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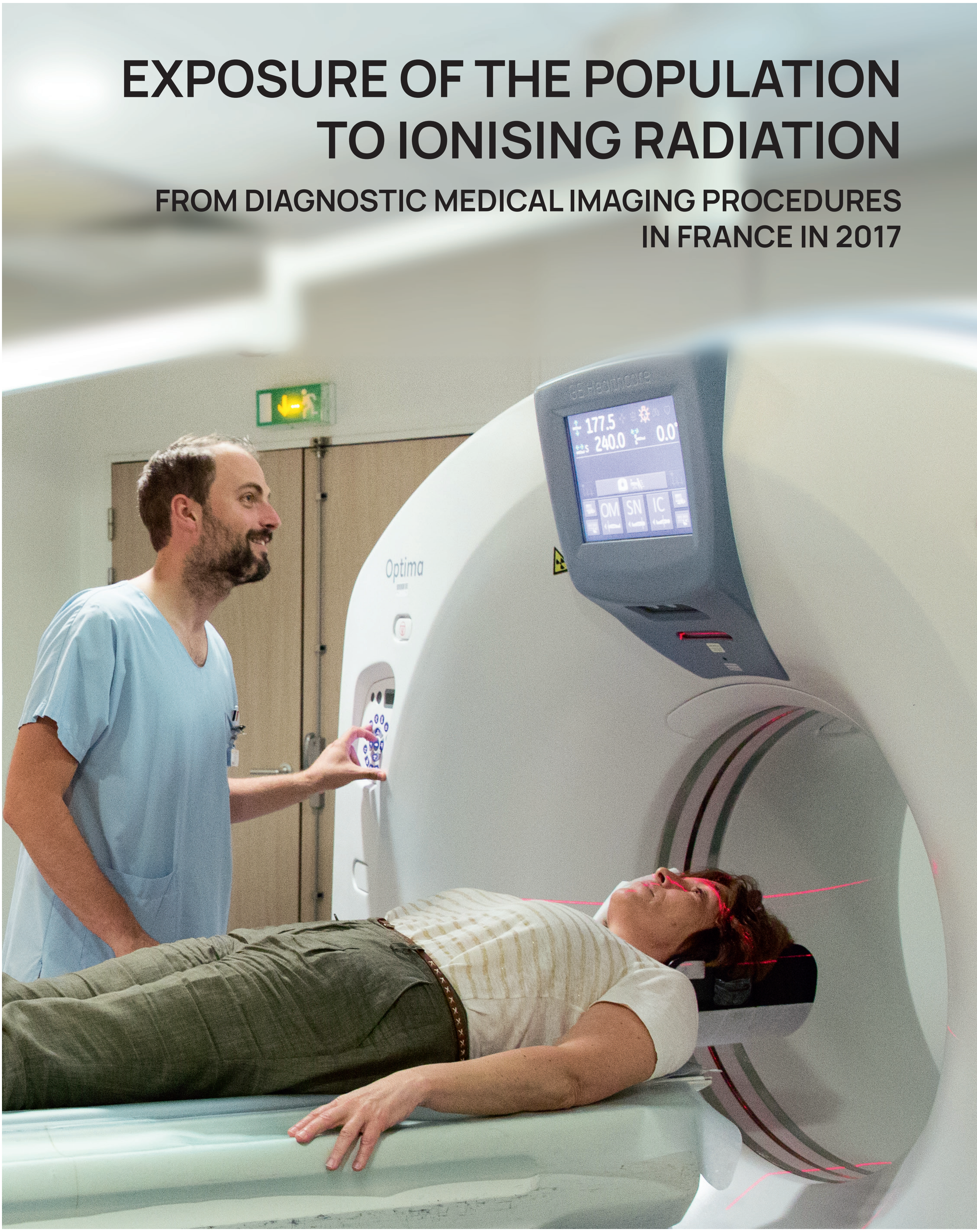
EXPOSURE OF THE POPULATION TO IONISING RADIATION

FROM DIAGNOSTIC MEDICAL IMAGING PROCEDURES IN FRANCE IN 2017



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ABSTRACT

This report is part of the ExPRI (Exposure of the population to ionising radiation) system launched in 2003, and aims to establish data on the exposure of the French population to ionising radiation from medical imaging for diagnosis purposes (conventional, dental and interventional radiology, computed tomography and nuclear medicine) for the year 2017 and to analyse variation in such data. The study was performed based on diagnostic imaging procedures taken from the *échantillon généraliste des bénéficiaires*, a sample on a 1/97th scale of the healthcare consumption of the population covered by the main French health insurance schemes.

The exposure of the French population had not changed significantly in 2017 compared with 2012. Variation detected in terms of the mean frequency of imaging procedures and the average per caput annual effective dose is generally minor, excluding dental radiology. In particular, the almost 90% increase recorded between 2002 and 2012 for the average per caput annual effective dose was no longer evident between 2012 and 2017, and levels stabilised at 1.53 mSv per caput (vs. 1.56 mSv in 2012). Nuclear medicine, which ranks number 3 in terms of the collective effective dose, recorded the greatest increase over this 5-year period, in terms of both frequency and contribution to the collective effective dose. Computed tomography remains the most significant contribution to the exposure faced by the population (74.2%) by far. However, the increase in collective effective dose attributable to computed tomography (+2.4%) remains well below the frequency of these imaging procedures, which increased substantially over the period in question (+17%). The frequency of dental radiology procedures is falling steeply (-16.8%). However, this variation was driven by major changes to the CCAM (social security) codes used to record dental radiological imaging over the 2012-2017 period and cannot therefore be considered as sufficiently reliable.

In 2017, 45.4% of the population was subjected to diagnostic medical imaging procedures one or several times, representing a slight increase since 2012 (43.8%). This percentage falls to 32.7% if dental examinations are excluded. Only a small percentage of patients – but representing several hundreds of thousands of patients throughout France – combined multiple computed tomography examinations, leading to high effective doses, potentially exceeding 100 mSv. Although these patients are very certainly treated for serious pathologies, potential long-term radio-induced effects must be considered.

KEYWORDS

MEDICAL EXPOSURE, POPULATION, IONISING RADIATION, EFFECTIVE DOSE, RADIOLOGY, COMPUTED TOMOGRAPHY, NUCLEAR MEDICINE.

GLOSSARY

ATIH	French technical agency for hospitalisation data
CCAM	Social security codes for medical procedures
CNAM	French health insurance body (CNAMTS prior to 1 January 2018)
CNAMTS	French health insurance body for employees (CNAM since 1 January 2018)
DAP	Dose Area Product
DCIR	SNIIRAM database for individual users
DLP	Dose Length Product
DREES	Direction de la Recherche et des Etudes Statistiques (Directorate for statistical studies and research)
EGB	Generalist sample panel of health insurance beneficiaries
EURATOM	European Atomic Energy Community
ExPRI	Exposure of the population to ionizing radiation
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
INSEE	Institut National de la Statistique et des Etudes Economiques (French Institute of Statistics and Economic Studies)
InVS	Institut de Veille Sanitaire, French institute responsible for monitoring public health and part of the French public health agency (Agence Nationale de Santé Publique) since May 2016
LMDE	Health insurance for students
MGD	Mean Glandular Dose
MSA	Social security system for farmers
NGAP	General French nomenclature for professional procedures
NIR	Social security number
DRL	Diagnostic reference levels
OPRI	Office de Protection contre les Rayonnements Ionisants (Office for protection against ionising radiation)
PET	Positron Emission Tomography
PMSI	Programme for the medical conversion of information systems
RSI	Social security system for sole traders
SFMN	Société Française de Médecine Nucléaire et imagerie moléculaire (French society for nuclear medicine and molecular imaging)
SFPM	Société Française de Physique Médicale (French society for medical physics)
SFR	Société Française de Radiologie (French society for radiology)
SLM	Local health insurance
SNIIRAM	French health insurance information system covering all sectors
T2A	Per procedure invoicing system
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation

1 INTRODUCTION

Medical imaging is a specialist medical field which has repeatedly proven its worth and provides undeniable benefits as part of patient treatment. Medical imaging makes extensive use of ionising radiation, however it is the main contributor to the exposure of the French population to artificial ionising radiation [1]. On this basis, it is important to regularly estimate and characterise this medical exposure, as additionally required by the European Union since 1997 [2]. This requirement was reinforced in 2013 by the European directive 2013/59/EURATOM [3], which has been recently transposed into French law. Article R. 1333-67 of the French Code of Public Health, amended by the decree of 4 June 2018 [4], stipulates that "*Mean exposure for type of imaging, in each anatomical region, per age and gender, of the population, to ionising radiation attributable to diagnostic medical procedures is periodically estimated and analysed by IRSN and described in a public report available on the IRSN website.* "

IRSN has played this role since 2003, the year in which IRSN participated, alongside of Institut de Veille Sanitaire (InVS, now part of the Agence Nationale de Santé Publique), in the creation of the national ExPRI (Exposure of the population to ionising radiation) system, which aims to provide 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 frequencies and types of diagnostic procedures carried out in France, and associated radiation doses and to characterise exposed groups. Since 2010, IRSN has implemented alone the ExPRI system. Three reports have been drafted on the exposure of the French population, at 5-year intervals (2002, 2007 and 2012) [5]–[7] as well as two reports on the exposure of the paediatric population [8], [9]. In addition to meeting regulatory requirements, the ExPRI system is also used to update the data transmitted to UNSCEAR as part of its report on the sources and effects of ionising radiation, for which IRSN is the French correspondent [10].

This report describes the analysis of the exposure of the population to ionising radiation from diagnostic imaging procedures in France in 2017, based on the following indicators :

- the frequency of each type of diagnostic imaging procedure using ionising radiation;
- the percentage of the population actually exposed, i.e. having benefited from at least one diagnostic imaging procedure using ionising radiation during this period;
- the contribution of each type of procedure to the mean per caput annual effective dose and for the "throughout France" population group;
- finally, the annual effective dose absorbed by people actually exposed.

The report starts by covering the methods used to select diagnostic imaging procedures, estimate frequency of use and the associated doses in chapters 2 and 3. Chapter 4 includes the results obtained for each type of imaging and each examination category for the population as a whole. All results are itemised by age and gender. Chapter 5 focuses on analysing the population actually exposed, using the same indicators. This chapter also focuses on the issue of multiple computed tomography examinations for some patients. Finally, chapter 6 describes variation in the main indicators since 2002 before reaching conclusions and mentioning a few potential improvements to the ExPRI system.

