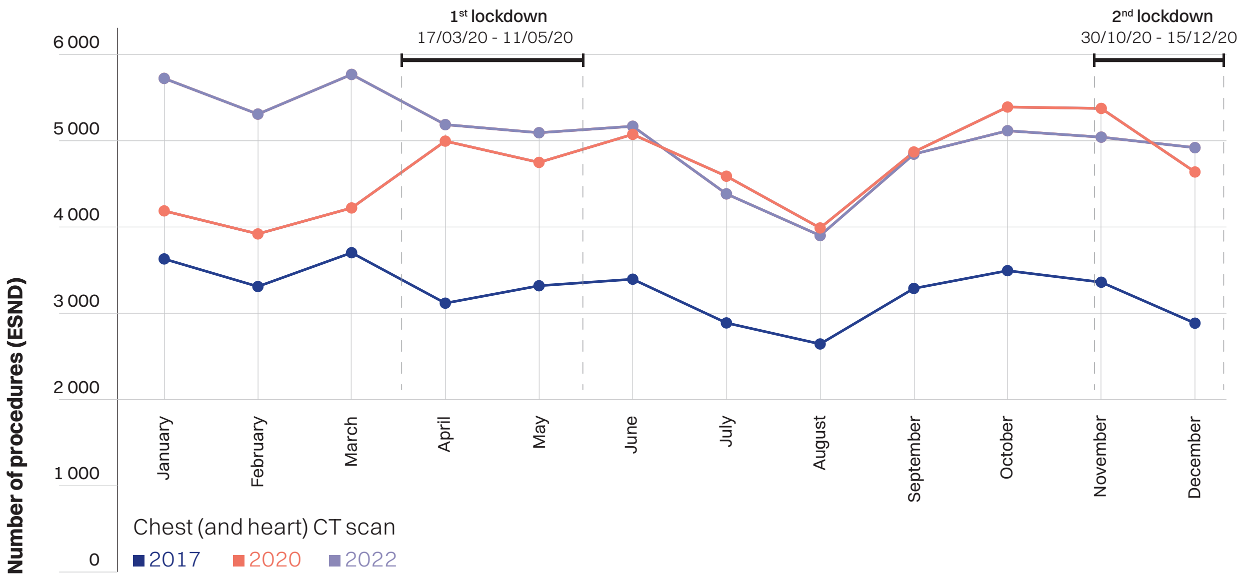


Figure 30. Number of chest and heart CT scan examinations performed on ESND beneficiaries in 2017, 2020, and 2022.

In conclusion, this analysis illustrates that the impact of the epidemic was not the same depending on the type of examination considered. Overall, the number of procedures, taking all examinations together, for 2020 is around 10% lower than the expected number of procedures, implying that patient exposure in that particular year is around 8% lower than expected. However, this trend is not the same for all examinations. In particular, the epidemic had an accelerating effect on the increase in chest and heart CT scans as chest CT scans without injection are the first-line screening test for Covid-19.

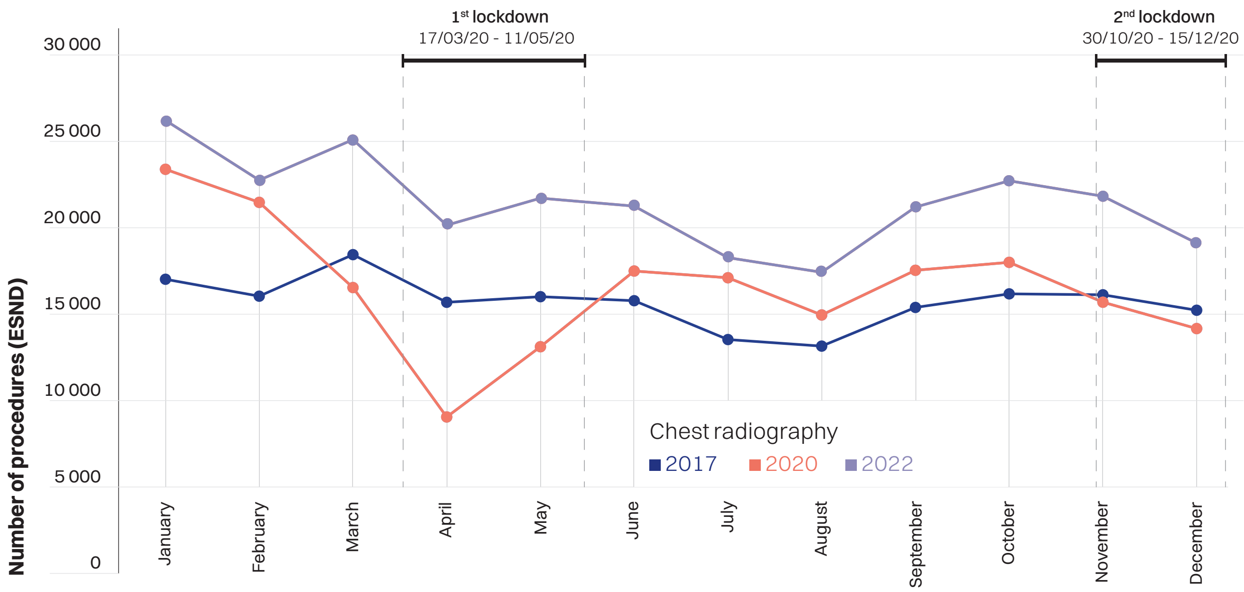


Figure 31. Number of chest radiographic examinations performed on ESND beneficiaries in 2017, 2020, and 2022.

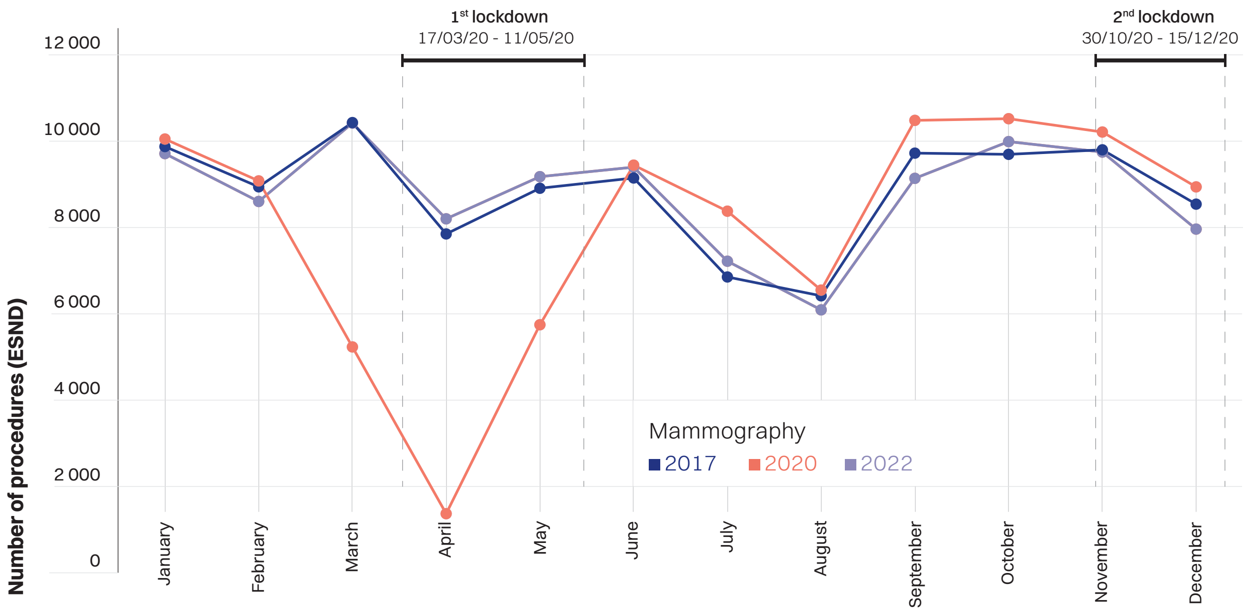


Figure 32. Number of mammography examinations performed on ESND beneficiaries in 2017, 2020, and 2022.