2 SELECTING TYPES OF PROCEDURES AND DETERMINING THEIR FREQUENCY

This chapter describes how the diagnostic medical imaging procedures included in this study and the methods used to determine their frequency in 2017 were selected. The general approach used is very similar to that used for the previous ExPRI study [7].

2.1 Selecting diagnostic imaging procedures for the study

This study only includes imaging procedures using ionising radiation for diagnosis purposes, i.e.:

- all conventional radiology procedures, including dental radiology;
- computed tomography procedures[1];
- nuclear medicine procedures exclusively used for diagnostic purposes. On this basis, therapeutic procedures are not covered by this study (unsealed source internal radiotherapy, transarterial radioembolization, etc.);
- interventional radiological procedures for exclusively diagnostic purposes. On this basis, this study excludes the following: therapeutic procedures, diagnostic procedures carried out during a therapeutic procedure (such as angiographies performed during a coronary angioplasty), surgical support procedures, etc.

These procedures are hereafter referred to as "**diagnostic procedures**". The full list of procedures covered by the study can be found in appendix, sorted per type of imaging and per examination category.

2.1.1 Identification of procedures: CCAM classification (social security codes for medical procedures)

CCAM codes are unique and cover all medical technical procedures for which the cost are paid by the social security. CCAM codes are used throughout France and became mandatory for all general practitioners and specialists on 31 December 2005 whether outside of hospitals (clinics, doctor's surgeries in town), or in public or private hospitals (inpatients and outpatients). These codes are used to establish pricing and analyse medical activity.

CCAM codes can be used to clearly identify and differentiate the different diagnostic procedures. Each type of procedure is identified by a full description and a code consisting of four letters and three figures: e.g. CCAM code ZBQK002 corresponds to the description "Radiography of the thorax". A keyword search was entered for version 49 of the CCAM classification for this study: 632 different codes were found for medical procedures using ionising radiation. After eliminating therapeutic procedures, biopsies and ex-vivo examinations, 401 codes were retained, including 24 new codes added since the study on 2012 [7].

It is important to take note that the CCAM codes for procedures by dental surgeons, which still only covered some procedures during the study for 2012, were in general use in 2017, with 92.5% of dental procedures assigned a CCAM code for this study. The percentage of dental radiological procedures without a CCAM code can however still be identified using a specific service reference (see section 2.2.3 for more details).

[1] This study does not cover biopsies with radiological guidance as these procedures depend strongly on the operator and operational difficulties, therefore representative dosimetric data is rare.

2.1.2 Combining procedures

The selected procedures for this study were combined into two categories for the purposes of analysis:

a. By type of imaging: conventional radiology (excluding dental radiology), dental radiology, computed tomography, nuclear medicine and diagnostic interventional radiology.

b. By examination category: diagnostic examination categories defined in this study are based on medical practice criteria and generally combine procedures on the same anatomical region (*head and neck, limbs, etc.*) or the same functional system of the human body (*digestive* *tract, nervous system, etc.*) when more pertinent, particularly in nuclear medicine. In some cases, the combination is based on the type of imaging device when a highly specific device is used (*mammography, bone density testing, PET*). Finally, dental radiological procedures are broken down into two categories depending on whether the image receiver is outside of the patient's mouth (the extraoral group includes dental panoramic scans, cone-beam CT and skull teleradiography) or placed in the patient's mouth (the intraoral group includes retroalveolar, retrocoronary and pelvibuccal radiography).

Table I indicates the examination categories taken into consideration for each type of imaging, and the number of CCAM codes actually used for this study (i.e. codes referring to at least one procedure in 2017 out of the population sample panel). The full list of CCAM codes included in this study can be found in appendix.

It is important to specify that the examination categories covered by this study differ from those used in the previous ExPRI study [7], for which the method recommended in European report no. 154 [11] had been applied. According to the European methodology, procedure categories are defined in terms of radiation protection, i.e. considering organs within the field of radiation. The radiological examination of the lumbar column, for example, is classified under the *abdominal* anatomical region, while this study uses the classification *vertebral column*. The method recommended by European report no. 154 was not used for this study for various reasons:

- Defining procedure categories according to the organs exposed is pertinent in dosimetric terms if the doses are calculated in the same manner for all procedures assigned to this category. This is not the case in this study, for which the doses are calculated using a specific approach for each procedure (*i.e.* for each CCAM code, see chapter 3).
- The categories defined in the European report do not correspond to the clinical categories which medical professionals general apply, which could lead to difficulties understanding the figures provided in this study.
- European report no. 154 was issued in 2008. This report was updated in 2015 by report no.180 [12], however the classification methodology was not modified. Some of the procedure categories defined in the report are now obsolete, in view of major changes to radiological techniques over the last decade.

Table I

Examination categories associated with each type of imaging and number of CCAM (social security) codes actually used.

Type of imaging *Examination category*	Number of CCAM codes
Conventional radiology	**121**
Head and neck	*8*
Vertebral column	*19*
Limbs	*35*
Thorax	*10*
Mammography	*5*
Digestive tract	*11*
Urogenital system	*11*
Pelvic bone	*11*
Bone density testing	*3*
Other	*8*
Dental radiology	**23**
Intraoral	*18*
Extraoral	*5*
Computed tomography	**49**
Head and neck	*13*
Vertebral column	*7*
Limbs	*10*
Thorax and heart	*3*
Abdomen and/or pelvis	*7*
Multiple regions	*5*
Other	*4*
Nuclear medicine	**74**
Cardiovascular system	*12*
Musculoskeletal system	*9*
Respiratory system	*6*
Urogenital system	*10*
Endocrine system	*10*
Immune & hematopoietic syst.	*8*
Nervous system	*5*
PET and oncology	*5*
Other	*9*
Diagnostic interventional radiology	**76**
Cardiac	*10*
Neurological	*10*
Biliary duct	*7*
Vascular	*49*
Total	343

However, in order to analyse changing medical practices over time for each type of imaging, the results of this study are also presented using the examination categories for previous studies (and therefore using the methodology recommended in European report no. 154) in chapter 6.

2.2 Estimating the frequency of diagnostic imaging procedures

The estimated frequency of procedures for the "throughout France" population is based on the frequency recorded for the population included in the "*Échantillon Généraliste des Bénéficiaires*" (EGB), the SNIIRAM generalist sample panel of health insurance beneficiaries, *i.e.* the anonymous database managed by CNAM and used to store invoicing data for medical procedures.

2.2.1 The "*Échantillon Généraliste des Bénéficiaires*" (EGB)

The SNIIRAM order of 20 June 2005 led to the creation of a national sample panel representing 1/97th of health insurance beneficiaries (general cover excluding local private health insurance), known as the "*Échantillon Généraliste des Bénéficiaires*" (EGB). The administrative and sociodemographic profiles of this permanent sample panel of beneficiaries are linked to their "use" of medical procedures over time (which may be none). According to a study published in 2009 by Roquefeuil *et al.* [13], the internal validity of the EGB, *i.e.* its unbiased representativeness of the beneficiaries of general social security cover, excluding local health insurances (SLM), and the healthcare consumption reimbursed to beneficiaries, has been demonstrated:

- the distribution of the sample panel in terms of gender and age matches that of the entire population ;
- the mean expense reimbursed by EGB beneficiary having received at least one medical procedure during the study year (2007) is very similar to that of the entire population.

Since this study, in 2011, the sample panel was extended to the beneficiaries of health insurance for farmers (MSA) and the social security system for sole traders (RSI), and in September 2015, the panel was extended to beneficiaries of 9 local health insurances (SLM)[2] and finally in March 2016, to a 10th SLM (Health insurance for students - LMDE). The sample panel is now representative of the health-related behaviour of 95.6% of the population covered by mandatory French social security, versus 74.9% at the time of the study by Roquefeuil *et al.* The results of this report, based on the generalist sample panel of beneficiaries for the year 2017, can be extrapolated to the entire French population with a high level of confidence.

[2] Mutuelle générale de l'éducation nationale (MGEN), mutuelle générale (LMG), mutuelle générale de la police (MGP), groupement MFP services, mutuelle nationale des hospitaliers (MNH), Harmonie fonction publique (HFP), mutuelle nationale territoriale (MNT), Intériale, caisse d'assurance maladie des industries électriques et gazières (CAMIEG).

EGB data can be accessed via a secure CNAM internet portal. Since late 2016, IRSN can permanently access this data by decree as part of its public service assignments, particularly when drafting this report [14].

Slightly over 700,000 beneficiaries were included in the sample panel for 2017. Interestingly for the scope of this study, these beneficiaries may have participated in one or several diagnostic procedures, or none at all, in the year 2017. The composition of the sample panel for 2017 is described in ***Table II***. The population was studied in 5-year age brackets, as per the recommendations of European report no. 154 [11], except individuals aged 90 or older, who are merged into one single age group for statistical reasons. The paediatric population aged from 0 to 15, for which it is particularly important to consider their sensitivity to ionising radiation, was covered by a specific study published in 2018 [9].

Table II

Number of beneficiaries in the EGB 2017 per gender and year of birth.

Years of birth	Men	Women	Total
2013-2017	19,812	18,682	**38,494**
2008-2012	21,852	20,991	**42,843**
2003-2007	21,667	20,742	**42,409**
1998-2002	20,834	19,424	**40,258**
1993-1997	18,174	17,375	**35,549**
1988-1992	22,214	22,332	**44,546**
1983-1987	22,341	22,654	**44,995**
1978-1982	23,686	23,121	**46,807**
1973-1977	23,227	22,774	**46,001**
1968-1972	24,804	24,124	**48,928**
1963-1967	23,953	23,543	**47,496**
1958-1962	21,798	22,770	**44,568**
1953-1957	20,131	21,547	**41,678**
1948-1952	19,368	20,957	**40,325**
1943-1947	14,752	16,462	**31,214**
1938-1942	9,848	12,070	**21,918**
1933-1937	8,148	11,453	**19,601**
1928-1932	5,294	9,250	**14,544**
1903-1927	3,201	7,886	**11,087**
Total	345,104	358,157	703,261

2.2.2 Counting procedures

When each beneficiary is subjected to a medical procedure, this input is periodically added to the sample panel using SNIIRAM invoicing data. Since June 2011, SNIIRAM has incorporated reimbursement data for medical services (non-hospital) and data for public and private hospitals, by integrating complementary data from the PMSI (Programme for the medical conversion of information systems) of the ATIH (French technical agency for hospitalisation data). CCAM codes are used for the procedures. Each beneficiary included in the sample panel is identified by their encoded social security number (NIR)[3]. On this basis, medical pathways can be reconstituted while maintaining anonymous patient data, whether in the private or public sector, and whether the procedure is received at home, in a doctor's surgery or at a hospital. The sample panel can, therefore, be used to count all diagnostic procedures performed on panel beneficiaries.

When compared with the study on the year 2012 **[7]**, the representativeness of SNIIRAM data available in 2017 has significantly improved in several ways:

- PMSI data for public hospitals is far more comprehensive. The per procedure invoicing system (T2A), introduced in 2004 and gradually extended since that time, are now almost the only type of financing for medical activities, surgery, obstetrics and odontology at both public and private medical establishments. All of the imaging procedures performed in these establishments are, therefore, part of the PMSI; on this basis, the programme can be considered as practically exhaustive for hospital activities in 2017.
- As beneficiaries for ten SLM have been integrated in the sample panel, it is more representative of the wide range of healthcare habits of the French population. In particular, integrating the health insurance scheme for students (LMDE) ensures that students are considered, as student healthcare habits are frequently assumed to differ from those of the general population.
- The progressive withdrawal of the NGAP codes (General French nomenclature for professional procedures) for dental radiological procedures, replaced by CCAM codes, has greatly boosted the reliability of the data collected. Over 92.5% of dental radiological procedures are allocated a CCAM code in EGB 2017, ensuring a detailed description of this sector.

EGB data exports for this study can, therefore, be considered as sufficiently comprehensive to describe the exposure of the population caused by diagnostic procedures by independent doctors or as outpatients or inpatients in a public hospital. However, three points must be carefully monitored in terms of the reliability of this data:

- The representativeness of the sample panel in terms of the student population remains below that of the rest of the population. In fact, only one health insurance provider for students is included in the panel (LMDE) and this provider only represents half of the French student population. The under-representation of this population is proved by the valley in the panel age structure for beneficiaries born between 1993 and 2002 (cf. ***Table II***), and therefore between 15 and 24 years old in 2017. It is important to take note that the integration of other health insurance providers for students is not currently under consideration for technical reasons **[15]**.
- CCAM codes for dental radiology have been extensively changed. Intraoral radiography codes increased from 5 in 2012 to 17 in 2017. 3 codes in particular were introduced specifically for radiographic images taken during endodontics therapeutic procedures, including a set rate for 1 to 3 images. In addition, retroalveolar or retrocoronary radiography codes are now set rates depending on a number of dental sectors (groups of 1 to 3 contiguous teeth). These changes to invoicing for radiological images probably had a major impact on how dental procedures are counted. Comparisons between numbers and frequencies of procedures between 2012 and 2017 must therefore be taken with caution to avoid incorrectly interpreting variation in the number of procedures as variation in radiological practices[4].
- The sample panel represents 1/97th of the population covered by mandatory French social security, therefore some infrequent procedures may only be included in small numbers. Extrapolating to the entire population is therefore unreliable due to the substantial increase in statistical uncertainty.

2.2.3 Exporting relevant parameters for the study

Enquiries were submitted to the SAS Enterprise Guide 7.1 software using the SNIIRAM and PMSI databases in order to export all diagnostic procedures for the sample panel between 1 January and 31 December 2017, and data on the beneficiary (gender and age at the time of the procedure). In practice, the date of birth of the beneficiary is not available in sample panel data to avoid any re-identification, therefore the age of the beneficiary at the

[3] Unique social security number assigned to physical persons.

[4] It is important to remember that CCAM codes refer to medical technical procedures and are designed for financial purposes. If procedures lead to the creation of a package of radiological images or if the number of images for one single procedure changes after a revision, the correspondence between the number of procedures and the number of radiological images will be affected.

time of the diagnostic procedure is calculated give or take one month, rounded up: a child born in February 2016 and requiring a radiological examination in February 2017 is considered as 12-months old at the time of the examination, despite the fact that their real age may be 11 or 12 months depending on whether the date of the examination is before or after the child's birthday.

Diagnostic procedures exported include:

- procedures in the private sector, i.e. by practitioners in the private sector, full-time hospital practitioners in the private sector, and practitioners employed by an establishment applying private rates, which therefore includes non-hospital procedures and those performed in private healthcare establishments (inpatients and outpatients), including dental care if a CCAM code is assigned to the procedure;
- procedures performed in public medical establishments, as inpatient or outpatient care;
- procedures by dental surgeons in the private sector, without CCAM codes.

Relevant parameters for each of these procedures for this study were as follows:

- the demographic characteristics of the beneficiary: encoded NIR, gender, month and year of birth;
- characteristics of the procedure:
  - type of reference service[5],
  - healthcare sector (independent, non-CCAM dental, inpatients and outpatients in public establishments),
  - CCAM code and description of the procedure, for all procedures except one part of dental radiology,
  - month and year of the procedure.

The analysis focused on:

- the frequency of each of these types of diagnostic procedures in 2017 according to the two classifications defined in section 2.1.2 (types of imaging and examination categories), and according to the age and gender of the beneficiaries;
- the percentage of the population actually exposed in 2017, *i.e.* having benefited from at least one diagnostic procedure during the year, and characterised by age and gender.

[5] The type of reference service is a variable used to define the type of healthcare service in SNIIRAM, for procedures in the independent sector. 10 values are assigned to this variable for radiological procedures. In practice, only 4 codes recorded a number of procedures other than zero (in decreasing order of number of procedures): 1351 (imaging procedures [excluding ultrasounds] CCAM), 1331 (radiology procedures), 9423 (oral-dental prevention – 4-image radiography) and 9422 (oral-dental prevention – 2-image radiography). Code 1351 is used for all radiological procedures with CCAM codes, including dental procedures. Codes 1331, 9422 and 9423 are exclusively used for dental radiological procedures without a CCAM code.

2.2.4 Extrapolating to the French population

The number of diagnostic procedures performed on the sample panel was extrapolated to the French population in an identical manner for the public and private sectors. In fact, as indicated in section 2.2.2, the sample panel can now be considered as exhaustive for procedures performed in public hospitals, therefore it is no longer necessary to differentiate between the public and private sectors when extrapolating data, unlike previous ExPRI studies. The reference extrapolation method involves applying coefficients to each age bracket and each gender of beneficiaries, provided by the CNAM on the basis of the ratio between exhaustive SNIIRAM data (DCIR, database for individual users) and sample panel data. These extrapolation coefficients were not available 2017 when this report was being written, therefore a general extrapolation process, ignoring the age and gender of the beneficiary, was applied, considering the representativeness of the sample panel in 2017 (95.6%, see 2.2.1) and the size of the panel (1/97th). This method, which is more approximate than the reference method, remains acceptable thanks to the significant increase in the representativeness of the sample panel of the French population since the study on 2012. However, as indicated in section 2.2.2, the uncertainty in relation to this extrapolation method increases substantially if the sample panel is small. For this reason, the frequencies of procedures and contributions to the mean annual effective dose are not indicated in the tables in appendix for CCAM codes for which less than 100 procedures were actually recorded in 2017. In addition, for the reasons also indicated in section 2.2.2, the sample panel is less representative of the student population. The results apply for the 18-25 age bracket must therefore be treated with more precaution than the other age brackets.

Consequently, the frequencies of procedures and mean annual effective doses indicated in chapter 4 are all related to the population covered by mandatory French social security and not the French population as defined by INSEE. The population covered by mandatory French social security, known as the *population of beneficiaries*, is registered on one of the social security systems, but does not necessarily live in France. The French population, as defined by INSEE, lives in France, but may not be registered with the French social security.

3 ESTIMATING DOSES ASSOCIATED WITH DIAGNOSTIC IMAGING PROCEDURES

3.1 Dosimetric indicator: effective dose

In accordance with the recommendations of European reports no.154 [11] and 180 [12], the effective dose (in millisievert, mSv) is used as the dosimetric indicator in this study to evaluate the exposure to ionising radiation of individuals due to diagnostic procedures. The effective dose indicates the risk of long-term damage to health (potential induction of cancers and hereditary disorders) due to exposure to ionising radiation (stochastic effects). This indicator can be used to assess the overall risk for the entire body, whether exposed in full or partially, considering the type and energy of radiation, and the specific radiosensitivity of each body organ exposed [16]. The effective dose is calculated based on weighting factors defined for the general population, covering all ages and genders, **and must not be used to quantify a risk for a specific population in absolute terms, nor, above all, to estimate an individual risk[6]. In addition, the low effective doses associated with examinations only affecting a small part of the body, such as dental radiography or mammography, must not mask the fact that local exposure for the salivary glands or the mammary gland in the above cases, can be relatively high.**

However, the effective dose is the only available means of estimating relative radiological risks for imaging examinations of different anatomic regions or using different types of imaging for the same anatomical region. As a standard indicator, the effective dose can also be used to compare different countries and study variation in the exposure of the population due to all medical procedures using ionising radiation or one specific type of procedure over time.

The mean effective doses per type of diagnostic procedure were calculated using the tissue weighting factors defined in publication 103 of the International Commission on Radiological Protection (ICRP) [16], with the exception of nuclear medicine, for which the most recent reference publication [17] systematically refers to the tissue weighting factors defined in ICRP publication 60 [18]. The individual annual effective dose is obtained by adding together the effective doses for the different procedures performed on one individual patient during the period considered.

These mean effective doses per type of procedure were estimated using various data sources in order to ensure that the doses are as representative as possible of French radiology and nuclear medicine practices in 2017. The mean effective doses per type of procedure can be found in appendix, classified per type of imaging, per examination category and per CCAM code. These figures have globally dropped since 2012 [7], to match the reduction in dosimetric indicators already mentioned in the recently published IRSN report on the analysis of updated data for diagnostic reference levels [19].