Focus
Comparison of French data with international data

Analyses of exposure data for the French population in the field of medical diagnostics from previous ExPRI reports, covering the years 2002, 2007, 2012, and 2017, were used to provide input for reports drawn up by UNSCEAR as part of studies on population exposure in the medical field at a global level. The last two UNSCEAR studies, covering the same periods as the years studied by ExPRI, were published in the following two reports:

- **Report** "UNSCEAR 2008" published in 2010 [32], covering the period 1997-2007.
- **Report** "UNSCEAR 2020/2021" published in 2022 [12] covering the period 2009-2018;

As the latest UNSCEAR report was published between the publication of the latest ExPRI 2017 (2020) report and this study, it seemed useful to put the French data into perspective in relation to the global situation.

Not all types of data analysed in ExPRI studies can be compared with data from UNSCEAR studies, particularly indicators relating to people actually exposed in a given year, as the time periods are not strictly identical between the two types of studies. Nevertheless, the main indicators have been compared and are presented in this Focus, by comparing the corresponding time periods.

Distribution of the number of procedures by imaging modality

The distribution of the number of procedures by imaging modality, is shown in **Figure 33** below.

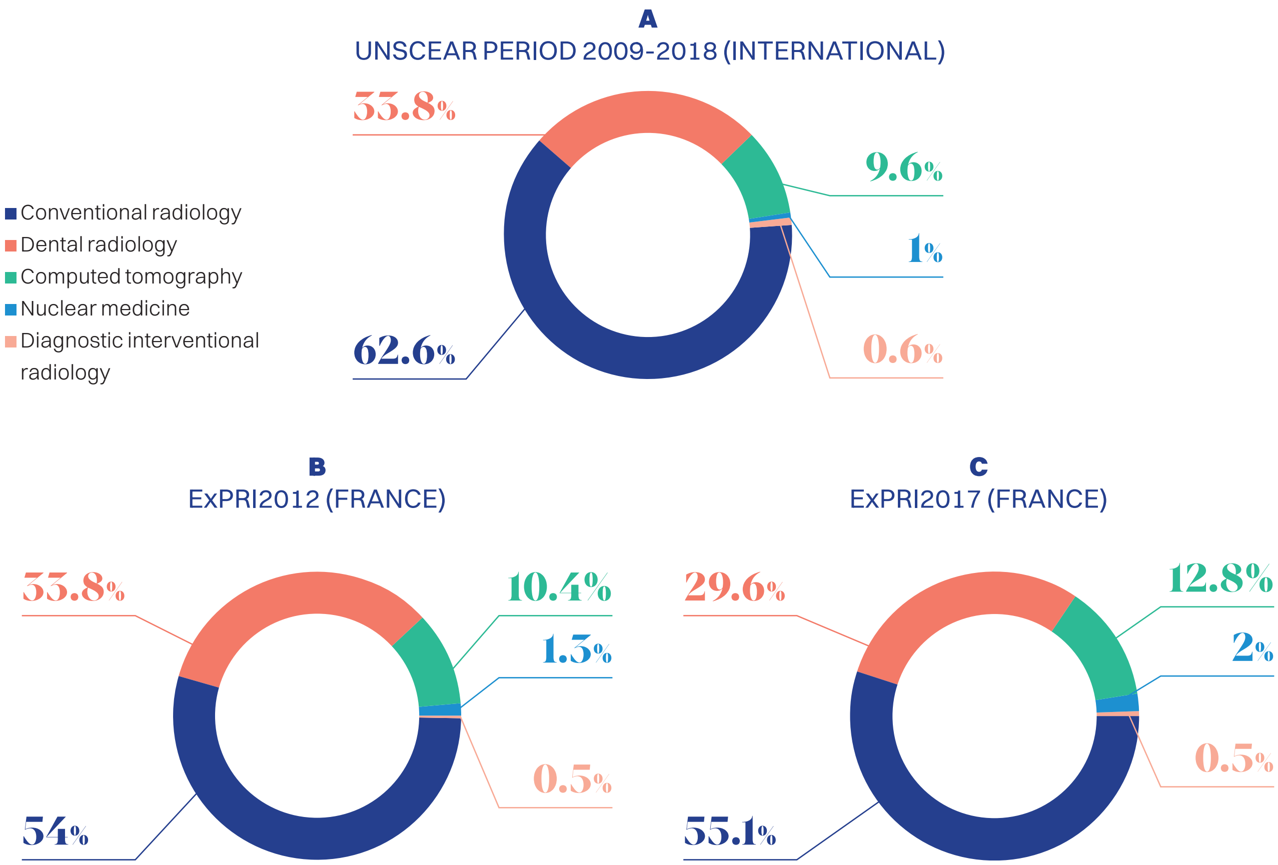


Figure 33. Distribution of procedures by imaging modality, internationally (UNSCEAR) and in France (ExPRI).

Generally speaking, over the period 2009-2018, the distribution of procedures by different modalities in France is fairly similar to the distribution worldwide:

- conventional radiology, excluding dental radiology, takes first place in terms of the number of procedures, both in France and worldwide, accounting for just over half of all procedures (around 55% and 63% respectively).
- dental radiology comes in 2nd place, accounting for around a third and a quarter of procedures in France and the rest of the world, respectively.
- CT scans come third, accounting for around 1/10th of all procedures, both in France and worldwide.
- diagnostic interventional radiology is uncommon, at around 0.5%.

However, although not very frequent in percentage terms, and of the same order of magnitude in France as worldwide, with more than 1.5% of procedures compared with 1%, diagnostic nuclear medicine is increasing very rapidly in France, rising to 2.6% by 2022, as mentioned in Chapter 4 of this report and shown in **Figure 34** below.

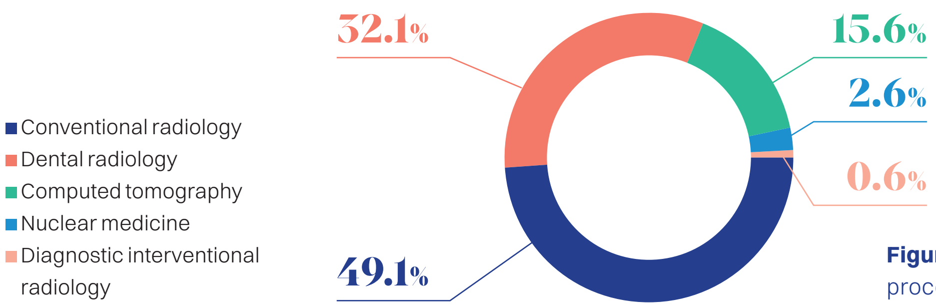


Figure 34. Distribution of procedures by imaging modality, in France in 2022

It should be noted that the conclusions drawn from these comparisons should be treated with caution, given the considerable uncertainties surrounding the frequency of procedures, particularly at global level.

The "UNSCEAR 2020/2021" report [12] announces an overall uncertainty of 30% on procedure frequencies, but which may vary depending on the modality, up to 80% for diagnostic interventional radiology.

Focus
Comparison of French data with international data

Frequency of procedures per 1,000 beneficiaries
The frequency of procedures per 1,000 beneficiaries over the period 2009-2018, is:

- In France, around 1,200 (1,247 in 2012 and then 1,187 in 2017)
- Worldwide, around 600
- Worldwide for high-income countries, around 1,600

Distribution of collective effective doses by imaging modality
The distribution of collective effective doses by imaging modality is shown in **Figure 35** below.