3.2 Estimated mean effective doses for each type of procedure

As no individual dosimetric data is available, and despite the frequent wide variation in doses for the same type of procedure [19], the exposure of the population is estimated by associating a mean effective dose to each type of procedure, defined on the basis of the CCAM code. These mean effective doses are calculated for an adult patient with a standard morphology, and are considered to be constant regardless of the age and gender of the patient, in accordance with the method recommended at European level [12]. Unless explicitly indicated otherwise in the description of this code, the effective doses used in this study correspond to a complete procedure, as recommended in the aforementioned European report RP 154. This report defines a complete procedure as «one or a series of x-ray 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, hospital or clinic».

[6] ICRP publication 103 [16] – «*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*».

To give just one example, computed tomography of the thorax with the intravenous injection of a contrast medium (code ZBQH001) is a complete procedure which may include one or several acquisition scans. On this basis, the associated effective dose is calculated by multiplying the dose for a single thoracic scan by the estimated mean number of scans for this procedure.

The different data sources used in the previous ExPRI study [7] were updated to integrate the results of studies reflecting clinical practices in 2017 as closely as possible, and are described in the following sections.

3.2.1 Data transmitted by imaging services when updating diagnostic reference levels

Since 2004, all managers of radiological or nuclear medicine facilities have been required to carry out an annual dosimetric evaluation for at least two types of procedures routinely performed at this facility, selected from a list published by order [20]. This dosimetric information, which is required by practitioners to evaluate and optimise their approaches, must also be transmitted to IRSN, which will publish a periodic analysis for French entities. The most recent review describes the analysis of dosimetric data collected over the 2016-2018 period [19], and particularly for adults:

- dose area product (DAP) for each conventional radiology image,
- mean glandular dose (MGD) for each mammography image,
- dose length product (DLP) for each computed tomography acquisition,
- the activity of the administered radiopharmaceutical for nuclear medicine.

The mean values of these different dosimetric indicators were especially calculated for the year 2017 for the purposes of this study.

With conventional radiology, effective doses are calculated by multiplying the mean DAP of the complete procedure by the conversion factor for the anatomical region imaged, if existing [12], or by simulating the diagnostic procedure using PCXMC V2.0 software [21].

With mammography, the effective dose was calculated by multiplying the cumulative mean glandular dose for the complete procedure by the factor WT defined for breasts (or half of this value for unilateral mammography) in ICRP publication 103 [16].

With computed tomography, the effective dose for each type of procedure was calculated by multiplying the mean DLP of the complete procedure by the conversion factor for the anatomical region imaged, if existing [12], [22], or by using CT Expo V2.5 software [23].

With nuclear medicine, the mean effective doses were calculated using the mean activity administered while applying the conversion factors recently updated by ICRP [17] for the main radiopharmaceuticals. It is important to take note that these conversion factors are systematically calculated on the basis of the tissue weighting factors in ICRP 60 [18], therefore the mean effective doses per nuclear medicine procedure are not strictly equivalent to the mean effective doses per procedure for the other types of imaging considered in this document, most of which are based on the tissue weighting factors from ICRP publication 103 [16]. Conversion factors based on ICRP publication 103 have been published [24], [25], but have not yet been formally adopted by ICRP, and are not used herein.

3.2.2 Recent studies by professional groups

In terms of computed tomography, the national study led by the SFPM (Société Française de Physique Médicale - French society for medical physics), in coordination with the SFR (Société Française de Radiologie - French society for radiology), focusing on clinical doses, included over 6,600 examinations and 53 radiology services and provided precise and recent data on the most frequent computed tomography scans [26]. The mean DLP for complete examinations and the mean number of scans per examination published in this study were used to update the mean effective doses for a significant number of computed tomography procedures.

With interventional cardiology, the multicentric national RAY-ACT 2 study updated the initial study performed in 2010 under the aegis of the *Collège national des cardiologues des hôpitaux* (French group of hospital-based cardiologists) and included 44 public hospital interventional cardiology services [27]. The mean effective dose associated with a coronarography was calculated using the mean DAP published in this study and the conversion factor for the anatomical region considered [11].

3.2.3 Guides to procedures published by professional groups

Various learned societies publish guides to procedures to complement the above data sources, offering a source of key information on technical parameters for examinations. The following main guides were used to confirm the estimated mean effective doses as part of this report:

• The *Guide de procédures radiologiques* (guide to radiological procedures) published by the SFR and the OPRI (Office de Protection contre les Rayonnements Ionisants - Office for protection against ionising radiation) in 2001 and updated in 2014 [28]. This guide was completed in 2013 by the *Guide pratique d'imagerie diagnostique* (guide to diagnostic imaging practices) for use by radiologists [29]. These guides propose technical parameters for these procedures, for the most frequent procedures, reconciling expected image quality with the lowest possible level of exposure.

• The guide to indications and procedures for radiological dental examinations [30].

• SFMN (Société Française de Médecine Nucléaire et Imagerie Moléculaire - French society for nuclear medicine and molecular imaging) guides to procedures [31]. These guides specify the radiopharmaceutical(s) to be used for certain types of diagnostic nuclear medicine procedures and the mean activity to be administered. These documents were used to confirm the effective doses used for the study.

3.3 Uncertainty for effective doses

The main sources of uncertainty when estimating the mean effective dose per type of procedure were described and discussed in the report for 2007 [6]. These points are still valid for this study and relate to:

• the dispersal of effective doses absorbed for a given type of procedure at national level, considering different practices and equipment;

• potential residual inconsistencies for some types of procedures between actual clinical practice and the CCAM classification;

• the scarcity of some types of procedures, which makes dosimetric evaluation unreliable.

European report RP no.180 [12] estimated uncertainty for the mean effective doses per type of procedure calculated for each of the countries participating in the Dose Datamed 2 study. The mean uncertainty for this estimation, based on the method proposed by Hart and Wall [32], is in a 20-40% bracket for all procedures considered.

The uncertainty for the mean annual per caput effective doses is mainly attributable to the uncertainty for the mean effective doses for the different types of procedures, which is much greater than the uncertainties for the frequency of the procedures or the size of the population, for this type of study. European report RP no. 180 [12] estimates that uncertainty for the estimated doses for the population falls between 12 and 25% depending on whether the mean effective doses for the different types of procedures are calculated based on actual clinical practice or estimated using figures from the literature. The mean effective doses of the different types of procedures covered in this study are partially calculated using actual data (DRL data or specific studies) and partially extrapolated from the literature, therefore uncertainty for the mean annual per caput effective doses calculated in this study should remain within this bracket.

4 EXPOSURE FOR THE ENTIRE POPULATION IN 2017

This chapter describes the results of the study for the entire sample panel population, for all individuals, regardless of whether or not a diagnostic procedure was required. The results can be found in:

- number of procedures extrapolated to the protected French population[7],
- collective dose extrapolated to the protected French population,
- frequency of procedures (number of procedures for 1,000 beneficiaries[7]),
- mean annual per caput effective dose

A total of 834,444 diagnostic procedures were performed during 2017 on beneficiaries in the sample panel. By extrapolating to the entire protected French population, it is estimated that slightly less than 85 million diagnostic procedures were completed in France in 2017. A collective effective dose of approximately 110,000 sievert (Sv) is assigned to these procedures as a whole. **These figures correspond to a mean value of 1,187 procedures per 1,000 beneficiaries (exposed or other) and a mean annual per caput effective dose of 1.53 mSv.** These mean values reflect the exposure of the French population to ionising radiation attributable to medical care (excluding therapeutic applications), and can be used to compare figures for different countries or estimate the exposure of French residents to ionising radiation, from all sources, as performed periodically by IRSN [1]. Despite this, the actual exposure of French residents varies widely as only a fraction of individuals in the sample panel actually participated in one or several diagnostic procedures in 2017. This population of patients who were actually exposed will be studied in chapter 5.

Table III

Number of diagnostic imaging procedures and associated collective effective doses.

Rounded values, extrapolated for all of France, 2017.

Type of imaging	Procedures		Coll. effective dose	
	nomber	%	mSv	%
Conventional radiology	46,681,000	55.1	12,938,000	11.8
Dental radiology	25,023,000	29.6	302,000	0.3
Computed tomography	10,866,000	12.8	81,170,000	74.2
Nuclear medicine	1,662,000	2.0	12,401,000	11.3
Diagnostic interv. radiology	435,000	0.5	2,652,000	2.4
All types of imaging	**84,667,000**	**100**	**109,463,000**	**100**

4.1 Distribution of exposure per type of imaging: frequencies of procedures and mean per caput effective doses

Table III and ***Figure 1*** show the number of imaging procedures and associated collective dose for 2017, distributed per type of imaging.

Most procedures use conventional radiology, representing almost 47 million procedures, and this type of radiology ranks second in terms of contributions to the collective effective dose. Approximately 25 million dental radiological procedures were recorded, establishing this type of imaging as the second contributor to the number of procedures, but the smallest contributor to the collective effective dose. On the other hand, computed tomography only ranks third in terms of frequency of procedures, with just under 11 million procedures, well behind dental radiology, but it contributes approximately 75% of the collective effective dose attributable to the diagnostic medical imaging sector. Nuclear medicine only represents a small percentage of procedures, but ranks third in terms of contributions to the collective effective dose at over 11%, just behind conventional radiology. Finally, diagnostic interventional radiology, which represents very few procedures in terms of number for this study, contributes 2.4% of the collective dose.

[7] The term «protected» refers to the population covered by mandatory French social security in 2017. The term «beneficiary» is used to refer to one individual in the protected population (cf. 2.2.4).

4.1.1 Frequency of procedures per type of imaging according to age and gender

In addition to the breakdown of the number of procedures, it is worthwhile calculating the frequencies of procedures, *i.e.* the number of annual diagnostic procedures performed on patients of a given age and gender, over the population of this age bracket and gender. These frequencies differ significantly depending on the age of the individuals and, to a lesser extent, their gender, as is apparent in ***Figure 2*** which shows frequencies as the number of procedures for 1000 individuals of a given gender and age bracket.

The frequency of procedures increases with the age of the individuals: from approximately 300 procedures for 1,000 children aged under 5 to over 2,000 procedures for 1,000 adults aged 75 - 84. A peak appears for children aged 10 - 14, and for teenagers aged 15 - 19, as previously identified in the report on the paediatric population [9], which is available for more details on this population category. Above the age of 85, the frequency of procedures drops substantially.

A clear difference is also apparent between men and women: procedures are performed more frequently for women in practically all age brackets, with particularly contrasting differences for the 40 - 75 age bracket. In general, considering all ages, the frequency of procedures is equal to 1,328 procedures for 1,000 women, versus 1,040 procedures for 1,000 men, as indicated in ***Table IV.***

Figure 1

Distribution of diagnostic procedures and collective effective dose per type of imaging.