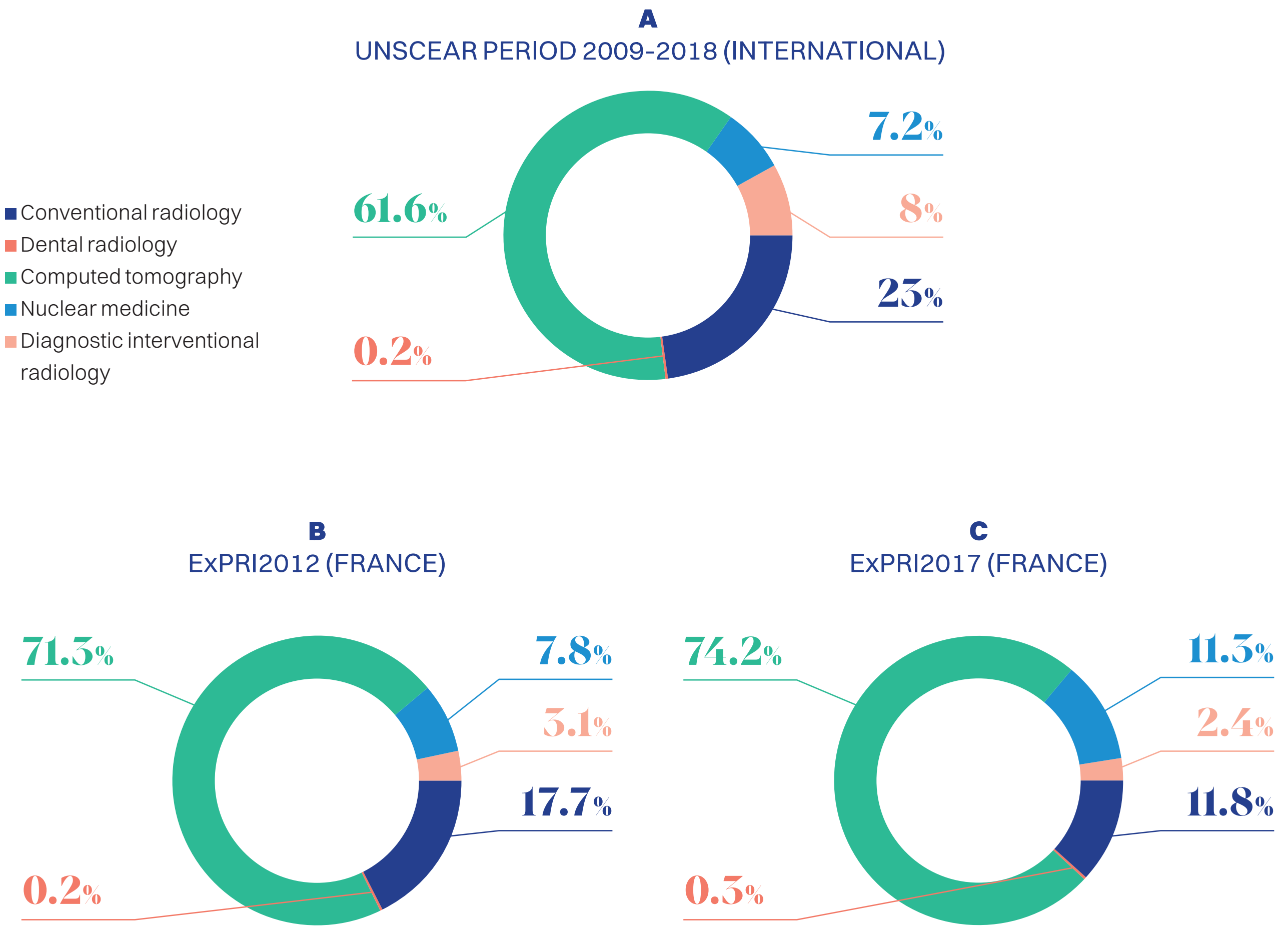


Figure 35. Distribution of collective effective doses by imaging modality in the UNSCEAR 2009-2018 report and in France in 2012 and 2017.

Generally speaking, over the period 2009-2018, most of the collective dose is due to computed tomography, which accounts for more than 60% worldwide and more than 70% in France.

Conventional radiology (excluding dental) is in second place, with a slightly higher share worldwide (around 23%) than in France (between 18% and 12% respectively in 2012 and 2017).

Nuclear medicine has a contribution of around one tenth, slightly higher in France (from around 8% to 11% in 2012 and 2017 respectively) than globally (around 7%).

Diagnostic interventional radiology makes a small contribution to collective effective dose in France (around 3% in 2012 and 2017) and a little more worldwide (around 8%).

Even more so than for the number of procedures, the conclusions drawn from these comparisons of dose data should be treated with caution, given the higher level of uncertainty in the estimation of effective doses at an international level, of around 30 to 90% according to the "UNSCEAR 2020/2021" report [12].

Average per caput effective dose

In the "UNSCEAR 2020/2021" report, the average per caput effective dose varies greatly depending on the income level of the country concerned. The French situation was also compared with the global situation for countries in the same category as France ('high income').

The average per caput effective dose in France between 2012 and 2022 (1.56 mSv, 1.53 mSv and 1.57 mSv in 2012, 2017, and 2022 respectively) is of the same order as in other high-income countries (around 1.5-1.7 mSv over the period 2008-2019 according to the latest UNSCEAR report).

In conclusion, French trends in the distribution of procedure frequencies and average per caput effective doses are similar to those found internationally, particularly for countries with comparable income levels.

CONCLUSION and perspectives

Conducted for the fifth time since 2003, the study of the French population's exposure to ionising radiation from diagnostic medical imaging procedures is based, for this edition using data from 2022, on a new sample called the ESND. This sample compiles procedures for around 2% of the population present in the main SNDS database.

ESND data for the year 2022 was used to determine the frequency of imaging procedures. Assessment of the effective doses resulting from these procedures is based primarily on analysis of the data collected by the ASNR (formerly the IRSN) as part of the diagnostic reference levels.

The main characteristics of exposure of the population to ionising radiation due to diagnostic medical imaging procedures performed in France in 2022 are as follows.

The number of procedures fell from 1,181 to 1,083 per 1,000 beneficiaries between 2017 and 2022, representing a reduction of 8%. This general decrease was mainly due to a reduction of around 19% in conventional radiology procedures. The frequency of CT scans and diagnostic nuclear medicine procedures increased by around +11% and +22% respectively.

The average annual effective dose per beneficiary rose very slightly between 2017 and 2022 (+2.6%), from 1.53 mSv to 1.57 mSv. This increase is mainly due to CT scans and nuclear medicine procedures, which generate higher doses, and for which the proportion increased over the period compared with conventional radiology, whose contribution to the annual effective dose continues to fall.

Thus, despite the drop in frequency of conventional radiology procedures, leading to a decrease in the total frequency of procedures, and despite a general trend towards lower doses per procedure, there was no reduction in the population's exposure to medical diagnostics.

In addition, by 2022, almost 43% of the population had benefited from one or more diagnostic procedures. The proportion of women exposed is much higher than that of men: 47.3% versus 37.8%. The proportion of exposed individuals in the population depends heavily on age, from around 15% for the youngest children to just under 70% for women 65 to 74 years old and around 55% for men 65 to 84.

Patients (i.e. the population who received at least one diagnostic procedure and who were therefore effectively exposed) received an average of 2.54 procedures during 2022. This number varies according to age: children under 10 have had an average of fewer than 2 procedures per year, while adults over 75 have had around 3.4.

The average individual effective dose accumulated by patients in 2022 was 3.7 mSv. The distribution of this dose is extremely heterogeneous: half the patients received a dose of less than or equal to 0.1 mSv, 75% received a dose of less than 1.9 mSv, while the 5% most exposed received a dose of more than 18.6 mSv.

There is a clear difference between male and female patients: men received on average around 1 mSv more than women in 2022. The cumulative effective dose per caput also varies markedly with the age of patients: less than 1 mSv in children and very young adults (< 20 years old), increasing with age to reach around 2 mSv before the age of 40. Beyond this age, annual exposure becomes significantly higher on average for men than for women (9 mSv and 5 mSv respectively between the ages of 70 and 74).

Because of the increase in the frequency of CT scans highlighted in this report, the ASNR plans to supplement the results for 2022 with two more specific studies concerning populations with particular radiation protection issues:

- In 2017, a specific study [8] highlighted the fact that a small proportion of patients - but representing several hundred thousand patients nationwide - accumulated high effective doses that could exceed 100 mSv in CT scans, raising the question of possible long-term radiation-induced effects for these patients, who are most likely being monitored for serious pathologies. As this concern is shared internationally ([33], [34], [35], [36], [37]), this study will be updated with the most recent data in order to monitor developments in this issue of repeated examinations in computed tomography.
- A report for 2015 dedicated to the paediatric population [10] highlighted a drop in children's exposure linked to the overall reduction in average doses per medical imaging procedure. A dedicated study of the paediatric population will be conducted to assess the impact that increased frequency of CT scans, observed in the general population, has on exposure in the paediatric population.

APPENDIX
List of CCAM codes, effective dose per procedure, and procedure frequency

All the CCAM codes actually used for this study, i.e. codes containing at least one procedure, are detailed below, from **Table XXI** to **Table XXV** for each imaging modality. Within each imaging modality, CCAM codes are classified by examination category. The "E / procedure" column shows the average effective dose associated with the CCAM code, in mSv. The "Frequency of procedure" column shows the frequency with which the procedure is performed, in number of procedures per 1,000 beneficiaries. The note N.S. (not significant) is present when fewer than 50 occurrences of the code were found.

Dental radiology procedures not coded in the CCAM are not included in the tables in this appendix. To calculate their contribution to the total effective dose, they were considered equivalent to one (respectively two and four) intraoral periapical and/or bitewing radiographs of a sector of 1 to 3 contiguous teeth (CCAM code HBQK389) for reference service code 1331 (respectively 9422 and 9423).

Table XXI. Effective dose per procedure and procedure frequency for **conventional radiology** CCAM codes.

CCAM code	Desc. of procedure	E/ procedure (mSv)	Freq. of procedure (/1000 indiv.)
	Urogenital system		
JAQH003	Transcutaneous cystography of the kidney with ultrasound and/or radiological guidance	2.4	NS
JBQH001	Transcutaneous descending pyeloureterography with ultrasound and/or radiological guidance	2.4	NS
JBQH002	Retrograde pyeloureterography [UPR]	2.4	0.53
JBQH003	Descending pyeloureterography, through an existing nephrostomy	2.4	NS
JDQH001	Retrograde cystourethrography	2.4	0.25
JDQH002	Cystourethrography through an existing cystostomy	2.4	NS
JDQH003	Cystourethrography, by transcutaneous puncture of the bladder	2.4	NS
JGQH004	Transcutaneous vesiculography of the vas deferens without guidance	2.4	NS
JKQH001	Hysterosalpingography	1.7	0.90
JNQK001	Radiography of the contents of the gravid uterus [uterine contents]	0.2	NS
JZQH001	Radiological investigation of anomalies of the urogenital sinus [External genitography]	2.5	NS
JZQH002	Intravenous urography without voiding cystourethrography	1.5	0.04
JZQH003	Intravenous urography with voiding cystourethrography	2.5	NS
	Other		
FCQH002	Lymphography of the lower limbs	8	NS
ZZQH002	Radiography of a fistula [Fistulography]	1.7	NS
ZZQK001	Bed-side radiographic examination with 3 or more views	1.4	NS
ZZQK002	Radiograph at the patient's bed side, with 1 or 2 views	0.48	3.64

Continued **Table XXI.** >

APPENDIX
List of CCAM codes, effective dose per procedure and procedure frequency

CCAM code	Desc. of procedure	E/ procedure (mSv)	Freq. of procedure (/1000 indiv.)
	Mammography		
QELH001	Transcutaneous marker placement in the breast with mammographic guidance	0.18	0.18
QEQH001	Galactography	0.18	NS
QEQH204	Unilateral or bilateral spectral angiomammography	2.34	NS
QEQK001	Bilateral mammography	0.36	31.66
QEQK004	Screening mammography	0.36	32.37
QEQK005	Unilateral mammography	0.18	5.21
	Limbs		
MBQK001	Arm radiography	0.001	1.50
MCQK001	Radiography of the forearm	0.001	2.33
MDQK001	Radiography of the hand or finger	0.00018	22.96
MDQK002	Bilateral radiography of the hand and/or wrist, 1 exposure on a single frontal view	0.00018	2.19
MFQH001	Arthrography of the elbow	0.004	0.05
MFQK001	Elbow radiography with 3 or more views	0.0015	3.07
MFQK002	Elbow radiography with 1 or 2 views	0.00076	5.20
MGQH001	Arthrography of the wrist	0.00048	0.33
MGQK001	Wrist radiography with 3 or more views	0.00037	8.63
MGQK002	Dynamic radiographic assessment of the wrist for non-dissociative sprain using 7 specific views	0.0008	NS
MGQK003	Wrist radiography with 1 or 2 views	0.0002	11.02
MHQH001	Metacarpal-phalangeal or inter-phalangeal arthrography of the finger	0.0005	0.10
MZQK001	Unilateral or bilateral teleradiography of the entire upper limb, front view	0.002	NS
MZQK003	Radiography of 2 segments of the upper limb	0.002	4.39
MZQK004	Radiography of 3 or more segments of the upper limb	0.003	0.60
NBQK001	Radiography of the thigh	0.001	2.08
NCQK001	Radiography of the leg	0.002	3.68
NDQK001	Unilateral radiography of the foot with 1 to 3 views	0.00018	18.62
NDQK002	Bilateral radiography of the foot with 1 to 3 views per side	0.00037	4.88
NDQK003	Foot radiography with 4 or more views	0.00037	2.61
NDQK004	Foot radiography with 4 or more views for podometric study	0.00046	3.62
NFQH001	Arthrography of the knee	0.005	1.01
NFQK001	Unilateral radiography of the knee with 1 or 2 views	0.0016	14.03
NFQK002	Bilateral knee radiography with 1 or 2 views per side	0.0032	2.00
NFQK003	Knee radiography with 3 or 4 views	0.0024	31.15
NFQK004	Knee radiography with 5 or more views	0.0048	12.41
NGQH001	Arthrography of the ankle	0.00048	0.20
NGQK001	Radiography of the ankle with 1 to 3 views	0.00018	12.76

CCAM code	Desc. of procedure	E/ procedure (mSv)	Freq. of procedure (/1000 indiv.)
NGQK002	Radiography of the ankle with 4 or more views	0.00037	6.16
NHQH001	Arthrography of the foot and/or toes	0.0005	0.11
NZQK001	Unilateral or bilateral teleradiography of the entire lower limb, frontal view with bipedal weight-bearing	0.005	3.84
NZQK003	Bilateral teleradiography of the entire lower limb, from the front with monopedal weight-bearing, one after the other	0.01	0.38
NZQK005	Radiography of 2 segments of the lower limb	0.003	4.95
NZQK006	Radiography of 3 or more segments of the lower limb	0.005	1.88
PAQK001	Comparative radiography of the epiphyseal cartilage of the long bones of the limbs	0.01	0.05
	Bone mineral densitometry		
PAQK007	Bone mineral densitometry at 2 sites, using the biphoton method	0.001	10.02
PAQK008	Whole body biphoton bone mineral densitometry, for constitutional bone disease in children	0.001	NS
PAQK900	Whole-body biphoton bone mineral densitometry, for non-constitutional bone disease	0.001	0.12
	Pelvis		
NAQK007	Radiography of the pelvic girdle using 2 views	0.99	2.66
NAQK015	Radiography of the pelvic girdle using 1 view	0.5	30.52
NAQK023	Radiograph of the pelvic girdle using 3 or more views	1.5	7.80
NAQK049	Radiograph of the pelvic girdle using 1 view and bilateral radiograph of the coxofemoral joint using 1 or 2 views per side	1.1	2.75
NAQK071	Radiograph of the pelvic girdle using 1 view and unilateral radiograph of the coxofemoral joint using 1 or 2 views	0.8	8.80
NEQH001	Functional assessment of unstable non-traumatic hip with arthrography and preparation of a rigid external immobilisation device, under general anaesthesia	0.25	NS
NEQH002	Arthrography of the hip	0.25	0.54
NEQK010	Radiography of the coxofemoral joint with 1 or 2 views	0.3	7.21
NEQK012	Radiograph of the coxofemoral joint with 4 or more views	0.74	2.38
NEQK035	Radiography of the coxofemoral joint using 3 views	0.45	5.62
ZCQK001	Pelvimetry by radiography	0.55	NS
	Spine		
AEQH001	Dorsal and/or lumbar myelography	9	0.07
AEQH002	Cervical myelography	0.6	NS
AFQH002	Saccoradiculography	9	0.05
LDQK001	Radiography of the cervical segment of the spine with 1 or 2 views	0.063	1.29
LDQK002	Radiography of the cervical segment of the spine with 3 or more views	0.17	8.02
LDQK004	Radiography of the cervical and thoracic segments of the spine	0.33	1.65
LDQK005	Radiography of the cervical and lumbar segments of the spine	0.85	0.51
LEQK001	Radiography of the thoracic segment of the spine	0.27	1.82
LEQK002	Radiography of the thoracic and lumbar segments of the spine	1	9.11
LFQK001	Radiography of the lumbar segment of the spine at 4 or more views	1	9.13

Continued **Table XXI.** >

APPENDIX
List of CCAM codes, effective dose per procedure and procedure frequency