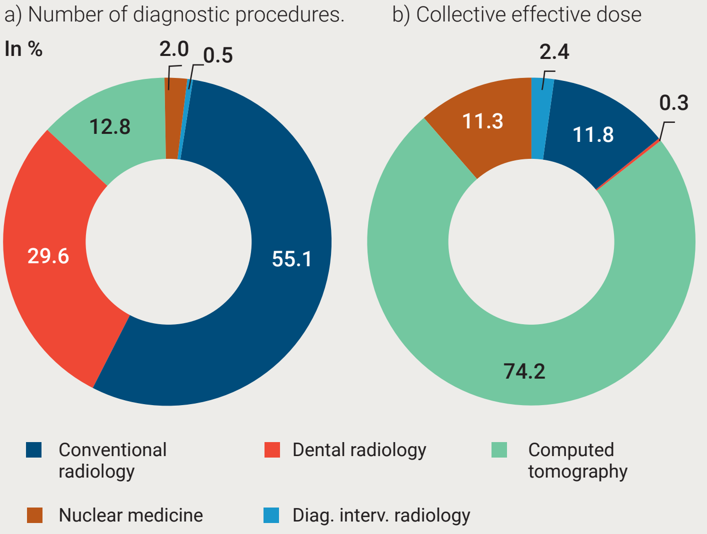


Figure 2

Frequency of procedures (all types of imaging) according to age bracket and gender.

Number of procedures for 1000 individuals.

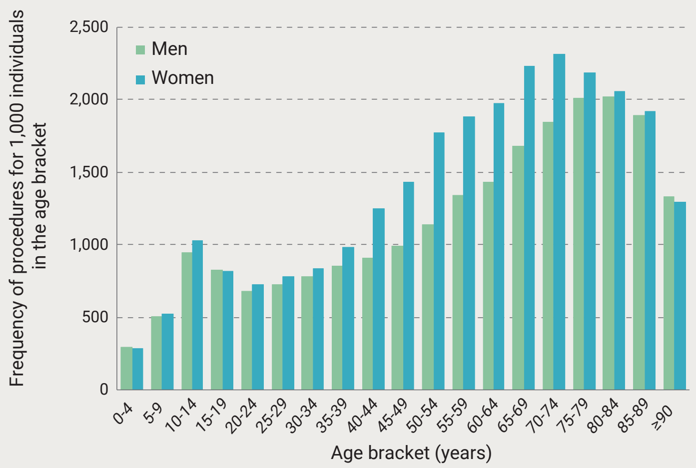


Table IV

Frequency of procedures according to gender and the type of imaging.

Type of imaging	Men		Women		Overall	
	/1,000 indiv.	%	/1,000 indiv.	%	/1,000 indiv.	%
Conventional radiology	525	50.5	779	58.7	654	55.1
Dental radiology	327	31.4	374	28.2	351	29.6
Computed tomography	158	15.2	147	11.0	152	12.8
Nuclear medicine	22	2.2	24	1.8	23	2.0
Diagnostic interv. radiology	8	0.8	4	0.3	6	0.5
All types of imaging	**1,040**	**100**	**1,328**	**100**	**1,187**	**100**

Figure 3

Comparison of frequencies of procedures per type of imaging and age bracket for men and women.

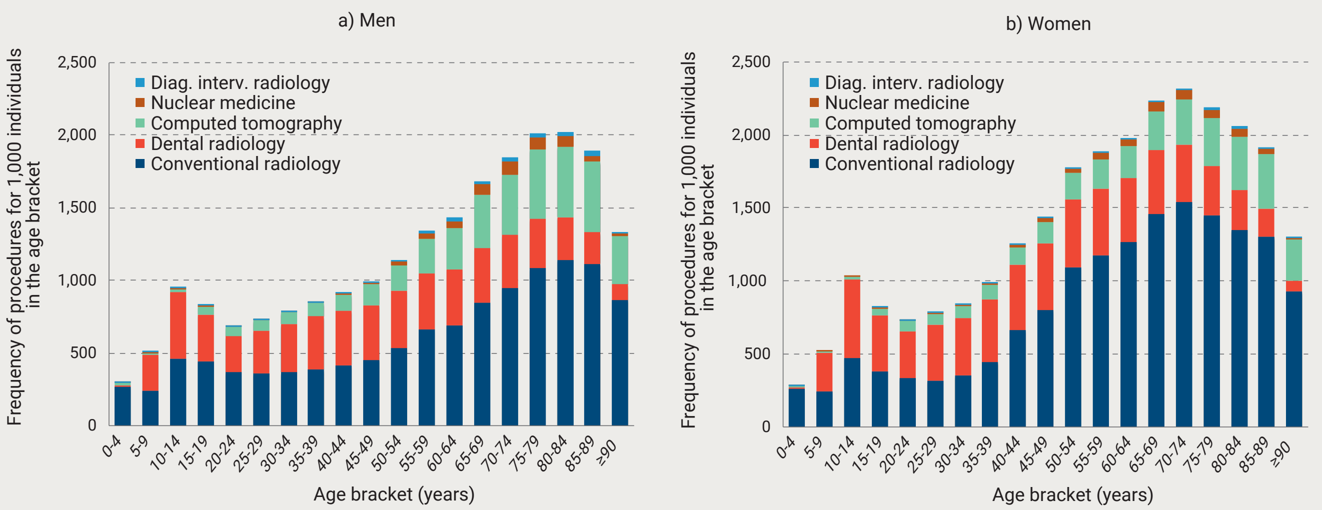


Figure 3 indicates the distribution of examinations according to age and gender, complementing *Table IV:*

- Conventional radiology is far more frequently used with women aged 40 to 90 than with men in the same age group. This difference is mainly due to mammography, as discussed later.
- Dental radiology is considerably more frequent for women, in practically all age brackets.
- The frequency of computed tomographic procedures is substantially higher for men, particularly over the age of 55. The frequency of computed tomography as a percentage increases regularly, for both genders, from the teenage years, until reaching a peak in the 80's.
- Nuclear medicine, and diagnostic interventional radiology even more so, only reach significant frequencies after the age of 40 - 50 and peak in the 70's.

4.1.2 Mean effective dose per type of imaging according to age and gender

This section focuses on the distribution of effective dose according to the age and gender of individuals. This refers to the mean annual per caput effective dose, *i.e.* the total effective dose for the diagnostic procedures performed on patients of a given age and gender, over the population of this age bracket and gender. This value indicates the exposure of the French population as a whole, with no differentiation between the population exposed to medical radiation and the population not exposed to medical radiation. The mean effective dose absorbed if we only consider individuals who are actually exposed will be studied in chapter 5.

Figure 4

Mean annual per caput effective dose according to age and gender.

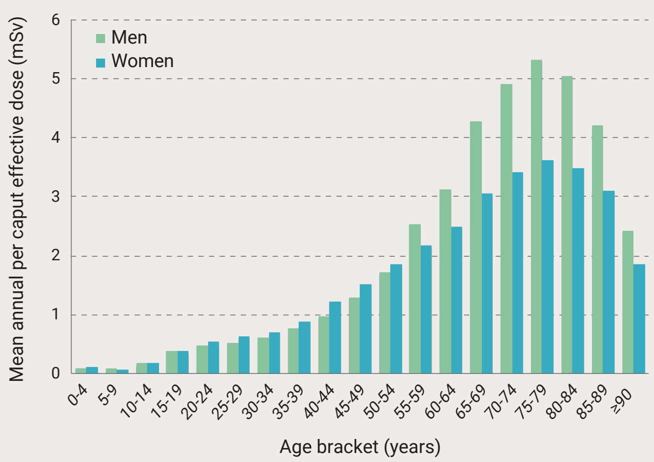
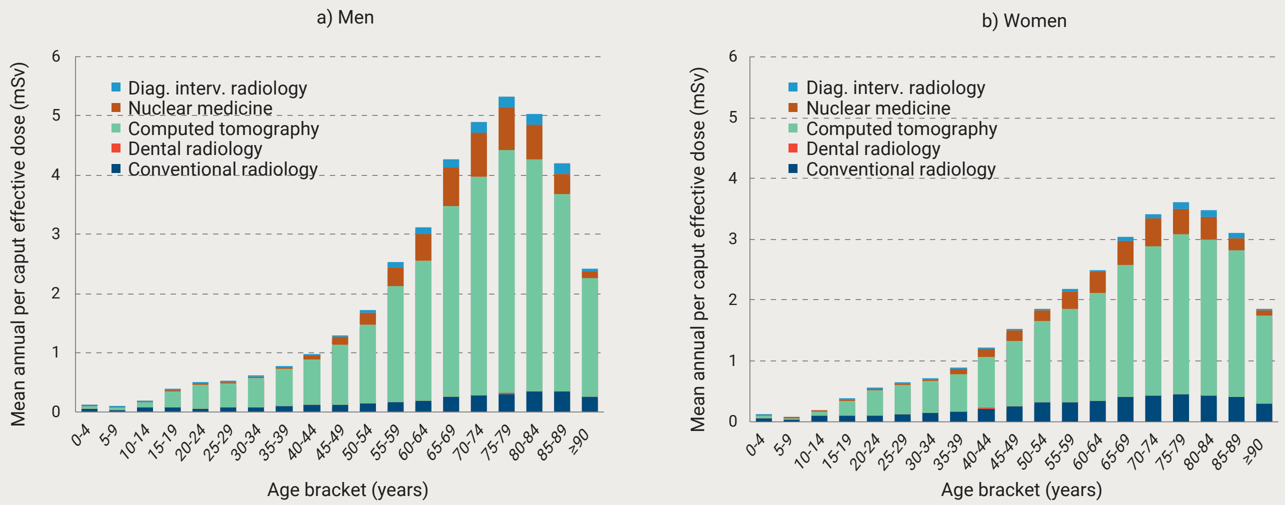


Figure 4 shows mean annual per caput effective doses per gender and age bracket, in mSv. Doses vary substantially depending on the age of the individual: from less than 0.1 mSv per year for children aged under 10 to over 5 mSv for men aged 75 - 85. In general, the dose

Figure 5

Comparison of men's and women's mean annual per caput effective doses, according to the type of imaging and age bracket.



increases more rapidly with age and reaches a maximum figure in the 75 - 79 age bracket, and then decreases fairly rapidly. It is important to remember that the mean annual effective dose of children aged under 1, which is not indicated in this study due to the selected age brackets, is significantly above the mean annual effective dose of other children, as explained in the previous report on the paediatric population **[9]**.