CCAM code	Desc. of procedure	E/ procedure (mSv)	Freq. of procedure (/1000 indiv.)
	Spine *(continued)*		
LFQK002	Radiography of the lumbar segment of the spine with 1 to 3 views	0.75	8.48
LGQK001	Radiography of the sacrum and/or coccyx	0.5	1.20
LHQH001	Arthrography of the posterior spinal joint	0.7	0.86
LHQH003	Single transcutaneous intervertebral discography	0.7	NS
LHQH004	Transcutaneous multiple intervertebral discography	1.5	NS
LHQK002	Teleradiography of the entire spine with 2 views	0.75	2.71
LHQK003	Teleradiography of the entire spine with 2 views and additional segmental views	1	0.74
LHQK004	Teleradiography of the entire spine with 1 view	0.35	0.66
LHQK007	Radiography of the entire spinal column	0.75	5.64
	Skeletal system		
PAQK002	Skeletal radiography to calculate bone age, after the age of 2 years	0.0086	0.75
PAQK003	Radiography of the complete skeleton, segment by segment, in children	1.8	0.32
PAQK005	Radiography of the hemiskeleton to calculate bone age, before the age of 2 years	0.0086	0.04
YYYY163	Radiography of the hemiskeleton or complete skeleton in adults	1.8	0.73
	Head and neck		
BBQH001	Unilateral or bilateral lacrimo-dacryo-cystography	0.5	0.03
HCQH001	Sialography	0.5	NS
HQQH002	Dynamic radiological study of swallowing, with recording [Dynamic pharyngography]	0.06	0.09
LAQK003	Radiographs of the skull and/or facial skeleton using 1 or 2 views	0.039	2.80
LAQK005	Radiographs of the skull and/or facial skeleton using 3 or more views	0.79	0.96
LBQK001	Unilateral or bilateral tomography of the temporomandibular joint	0.5	0.10
LBQK005	Unilateral or bilateral radiography of the temporomandibular joint	0.012	0.27
LCQK002	Radiography of the soft tissues of the neck	0.06	0.30
	Chest		
LJQK001	Radiography of the thoracic skeleton	0.079	1.16
LJQK002	Chest radiography with radiograph of the thoracic skeleton	0.09	5.28
LJQK015	Radiography of the sternum and/or sternoclavicular joints	0.079	0.59
MAQK001	Radiography of the shoulder girdle and/or shoulder with 3 or 4 views	0.017	16.09
MAQK002	Radiography of the shoulder girdle and/or shoulder with 5 or more views	0.026	8.26
MAQK003	Radiography of the shoulder girdle and/or shoulder with 1 or 2 views	0.0086	13.24
MEQH001	Arthrography of the shoulder	0.026	1.89
ZBQK002	Chest radiography	0.053	76.00
ZBQK003	Dynamic radiological examination of the chest to study respiratory and/or cardiac function	0.11	0.13

CCAM code	Desc. of procedure	E/ procedure (mSv)	Freq. of procedure (/1000 indiv.)
	Digestive tract		
HEQH001	Radiography of the oesophagus with contrast agent opacification [Esophageal transit]	1.2	0.11
HEQH002	Upper GI radiography with contrast agent opacification [oesophageal-gastric-duodenal transit]	10	1.16
HFMP002	Secondary radiological control of the position and/or function of an adjustable gastric band, with contrast agent opacification	2.4	0.06
HGPH001	Removal of blockage in small intestine by intestinal enema for meconium ileus, with radiological control	6	NS
HGQH001	Radiography of the small intestine with administration of contrast agent through a nasoduodenal tube [enteroclysis]	6	NS
HGQH002	Radiography of the small intestine with ingestion of contrast agent [Transit of the small intestine]	3.3	NS
HHQH001	Radiography of the colon with contrast agent opacification	9	0.10
HPMP002	Secondary radiological control of the position and/or function of a peritoneal drain, peritoneal dialysis catheter, or peritoneovenous shunt, with contrast agent opacification	2.4	NS
HTQH002	Defecography [Dynamic rectography]	9	NS
HZMP002	Secondary radiological control of the position and/or functioning of a digestive tube, biliary drain, or biliary endoprosthesis with contrast agent opacification	2.4	0.06
JLQH002	Dynamic colpocystorectography	9	NS
ZCQK002	Radiography of the abdomen without preparation	0.9	5.62

APPENDIX

List of CCAM codes, effective dose per procedure and procedure frequency

Table XXII. Effective dose per procedure and procedure frequency for **dental radiology** CCAM codes.

CCAM code	Desc. of procedure	E/ procedure (mSv)	Freq. of procedure (/1000 indiv.)
	Extraoral		
HBQK002	Panoramic dental-maxillary radiograph	0.019	108.51
LAQK001	Teleradiography of the skull and facial skeleton using 2 views	0.026	1.05
LAQK008	Teleradiography of the skull and facial skeleton using 3 views	0.039	0.04
LAQK012	Teleradiography of the skull and facial skeleton using 1 view	0.013	4.86
LAQK027	Cone beam computerised tomography (CBCT) of the maxilla, mandible and/or dental arch	0.100	12.16
	Intraoral		
HBQK001	Occlusal radiography	0.025	0.48
HBQK040	Intraoral retroalveolar radiographs over a sector of 1 to 3 contiguous teeth pre- or peri-operative with final radiograph for endodontic therapeutic procedure	0.007	24.25
HBQK041	Periapical and/or bitewing intraoral radiographs of 14 distinct sectors of 1 to 3 contiguous teeth	0.050	0.87
HBQK046	Periapical and/or bitewing intraoral radiographs of 9 distinct sectors of 1 to 3 contiguous teeth	0.032	0.18
HBQK061	Intraoral periapical and/or bitewing final radiography of a sector of 1 to 3 contiguous teeth for endodontic procedure or peri-operative and/or final, outside of an endodontic procedure	0.004	8.73
HBQK065	Periapical and/or bitewing intraoral radiographs of 10 distinct sectors of 1 to 3 contiguous teeth	0.036	0.43
HBQK093	Periapical and/or bitewing intraoral radiographs of 13 distinct sectors of 1 to 3 contiguous teeth	0.047	0.05
HBQK142	Periapical and/or bitewing intraoral radiographs of 8 distinct sectors of 1 to 3 contiguous teeth	0.029	0.58
HBQK191	Intraoral periapical and/or bitewing final radiographs of 2 distinct sectors of 1 to 3 contiguous teeth	0.007	21.27
HBQK303	Intraoral retroalveolar radiographs of a sector of 1 to 3 contiguous teeth, pre-operative, peri-operative, and final for endodontic therapeutic procedure	0.011	24.00
HBQK331	Intraoral periapical and/or bitewing final radiographs of 3 distinct sectors of 1 to 3 contiguous teeth	0.011	5.02
HBQK389	Intraoral periapical and/or bitewing radiograph of a sector of 1 to 3 contiguous teeth	0.004	87.68
HBQK424	Periapical and/or bitewing intraoral radiographs of 11 distinct sectors of 1 to 3 contiguous teeth	0.040	0.09
HBQK428	Periapical and/or bitewing intraoral radiographs of 5 distinct sectors of 1 to 3 contiguous teeth	0.018	1.79
HBQK430	Periapical and/or bitewing intraoral radiographs of 7 distinct sectors of 1 to 3 contiguous teeth	0.025	0.35
HBQK443	Intraoral periapical and/or bitewing final radiographs of 4 distinct sectors of 1 to 3 contiguous teeth	0.014	13.37
HBQK476	Periapical and/or bitewing intraoral radiographs of 12 distinct sectors of 1 to 3 contiguous teeth	0.043	0.17
HBQK480	Periapical and/or bitewing intraoral radiographs of 6 distinct sectors of 1 to 3 contiguous teeth	0.022	1.10

Table XXIII. Effective dose per procedure and procedure frequency for CCAM **CT scan** codes.

CCAM code	Desc. of procedure	E/ procedure (mSv)	Freq. of procedure (/1000 indiv.)
	Abdomen and/or pelvis		
ELQH001	CT scan of liver vessels to study vascularisation over at least 3 different times	22	0.040
ELQH002	CT scan of the vessels of the abdomen and/or pelvis [Abdominal-pelvic CT angiography]	19	1.011
HHQH365	CT scan of the colon with insufflation [virtual colonoscopy], and intravenous injection of contrast agent	9.8	NS
HHQK484	CT scan of the colon with insufflation [virtual colonoscopy], without intravenous injection of contrast agent	6.5	0.139
ZCQH001	CT scan of the abdomen and pelvis, with intravenous injection of contrast agent	8.9	26.067
ZCQH002	CT scan of the abdomen or pelvis, with intravenous injection of contrast agent	9.8	1.534
ZCQK003	Pelvimetry by CT scan	0.37	0.273
ZCQK004	CT scan of the abdomen and pelvis, without intravenous injection of contrast agent	6.5	9.307
ZCQK005	CT scan of the abdomen or pelvis, without intravenous injection of contrast agent	6.5	1.177
	Other		
PDQK001	Quantification of the various components of soft tissue using CT scans	1	NS
ZZQH001	CT scan of a fistula	7.3	NS
	Limbs		
EKQH001	CT scan of the vessels of the upper limbs [upper limb CT angiography]	16	0.051
EMQH001	CT scan of the vessels of the lower limbs [lower limb CT angiography]	20	1.335
MZQH001	Arthrography of the upper limb with CT scan	5.8	1.198
MZQH002	Unilateral or bilateral CT scan of an upper limb segment, with injection of contrast agent	4.8	0.093
MZQK002	Unilateral or bilateral CT scan of an upper limb segment, without injection of contrast agent	3.8	3.691
NZQH001	Unilateral or bilateral CT scan of a lower limb segment, with injection of contrast agent	0.2	0.256
NZQH002	Arthrography of the lower limb with CT scan	3.8	0.848
NZQH005	CT scan of the hip and lower limb for integrated design of a custom-made osteoarticular prosthesis	10	0.135
NZQK002	Unilateral or bilateral CT scan of a segment of the lower limb, without injection of contrast agent	0.2	5.572
NZQK004	Telemetry of the lower limbs using CT scan	5.5	0.039

Continued **Table XXIII.** >

APPENDIX
List of CCAM codes, effective dose per procedure and procedure frequency

CCAM code	Desc. of procedure	E/ procedure (mSv)	Freq. of procedure (/1000 indiv.)
	Spine		
AFQH001	Saccoradiculography with spinal CT scan	11	0.077
AFQH003	Myelography with CT scan of the spine [Myelogram]	11	NS
LHQH002	CT scan of several segments of the spinal column, with intravenous injection of contrast agent	13	0.090
LHQH005	Single transcutaneous intervertebral discography, with spinal CT scan [discogram]	11	NS
LHQH006	CT scan of a segment of the spinal column, with intravenous injection of contrast agent	10	0.472
LHQK001	CT scan of a segment of the spinal column, without intravenous injection of contrast agent	8.6	14.019
LHQK005	CT scan of several segments of the spinal column, without intravenous injection of contrast agent	10	1.362
	Breast		
QEQK006	CT scan of the breast, without intravenous injection of contrast agent	4.6	NS
	Head and neck		
ACQH001	CT scan of the skull and its contents, with intrathecal injection of contrast agent [Cisternogram]	1.9	0.051
ACQH003	CT scan of the skull and its contents, with intravenous injection of contrast agent	2.6	4.282
ACQK001	CT scan of the skull and its contents, without injection of contrast agent	1.3	16.153
EAQH002	CT scan of the blood vessels of the brain [Cerebral CT angiography]	2.3	0.727
EBQH004	CT scan of the cervicocerebral blood vessels [Cervicocerebral CT angiography]	3.6	2.203
EBQH006	CT scan of the cervical blood vessels [Cervical CT angiography]	3.1	0.720
HCQH002	Sialography with CT scan of the salivary glands	1.8	NS
LAQK002	Unilateral or bilateral CT scan of the petrous portion of the temporal bone and middle ear	1.3	1.360
LAQK009	CT scan of the face with CT scan of the soft tissues of the neck	1.8	0.852
LAQK011	Unilateral or bilateral CT scan of the cerebellopontine angle and/or the internal acoustic meatus [internal auditory canal]	1.1	0.048
LAQK013	CT scan of the face = dentascanner	0.61	5.100
LBQH002	Unilateral or bilateral CT arthrography of the temporomandibular joint	0.5	NS
LCQH001	CT scan of the soft tissues of the neck, with intravenous injection of contrast agent	4.2	1.776
LCQK001	CT scan of the soft tissues of the neck, without intravenous injection of contrast agent	3.3	0.291
	Chest and heart		
ECQH010	CT scan of the blood vessels of the chest and/or heart [Thoracic CT angiography]	11	8.403
ZBQH001	CT scan of the chest, with intravenous injection of contrast agent	3.7	8.882
ZBQK001	CT scan of the chest, without intravenous injection of contrast agent	3.9	22.226

CCAM code	Desc. of procedure	E/ procedure (mSv)	Freq. of procedure (/1000 indiv.)
	Multiple areas		
ACQH002	CT scan of the skull, its contents and the chest with intravenous injection of contrast agent	5	0.598
ACQH004	CT scan of the skull, its contents and the trunk with intravenous injection of contrast agent	16	0.479
ECQH011	CT scan of blood vessels in the chest and/or heart, with CT scan of the blood vessels of the abdomen and/or pelvis [Thoracic CT angiography with CT angiography of the abdomen and/or pelvis]	18	1.509
ZZQH033	CT scan of 3 or more anatomical areas, with intravenous injection of contrast agent	15	21.939
ZZQK024	CT scan of 3 or more anatomical areas, without injection of contrast agent	9.2	1.855

Table XXIV. Effective dose per procedure and procedure frequency for **nuclear medicine** CCAM codes.

CCAM code	Desc. of procedure	E/ procedure (mSv)	Freq. of procedure (/1000 indiv.)
	Circulatory system		
DAQL001	Myocardial perfusion tomo-scintigraphy after stress test or pharmacological test, without synchronisation with the electrocardiogram	3.7	NS
DAQL002	Scintigraphy of the chambers of the heart at rest with 1 view	4.9	0.41
DAQL003	Resting myocardial perfusion tomo-scintigraphy, without synchronisation with the electrocardiogram	2.4	NS
DAQL006	Myocardial positron emission tomo-scintigraphy with dedicated PET camera	4.8	NS
DAQL007	Myocardial scintigraphy without the use of perfusion tracers	5	NS
DAQL008	Scintigraphy of the chambers of the heart at rest using several views	4.9	0.04
DAQL009	Resting myocardial perfusion tomo-scintigraphy with myocardial perfusion tomography after stress test or pharmacological test synchronised with the electrocardiogram	9.5	3.56
DAQL010	Myocardial perfusion tomo-scintigraphy after stress test or pharmacological test, synchronised with the electrocardiogram	3.7	1.72
DAQL011	Myocardial perfusion tomo-scintigraphy at rest, with myocardial perfusion tomo-scintigraphy after stress test or pharmacological test without synchronisation with the electrocardiogram	9.5	NS
DAQL012	Scintigraphy of chambers of the heart for rhythmological purposes	4.9	NS
DAQL014	Resting myocardial perfusion tomo-scintigraphy synchronised with the electrocardiogram	7	0.55
DAQL015	Tomo-scintigraphy of the chambers of the heart at rest, synchronised with the electrocardiogram	5.9	NS

Continued **Table XXIV.** >

APPENDIX
List of CCAM codes, effective dose per procedure and procedure frequency