Unlike apparent trends for the frequencies of procedures, the male population aged over 55 absorbs a mean effective dose which is significantly greater than the female population, as clearly apparent in ***Figure 4***. In general, considering all ages, the mean annual effective dose is approximately 1.6 mSv for each man versus 1.47 mSv for each woman, as indicated in ***Table V***. This difference appears to be essentially caused by computed tomography, which, as indicated in the previous section, is used more frequently for men, and, to a lesser extent, nuclear medicine and diagnostic interventional radiology. Despite this, the contribution of conventional radiology is far higher for women than men due to mammograms, as demonstrated in section 4.2.1.

Figure 5 more clearly highlights the contributions of each type of imaging according to age and gender, complementing ***Table V***:

- The increasing contribution of computed tomography with the age of the individual is very clearly visible: most of the collective effective dose for all age brackets above 15 is attributable to computed tomography procedures, for both genders. However, the contribution of computed tomography is substantially higher for men above the age of approx. 55.

Table V

Mean annual effective dose according to gender and type of imaging, for all ages.

Type of imaging	Men		Women		Overall	
	µSv/indiv.	%	µSv/indiv.	%	µSv/indiv.	%
Conventional radiology	130	8.1	231	15.6	181	11.8
Dental radiology	4	0.2	5	0.3	4	0.3
Computed tomography	1,224	76.7	1,054	71.5	1,138	74.2
Nuclear medicine	189	11.8	159	10.8	174	11.3
Diagnostic interv. radiology	49	3.1	26	1.7	37	2.4
All types of imaging	**1,596**	**100**	**1,474**	**100**	**1,534**	**100**

- The dose attributable to conventional radiology is substantially higher for women above the age of 10. The more significant differences between men and women are apparent in the 50-75 age brackets.
- Dental radiology does not significantly contribute to the mean effective dose in any age bracket. This due to the characteristics of this type of diagnostic imaging procedure (very local exposure of a region with few radiosensitive organs). This must not mask the fact that local exposure, particularly of the salivary glands, can be relatively high; it is therefore important to interpret these results with caution (cf. 3.1).
- Nuclear medicine makes a significant contribution to the mean effective dose from the age of 45, particularly for men, for which this type of procedure ranks second in terms of dose contributions, well ahead of conventional radiology.
- Finally, diagnostic interventional radiology makes a fairly significant contribution to the mean effective dose from the 55-60 age bracket, an effect which is once again more visible for men than women.

4.2 Distribution of exposure per examination category: frequencies of procedures and mean per caput effective doses

This section studies frequencies per type of imaging as assigned to groups of procedures. These groups of procedures were defined in chapter 2 (cf. ***Table I***) and correspond to anatomical regions or types of examinations if anatomical regions are not pertinent. A table summarising the mean frequencies of procedures and mean annual effective doses for each group of procedures is provided for each successive type of imaging, for the entire population and for each gender. Groups of procedures are classified per decreasing frequency of procedures for the general population. Frequencies of procedures per age bracket are then shown by two graphs, for each gender.

4.2.1 Conventional radiology

Most conventional radiology procedures target limbs for both men and women: they represent approximately one third of annual procedures (cf. ***Table VI***). These procedures are required much more frequently by women. On the other hand, the effective doses for radiograms of limbs are very low due to the absence of organs considered as radiosensitive in the region covered, therefore the contribution of procedures in this anatomical region to the mean annual per caput effective dose is extremely low. As is the case for dental radiology, this effect is caused by the characteristics of these radiographies (very local exposure of a region with few radiosensitive organs) and must not mask the fact that local exposure can be relatively high. These results must be carefully interpreted (cf. 3.1).

Thorax radiography is the second most frequent group of procedures, for both genders, with approximately 170 procedures for 1,000 individuals. Their contribution to the mean annual per caput effective dose is significantly

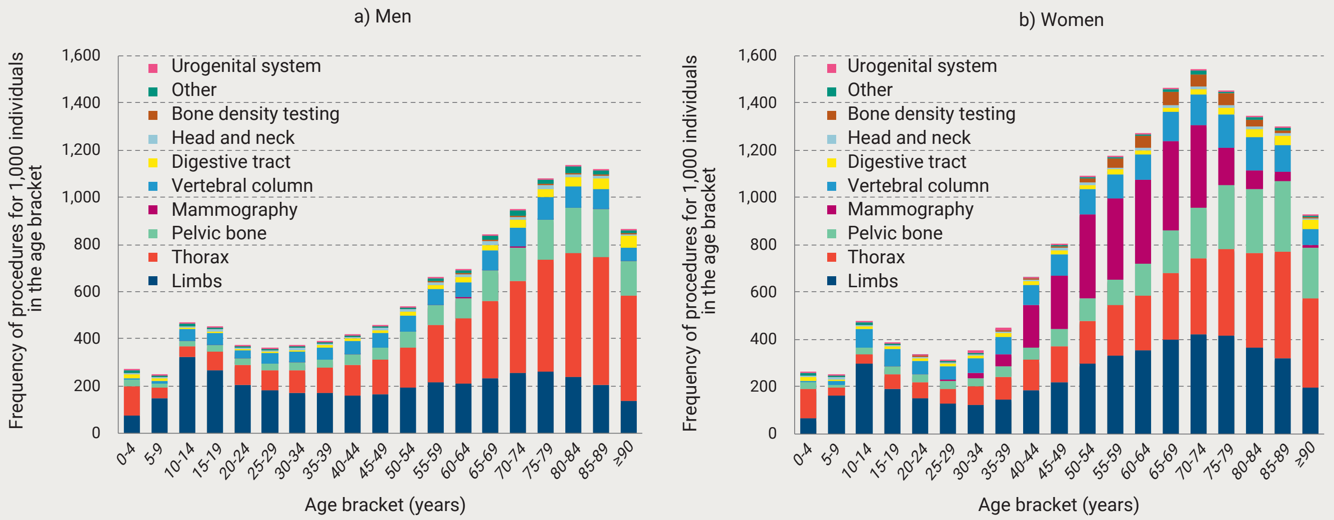
Table VI

Distribution of exposure per examination category for conventional radiology: frequencies of procedures and mean per caput effective doses.

Examination category	Freq. of procedures (/1,000 indiv.)			Mean annual eff. dose (µSv/indiv.)		
	Men	Women	Overall	Men	Women	Overall
Limbs	198.2	241.6	220.3	0.28	0.36	0.32
Thorax	174.9	165.0	169.8	9.2	8.3	8.8
Pelvic bone	60.7	93.3	77.3	40.0	61.7	51.0
Mammography	0.5	145.0	74.1	0.2	43.4	22.2
Vertebral column	54.0	82.4	68.5	41.8	61.4	51.8
Digestive tract	14.6	16.7	15.7	27.7	42.3	35.1
Head and neck	10.1	8.8	9.4	2.2	2.6	2.4
Bone density testing	2.1	16.5	9.4	0.002	0.016	0.009
Other	7.8	6.1	6.9	4.7	4.1	4.4
Urogenital system	1.4	3.2	2.3	3.3	5.9	4.6
Total	**524.4**	**778.5**	**653.8**	**129.4**	**230.1**	**180.7**

Figure 6

Comparison of frequencies of conventional radiological procedures per examination category and age bracket for men and women.



higher than that of procedures focusing on limbs, but remains moderate compared with other anatomical regions such as the pelvis or vertebral column.

Procedures imaging the pelvic bone rank 3rd for men and 4th for women, however such procedures are required far more frequently for men compared with women, with an approx. 50% difference. These procedures, with the vertebral column group, represent one of the two groups with the greatest impact on the mean annual per caput effective dose.

Mammography is the third most frequent group of procedures for women, with a mean annual frequency of 145 procedures for 1,000 individuals. This frequency will naturally vary widely depending on the age of the women, as is apparent in ***Figure 6b***. Mammography ranks 3rd in terms of contributions to the mean annual effective dose per women, with slightly over 43 µSv. In the same way as for radiography on limbs, this figure is partially caused by the characteristics of these examinations (local exposure of one single radiosensitive organ). This must not mask the fact that exposure of the mammary gland can be relatively high; it is therefore important to interpret these results with caution (cf. 3.1).

Procedures targeting the vertebral column group rank 4th for men and 5th for women in terms of frequency, however such procedures are required far more frequently for women. Such procedures represent the highest proportion of the mean annual effective dose attributable to conventional radiology, at a similar level to procedures imaging the pelvic bone.

Procedures focusing on the digestive tract, which are approximately 10 times less frequent than procedures focusing on the thorax, do however rank as the 3rd contributor to the mean annual per caput effective dose, due to the relatively high effective doses for this type of radiography.

Procedures focusing on other anatomical regions are both infrequent and do not significantly contribute to the mean annual per caput effective dose, particularly bone density testing.

Figure 6 highlights significant variation in the distribution of the locations of radiological procedures based on age, and certain particularities attributable to gender:

- Limb radiography is a very frequent procedure for children aged 10 - 14, and reduces in frequency for adults before re-increasing once again, particularly for women, and peaking towards the age of 75.
- The frequency of thorax radiographies increases proportionally with the age of individuals, and ranks as the most frequent group of procedures from the age of 55 for men, and 80 for women. Children under the age of 5 are a special case as thorax radiograms rank no. 1 in terms of frequency.

- The frequency of procedures imaging the pelvic bone also increase substantially in proportion to age. Pelvis procedures are required more frequently for women, in all age brackets.
- Mammography is a special group, as almost exclusively women require such imaging, and most mammograms are taken in the 40 - 74 age bracket. Mammography is the most frequent group of procedures for women aged 45 - 65.
- Vertebral column imaging is a more frequent group of procedures for women than for men, at any age. Frequency increases with the age of individuals, but to a lesser degree than thorax or pelvic bone imaging.