CCAM code	Desc. of procedure	E/ procedure (mSv)	Freq. of procedure (/1000 indiv.)
	Digestive system		
FEQL003	Topographical search for digestive blood loss using the radioisotope method	4.8	NS
HCQL001	Scintigraphy of the salivary glands	1.8	NS
HEQL001	Radioisotope search for gastro-oesophageal reflux disease	0.6	NS
HEQL002	Scintigraphy of oesophageal transit using solid or liquid substances	0.9	NS
HEQL003	Scintigraphy of oesophageal transit using solid and liquid substances	0.6	NS
HFQL001	Scintigraphy of the gastric or duodenal transit by solid and liquid substances with pharmacological test	0.5	NS
HFQL002	Scintigraphy of the gastric or duodenal transit by solid or liquid substance without pharmacological test	0.3	0.03
HFQL003	Scintigraphy of gastric or duodenal transit by solid or liquid substance with pharmacological test	0.4	NS
HFQL004	Scintigraphy of the gastric or duodenal transit by solid and liquid substances without pharmacological test	0.6	NS
HLQL001	Scintigraphy of the liver and spleen using a tracer of the reticuloendothelial system	1.4	NS
HMQL001	Scintigraphy of the bile duct	2.9	NS
	Osteoarticular and muscular system		
PAQL002	Multi-stage whole-body bone scan	3.1	2.82
PAQL003	Single-stage [late-stage] whole-body bone scan	3.1	1.97
PAQL004	Single-stage segmental bone scan [late stage], with additional acquisition using a pinhole collimator	3.1	NS
PAQL005	Whole-body bone scan, segment by segment in several stages, without additional acquisition using a pinhole collimator	3.1	0.05
PAQL006	Single-stage segmental bone scan [late stage], without additional acquisition using a pinhole collimator	3.1	NS
PAQL007	Multi-stage segmental bone scan with additional acquisition using a pinhole collimator	3.1	NS
PAQL008	Multi-stage segmental bone scan, without additional acquisition using a pinhole collimator	3.1	0.17
PAQL009	Single-stage whole-body segmental bone scan [late stage], without additional acquisition using a pinhole collimator	3.1	NS
PAQL010	Multi-stage whole-body segmental bone scan, with additional acquisition using a pinhole collimator	3.1	NS
PCQL001	Radioisotope examination of skeletal muscle mass after exercise	4.4	NS
PCQL002	Radioisotope examination of skeletal muscle mass at rest	4.4	NS
	Respiratory system		
GFQL001	Tomo-scintigraphy of lung ventilation	0.2	NS
GFQL002	Tomo-scintigraphy of lung ventilation and perfusion	2.6	0.59
GFQL004	Scintigraphy of lung ventilation	0.2	NS
GFQL005	Tomo-scintigraphy of lung perfusion	2.4	0.04
GFQL006	Scintigraphy of lung ventilation and perfusion	2.6	0.08
GFQL007	Scintigraphy of lung perfusion	2.4	NS
GLQL002	Radioisotope measurement of alveolar-capillary permeability	3.8	NS

CCAM code	Desc. of procedure	E/ procedure (mSv)	Freq. of procedure (/1000 indiv.)
	Urogenital system		
JAQL001	Glomerular or tubular renal scan [radioisotope renography] without pharmacological test	1.3	0.03
JAQL002	Renal cortical scan	0.98	0.10
JAQL003	Glomerular or tubular renal scan [radioisotope renography] with pharmacological test	1.3	0.13
JAQL004	Glomerular or tubular renal scan with measurement of plasma radioisotope clearance	1.3	NS
JAQL005	Glomerular or tubular renal scan [radioisotope renography] without pharmacological test, with anterograde scan of the bladder	1.3	NS
JAQL007	Glomerular or tubular renal scan [radioisotope renography] with pharmacological test and reinjection of radioisotope product	1.9	NS
JBQL001	Ureteropelvic elimination scintigraphy	0.9	NS
JDQL001	Retrograde bladder scan	0.2	NS
KGQL001	Measurement of plasma and urinary radioisotope clearance	0.036	NS
KGQL004	Measurement of plasma radioisotope clearance	0.02	NS
	Other		
ZZQL010	Intraoperative detection of lesions after injection of radioisotopic product	0.3	0.80
	Endocrine system		
KCQL001	Thyroid gland scintigraphy with radioisotope measurement of thyroid iodine uptake	1.8	0.15
KCQL002	Radioisotope measurement of thyroid iodine uptake	2	NS
KCQL003	Thyroid gland scintigraphy	1.3	0.52
KDQL001	Parathyroid gland scintigraphy	6.1	0.18
KEQL001	Scintigraphy of the adrenal medulla	3.2	NS
KEQL002	Scintigraphy of the adrenal cortex	100	NS
KGQL003	Radioisotope measurement of biological compartments	5	NS
KZQL002	Somatostatin analogue scintigraphy with additional tomo-scintigraphy, whole-body scintigraphy in addition to a segmental image and whole-body scan at 72 hours	9.3	NS
KZQL003	2-stage somatostatin analogue scintigraphy	8	NS
KZQL004	2-stage somatostatin analogue scintigraphy, with whole-body scan in addition to a segmental image	8.7	NS
	Nervous system		
ABQL002	Radioisotope cisternography	1.5	NS
ABQL003	Radioisotope search for an osteomeningeal breach	1.4	NS
ACQL001	Cerebral tomo-scintigraphy using markers of neurotransmission and/or metabolism	7.8	0.26
ACQL002	Cerebral positron emission tomo-scintigraphy, with dedicated PET camera	3.8	0.31
ACQL007	Cerebral perfusion tomo-scintigraphy without activation test	5.9	0.04
ACQL008	Cerebral perfusion tomo-scintigraphy after pharmacodynamic testing	8	NS

Continued **Table XXIV.** >

APPENDIX
List of CCAM codes, effective dose per procedure and procedure frequency

CCAM code	Desc. of procedure	E/ procedure (mSv)	Freq. of procedure (/1000 indiv.)
	Immune and haematopoietic systems		
FCQL001	Lymphoscintigraphy	0.4	0.14
FDQL001	Bone marrow scintigraphy	2.9	NS
FEQL002	Radioisotope measurement of platelet lifetime	5.5	NS
FEQL007	Radioisotope measurement of blood volume	0.2	0.06
FFQL001	Spleen scintigraphy, using injection of a specific radioisotope tracer	1	NS
ZZQL006	Search for a site of infection or inflammation by injecting marker polymorphonuclear leukocytes, without separation of lymphocytes	3.6	NS
ZZQL011	Search for a site of infection or inflammation by injecting marker polymorphonuclear leukocytes, with separation of lymphocytes	7	NS
ZZQL015	Search for a site of infection or inflammation by injecting antibodies or marker peptides, or non-specific radioisotopic tracers	12	NS
	PET and oncology		
ZZQL005	Scintigraphic search for tumours using a non-specific single-photon emitter for tumours	18	NS
ZZQL012	Scintigraphic search for tumours using a specific single-photon emitter for tumours	5	NS
ZZQL013	Preoperative radioisotope detection of lesions by transcutaneous intratumoral or peritumoral injection, with intraoperative radioisotope detection	0.3	0.74
ZZQL016	Whole-body positron emission tomo-scintigraphy, with dedicated PET camera	11	12.21

Table XXV. Effective dose per procedure and procedure frequency for **diagnostic interventional radiology** CCAM codes.

CCAM code	Desc. of procedure	E/ procedure (mSv)	Freq. of procedure (/1000 indiv.)
	Cardiac		
DDQH006	Transcutaneous arterial angiography of coronary bypass surgery	5.6	NS
DDQH009	Transcutaneous coronary arteriography without left ventriculography	4	3.83
DDQH010	Coronary arteriography with left ventriculography and unilateral or bilateral internal thoracic [mammary] arteriography, by transcutaneous arterial route	5.6	NS
DDQH011	Coronary arteriography with angiography of a coronary bypass and left ventriculography, by transcutaneous arterial route	5.6	NS
DDQH012	Coronary arteriography with left ventriculography by transcutaneous arterial route	4	0.62
DDQH013	Coronary arteriography with angiography of several coronary bypasses without left ventriculography, by transcutaneous arterial route	5.6	0.12
DDQH014	Coronary arteriography with angiography of a coronary bypass without left ventriculography, by transcutaneous arterial route	5.6	0.04
DDQH015	Coronary arteriography with angiography of several coronary bypasses and left ventriculography, by transcutaneous arterial route	5.6	NS
DFQH001	Selective arteriography of the trunk and/or branches of the pulmonary artery, by transcutaneous venous route	5	NS
DFQH002	Hyperselective transcutaneous venous arteriography of the pulmonary arteries	5	NS