4.2.2 Dental radiology

Dental radiology procedures are split into two groups in *Table VII*: intraoral radiography, representing approximately two thirds of procedures, and extraoral radiography (which includes dental panoramic imaging and cone-beam CT) for the final third. These procedures are required far more frequently for women, for both categories, with a difference of approximately 15%. Consequently, the mean annual effective dose per woman attributable to dental radiology is approximately 18% higher than the same dose for men. The extraoral group represents approximately two thirds of this figure, which is ultimately a very low percentage of the collective effective dose attributable to diagnostic medical imaging (0.3%, cf. 4.1).

The distribution of the two groups of dental radiological procedures per age bracket is visible in *Figure 7*. The frequency of procedures peaks in the 10-14 age bracket, for both groups of procedures and both genders. This frequency then decreases up to the 20-25 age bracket. The frequency of extraoral radiography then remains relatively stable, at approximately 110 procedures for 1,000 men and 135 procedures for 1,000 women, up to the age of 70, before rapidly decreasing. The frequency of intraoral radiography increases progressively from age 25 up to 50-54, at which point it reaches 285 procedures for 1,000 men and 333 procedures for 1,000 women. This frequency then subsequently slowly decreases, before falling rapidly after the age of 75 years.

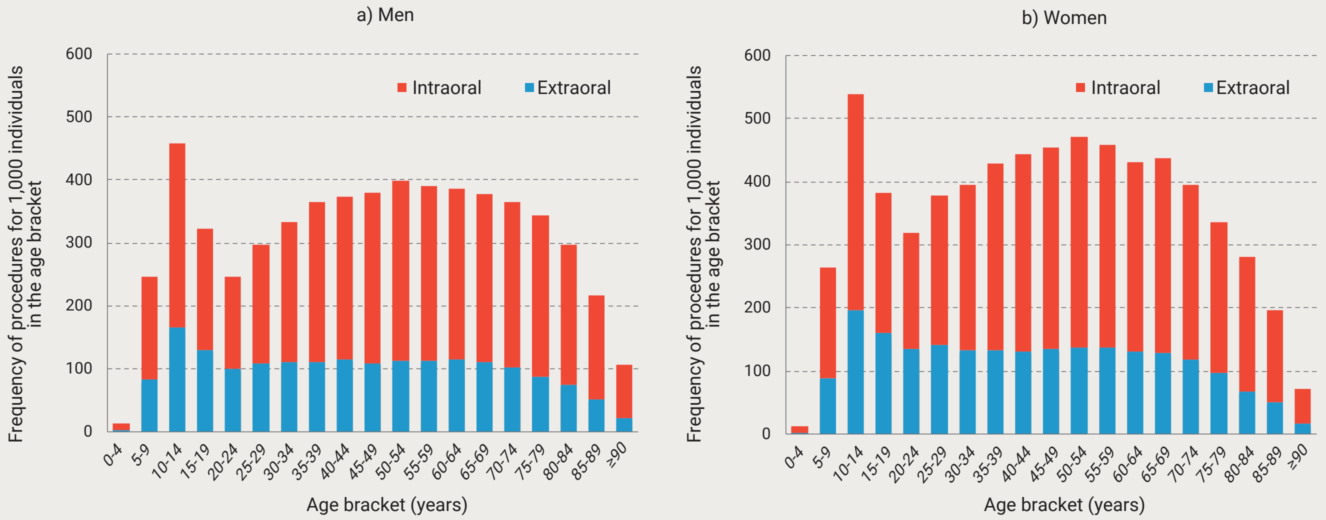
Table VII

Distribution of exposure per examination category for dental radiology: frequencies of procedures and mean per caput effective doses.

Group	Freq. of procedures (/1,000 indiv.)			Mean annual eff. dose (µSv/indiv.)		
	Men	Women	Overall	Men	Women	Overall
Intraoral	223.3	253.6	238.7	1.4	1.6	1.5
Extraoral	103.2	120.4	112.0	2.5	3.0	2.7
Total	**326.5**	**374.0**	**350.7**	**3.9**	**4.6**	**4.2**

Figure 7

Comparison of frequencies of dental radiological procedures per examination category and age bracket for men and women.



4.2.3 Computed tomography

As shown in ***Table VIII***, the abdominal-pelvic and head & neck anatomical regions are most frequently targeted by computed tomography, and frequencies are approximately equal for men and women. However, the abdominal-pelvic region contributes six times more to the mean annual per caput effective dose than the head and neck region, and this trend is slightly more pronounced in men.

Computed tomography scans of the thorax and heart rank third and those covering multiple regions[8] rank 4th. The frequency of procedures for both of these two groups is significantly higher in men than in women, and this difference increases yet again when we consider the mean annual effective doses, particularly for computed tomography scans covering multiple regions, which record a difference of approximately 100 µSv per individual.

Computed tomography of the vertebral column is the only group where both the frequency of procedures and the mean annual effective dose are higher for women than men.

Computed tomography focusing on the limbs are fairly infrequent and do not significantly contribute to the mean annual per caput effective dose.

[8] *i.e.* focusing on at least two of the defined regions, e.g. skull-thorax or thorax-abdomen-pelvis.

Figure 8 shows that variation in the frequency of procedures with the age of individuals is relatively similar for all groups of computed tomography procedures. The frequency of procedures is extremely low before the age of 15, and increases progressively with age before reaching a maximum between age 75 and 90, depending on the anatomical region. Above the age of 90, the frequency of procedures drops substantially. For all examination categories, the frequency of procedures for both men and women is fairly similar for adults in the 20 - 50 age bracket, the difference increases rapidly above the age of 55, to the benefit of men.

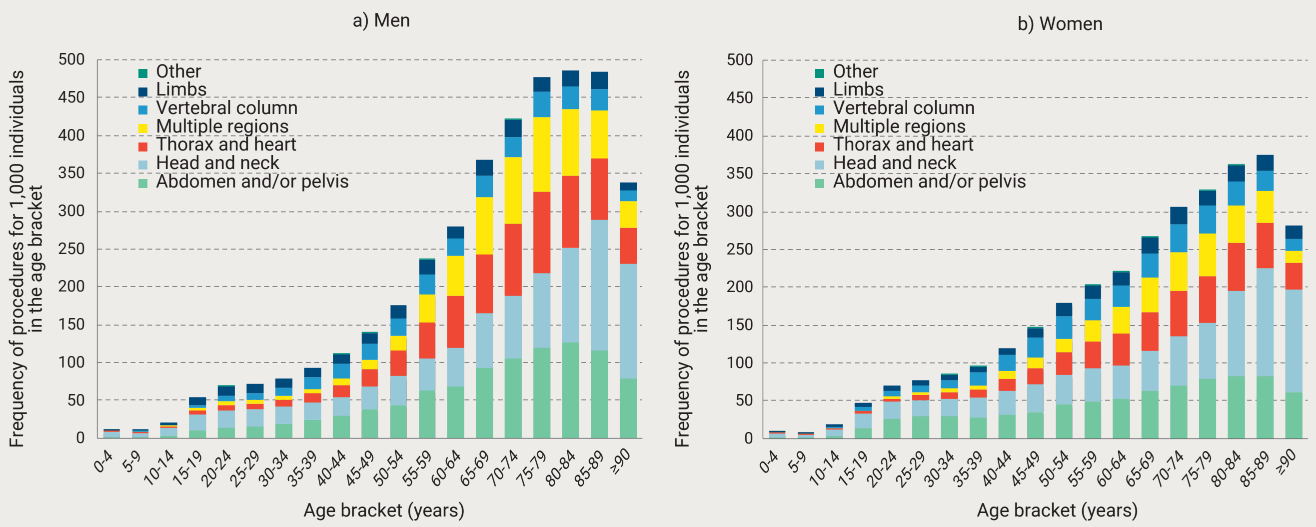
Table VIII

Distribution of exposure per computed tomography examination category: frequencies of procedures and mean per caput effective doses.

Anatomic region	Freq. of procedures (/1,000 indiv.)			Mean annual eff. dose (µSv/indiv.)		
	Men	Women	Overall	Men	Women	Overall
Abdomen and/or pelvis	39.5	36.8	38.1	382.0	341.6	361.4
Head and neck	37.3	38.9	38.1	62.8	61.9	62.3
Thorax and heart	29.9	23.5	26.6	168.4	135.0	151.4
Multiple regions	23.4	17.5	20.4	401.6	301.9	350.8
Vertebral column	15.5	18.4	17.0	147.8	175.4	161.9
Limbs	12.5	11.4	12.0	61.9	37.6	49.5
Other	0.0	0.1	0.0	0.1	0.3	0.2
Total	**158.2**	**146.6**	**152.3**	**1,224.5**	**1,053.8**	**1,137.5**

Figure 8

Comparison of frequencies of computed tomography procedures per examination category and age bracket for men and women.



4.2.4 Nuclear medicine

The frequency of nuclear medicine procedures (*Table IX*) is very similar for three main categories of procedures and is substantially higher than for other categories: with PET and oncology leading the way, followed by the musculoskeletal system and by the cardiovascular system, almost equally. These three groups are also the main contributors to the mean annual per caput effective dose: PET and oncology lead the way, followed by cardiovascular system procedures, well ahead of musculoskeletal imaging. Procedures focusing on the endocrine system rank 4th in terms of the frequency of procedures and mean annual effective doses. Very low frequencies are recorded for the other categories of procedures.

The frequency of procedures for women exceeds those of men for most groups of procedures, the key exception being procedures imaging the cardiovascular system, where men require 50% more examinations than women, which globally contributes to a mean annual per caput effective dose which is generally higher for men versus women for all nuclear medicine procedures.

Figure 9 shows that the frequency of nuclear medicine procedures in men is tightly distributed around the 65-85 age bracket, while this distribution is more spread out for women, with a relatively high frequency for the 40 - 65 age bracket for this group for women. The frequency of procedures increases significantly over the 35-70 age bracket for women, and the 45-70 age bracket for men, for the three most frequent examination categories, before levelling off and then rapidly decreasing from the age of 80, for both genders.