CCAM code	Desc. of procedure	E/ procedure (mSv)	Freq. of procedure (/1000 indiv.)
	Neurological		
EBQH001	Global phlebography of a cervicocephalic axis, using a transcutaneous venous approach	5	NS
EBQH002	Selective arteriography of 3 or more cervicocephalic axes, by transcutaneous arterial route	5	0.19
EBQH005	Hyperselective cervicocephalic arteriography by transcutaneous arterial route	5	0.05
EBQH007	Supraselective cervicocephalic arteriography by transcutaneous arterial route	5	NS
EBQH008	Arteriography of several cervicocephalic axes, by multiple transcutaneous intra-arterial injections	5	NS
EBQH009	Phlebography of a cervicocephalic axis, by transcutaneous intra-jugular injection	5	NS
EBQH010	Arteriography of a cervicocephalic axis using a single transcutaneous intra-arterial injection	5	0.05
EBQH011	Selective arteriography of 1 or 2 cervicocephalic axes by transcutaneous arterial route	5	0.06
ECQH012	Selective or hyperselective arteriography of the entire spinal cord by transcutaneous arterial route	60	NS
ECQH013	Selective or hyperselective arteriography of a segment of the spinal cord by transcutaneous arterial route	60	NS
ECQH014	Supraselective arteriography of the spinal cord by transcutaneous arterial route	60	NS
	Biliary tract		
HMQH002	Endoscopic retrograde cholangiopancreatography with sphnicter of Oddi manometry	1.6	NS
HMQH003	Endoscopic retrograde cholangiopancreatography with infundibulotomy [diathermic puncture of the biliary infundibulum] or pre-cutting of the major duodenal papilla	1.6	0.05
HMQH004	Cholangiography by injection of contrast into the bile ducts, transcutaneously, with ultrasound and/or radiological guidance	1.6	NS
HMQH005	Endoscopic retrograde cholangiopancreatography without sphnicter of Oddi manometry	1.6	NS
HMQH006	Cholangiography, by injection of contrast product into an external biliary drain	1.6	0.06
HMQH007	Endoscopic retrograde cholangiography	1.6	0.18
HNQH003	Endoscopic retrograde pancreatography by catheterisation of the major duodenal papilla	1.6	NS
	Vascular		
DGQH001	Global arteriography of the abdominal aorta and lower limbs, by transcutaneous arterial route	12	0.20
DGQH002	Global arteriography of the abdominal aorta by transcutaneous arterial route	12	0.07
DGQH003	Arteriography of the abdominal aorta and lower limbs by transcutaneous intra-aortic lumbar injection	12	NS
DGQH004	Arteriography of the aorta and its branches by transcutaneous intravenous injection	5	NS
DGQH005	Global arteriography of the thoracic and abdominal aorta by transcutaneous arterial route	12	NS
DGQH006	Global arteriography of the thoracic aorta by transcutaneous arterial route	5	0.12
DGQH007	Global arteriography of the aortic arch and its cervicocerephalic branches [aortic sheath] by transcutaneous arterial route	5	0.05
DHQH001	Selective phlebography of several branches of the common iliac veins and/or the inferior vena cava, using a transcutaneous venous approach	12	NS

Continued **Table XXV.** >

APPENDIX
List of CCAM codes, effective dose per procedure and procedure frequency

CCAM code	Desc. of procedure	E/ procedure (mSv)	Freq. of procedure (/1000 indiv.)
	Vascular *(continued)*		
DHQH002	Phlebography of the inferior vena cava [Inferior cavography], by transcutaneous venous route	12	NS
DHQH003	Phlebography of the superior vena cava [Superior cavography], by transcutaneous intravenous injection	5	0.08
DHQH004	Selective phlebography of a branch of the common iliac vein or inferior vena cava, using a transcutaneous venous approach	12	NS
DHQH005	Phlebography of the iliac and inferior vena cava [Iliocavography] by unilateral or bilateral transcutaneous intravenous femoral injection	12	NS
DHQH006	Global phlebography of the superior vena cava [Superior cavography], by transcutaneous venous route	5	NS
DHQH007	Hyperselective phlebography of a branch of the common iliac vein or inferior vena cava, using a transcutaneous venous approach	12	0.08
ECQH001	Bilateral arteriography of the upper limb by arterial route or transcutaneous intra-arterial injection, with positional manoeuvre	8	NS
ECQH002	Supraselective arteriography of the upper limb by transcutaneous arterial route	8	NS
ECQH004	Unilateral arteriography of the upper limb by arterial route or transcutaneous intra-arterial injection, with positional manoeuvre	8	NS
ECQH005	Selective or hyperselective arteriography of the upper limb, by transcutaneous arterial route	8	NS
ECQH006	Arteriography of the upper limb by transcutaneous intra-arterial injection, without positional manoeuvre	8	NS
ECQH007	Bilateral arteriography of the hand by transcutaneous intra-arterial injection	8	NS
ECQH015	Selective or hyperselective arteriography of intra-thoracic arteries to a parietal and/or visceral destination, by transcutaneous arterial route	5	NS
ECQH016	Supraselective arteriography of intra-thoracic arteries to the parietal and/or visceral areas and/or visceral arteries, by transcutaneous arterial route	5	NS
EDQH001	Supraselective arteriography of the extradigestive branch of the abdominal aorta or branch of the internal iliac artery, by transcutaneous arterial route	12	NS
EDQH003	Selective or hyperselective transcutaneous arteriography of an extradigestive branch of the abdominal aorta or a branch of the internal iliac artery	12	0.05
EDQH005	Selective and/or hyperselective arteriography of several extradigestive branches of the abdominal aorta or several branches of the internal iliac artery by transcutaneous arterial route	12	NS
EDQH006	Selective and/or hyperselective arteriography of several digestive branches of the abdominal aorta, by transcutaneous arterial route	12	NS
EDQH007	Supraselective arteriography of the digestive branch of the abdominal aorta, by transcutaneous arterial route	12	NS
EDQH008	Selective or hyperselective arteriography of a digestive branch of the abdominal aorta, by transcutaneous arterial route	12	NS
EEQH001	Bilateral arteriography of the lower limb, by bilateral transcutaneous femoral intra-arterial injection	8	NS
EEQH002	Selective or hyperselective arteriography of the lower limb, by transcutaneous arterial route	8	0.04
EEQH003	Arteriography of the foot, by intra-arterial injection or transcutaneous arterial route	8	NS

CCAM code	Desc. of procedure	E/ procedure (mSv)	Freq. of procedure (/1000 indiv.)
EEQH004	Supraselective arteriography of the lower limb by transcutaneous arterial route	8	NS
EEQH005	Global arteriography of the lower limb by transcutaneous arterial route	8	0.06
EEQH006	Unilateral arteriography of the lower limb by transcutaneous femoral intra-arterial injection	8	0.07
EFQH001	Selective phlebography of the upper limb using a transcutaneous venous approach, without study of the proximal trunk veins	8	NS
EFQH002	Selective phlebography of the brachiocephalic vein or superior vena cava, by transcutaneous venous route	5	NS
EFQH003	Bilateral phlebography of the upper limb by transcutaneous intravenous injection, with study of the proximal trunk veins and superior vena cava	8	NS
EFQH005	Unilateral phlebography of the upper limb by intravenous injection or transcutaneous venous route, with study of the proximal trunk veins and superior vena cava	8	NS
EFQH006	Unilateral phlebography of the upper limb by transcutaneous intravenous injection, without study of the proximal trunk veins	8	NS
EFQH007	Hyperselective phlebography of the brachiocephalic vein or superior vena cava, using a transcutaneous venous approach	5	NS
EHQH001	Selective phlebography of the hepatic [sushepatic] vein by transcutaneous venous route	12	NS
EJQH003	Retrograde phlebography of the lower limb, using transcutaneous intravenous injection of the homolateral femoral vein or the contralateral femoral vein	8	NS
EJQH004	Bilateral phlebography of the lower limb by transcutaneous intravenous injection in the foot	8	NS
EJQH005	Retrograde phlebography of the lower limb by transcutaneous popliteal intravenous injection	8	NS
EJQH006	Unilateral phlebography of the lower limb by transcutaneous intravenous injection in the foot	8	NS
EKQH002	Angiography of arteriovenous access of the upper limb with exploration of the proximal deep trunk veins and superior vena cava by transcutaneous intravascular injection	5	0.10
EZMH001	Secondary radiological control of the patency and/or position of a vascular access device or stent, using injection of contrast agent	0.1	0.20
EZQH002	Angiography of an arteriovenous vascular access to a limb by transcutaneous vascular route	8	NS
EZQH003	Angiography of an arteriovenous vascular access to a limb by transcutaneous intravascular injection	8	NS
YYYY024	Complete venous radiological assessment of the lower limbs for complex venous pathology requiring several approaches, potential fitting of tourniquets, and images taken in various positions	8	NS

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