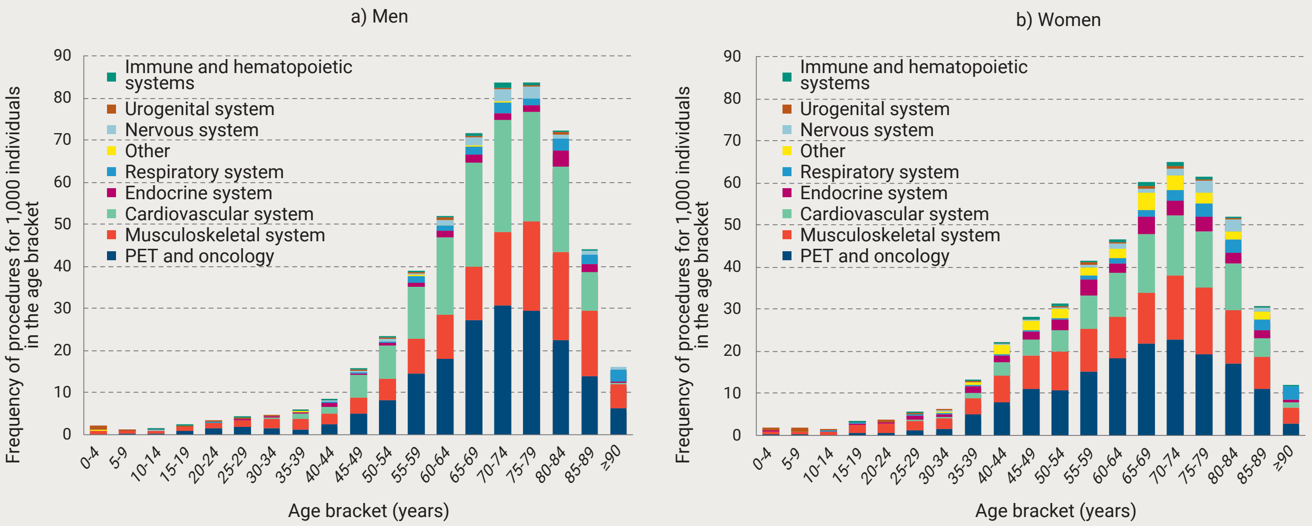
Table IX

Distribution of exposure per examination category for nuclear medicine: frequencies of procedures and mean per caput effective doses.

Examination category	Freq. of procedures (/1,000 indiv.)			Mean annual eff. dose (µSv/indiv.)		
	Men	Women	Overall	Men	Women	Overall
PET and oncology	7.9	8.4	8.1	102.0	93.6	97.7
Musculoskeletal system	5.4	6.2	5.8	17.1	19.9	18.6
Cardiovascular system	6.8	4.4	5.6	61.6	34.3	47.7
Endocrine system	0.7	1.7	1.2	2.2	4.9	3.6
Respiratory system	0.6	0.9	0.7	1.6	2.2	1.9
Other	0.1	1.3	0.7	0.1	0.4	0.3
Nervous system	0.5	0.5	0.5	3.2	3.0	3.1
Urogenital system	0.3	0.3	0.3	0.3	0.3	0.3
Immune & hematopoiet. syst.	0.2	0.3	0.3	0.6	0.8	0.7
Total	22.5	24.1	23.3	188.7	159.4	173.8

Figure 9

Comparison of frequencies of nuclear medicine procedures per examination category and age bracket for men and women.



4.2.5 Diagnostic interventional radiology

Table X indicates that most diagnostic interventional radiological procedures[9] are cardiology procedures, which explains why this category is the main contributor to the mean annual effective dose associated with the type of imaging. Procedures imaging the vascular system rank second and are approximately three times less frequent than cardiac procedures. Biliary and neurological categories rank after the above, are infrequent and only contribute very moderately to the mean annual per caput effective dose. Procedures are far more frequent for men than women for the vascular groups, and for cardiac groups to a greater extent, as well as the associated mean annual effective doses.

It is important to remember that diagnostic interventional radiological procedures are very frequently associated with a therapeutic procedure and, on this basis, are not systematically assigned a specific CCAM code. This study probably, therefore, excludes a high number of diagnostic procedures. On this basis, these figures must not be considered as representative of clinical practice.

[9] refer to section 2.1 for the definition of diagnostic interventional radiology.

As indicated in ***Figure 10***, cardiology procedures occur extremely infrequently up to the age of 35-40, and then increase rapidly in men, and at a slower rate in women, until reaching a peak between 75 and 84. This variation with age is approximately identical in other categories of diagnostic interventional radiological procedures, even if the interpretation is unreliable due to the low numbers of procedures recorded, particularly for the biliary or neurological groups.

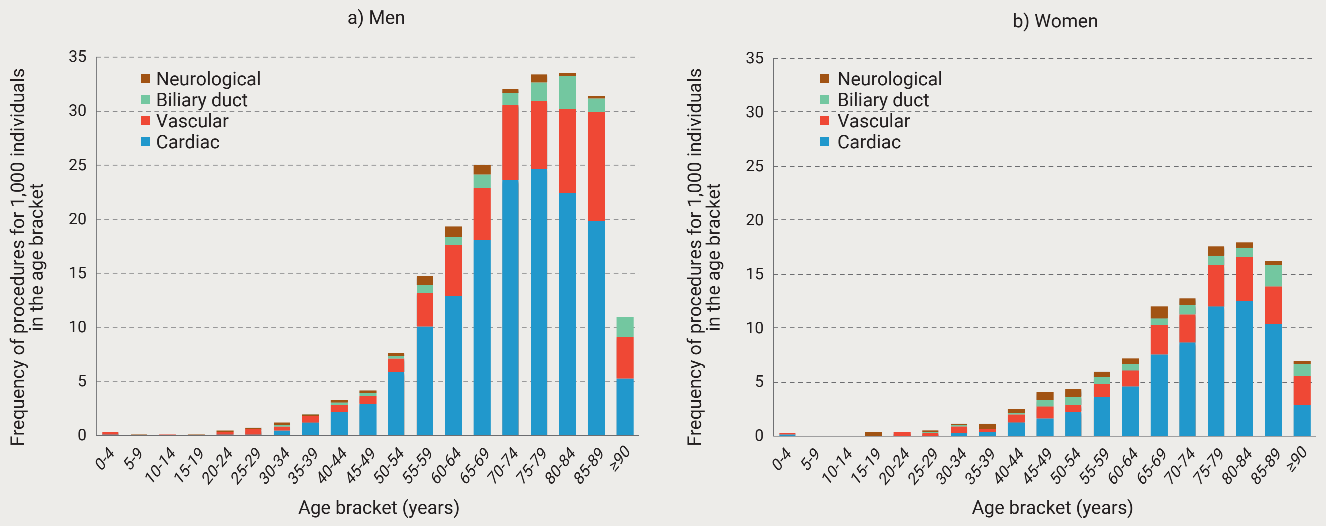
Table X

Distribution of exposure per examination category for diagnostic interventional radiology: frequencies of procedures and mean per caput effective doses.

Examination category	Freq. of procedures (/1,000 indiv.)			Mean annual eff. dose (µSv/indiv.)		
	Men	Women	Overall	Men	Women	Overall
Cardiac	5.8	2.8	4.3	32.3	15.9	23.9
Vascular	1.9	1.1	1.5	14.2	7.2	10.6
Biliary duct	0.4	0.4	0.4	0.7	0.6	0.6
Neurological	0.3	0.4	0.3	2.6	2.6	2.6
Total	**8.3**	**4.7**	**6.5**	**49.7**	**26.3**	**37.8**

Figure 10

Comparison of frequencies of diagnostic interventional radiological procedures per examination category and age bracket for men and women.



5 POPULATION ACTUALLY EXPOSED IN 2017

Sample panel data is provided by both SNIIRAM in the private sector and PMSI for inpatients and outpatients in the public sector, therefore the percentage of the population studied actually exposed, i.e. individuals who actually participated in a diagnostic imaging procedure using ionising radiation during the year, can be determined. **On this basis, this chapter focuses on the population actually exposed in 2017. Exposed individuals in this population will hereafter be called patients.** Patient exposure will be characterised in terms of the number and type of procedures, and the individual annual effective dose.

5.1 Characterisation of the exposed population

5.1.1 Percentage of individuals actually exposed (patients) in the protected population

319,187 of the 703,261 individuals in the sample panel in 2017, *i.e.* 45.4%, participated in one or several diagnostic procedures in 2017. As is apparent in ***Table XI***, this percentage varies substantially depending on the gender of the individuals: a much higher percentage of women is exposed than men: 50.2% versus 40.4%. However, this difference is reduced by half if mammography is excluded from the list of diagnostic procedures considered. Even without considering this procedure, which is almost exclusively required for women[10], we can conclude that women require a diagnostic imaging procedure more often than men, with a difference of almost 5 percent. When dental radiological procedures, which have a very minor contribution to the collective effective dose, are excluded, the percentage of exposed individuals in the population falls steeply: 32.7%, *i.e.* a decrease of almost 13 percent. On this basis, we can consider that one third of the French population participated in at least one diagnostic procedure in 2017, excluding dental radiology.

Table XI

Percentage of the sample panel having benefited from at least one diagnostic imaging procedure in 2017.

	Men (%)	Women (%)	Overall (%)
All types of imaging	40.4	50.2	**45.4**
Excluding dental radiology	27.3	37.9	**32.7**
Excluding mammography	40.4	45.3	**42.9**

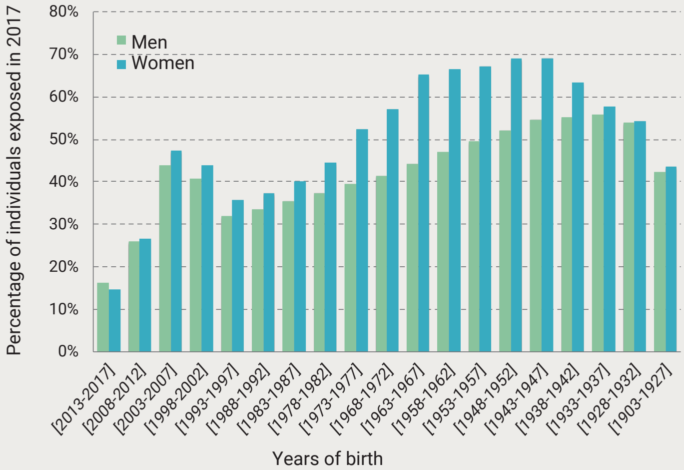
[10] 183 mammography procedures were performed on men, versus 51,947 on women in the sample panel in 2017.

The percentage of exposed individuals in the population also depends strongly on age, as shown in ***Figure 11***. The percentage of the population having benefited from at least once diagnostic procedure is indicated, per bracket of year of birth, as a percentage of the male and female populations respectively. The age of the individuals in the sample panel will necessarily vary by one year over the course of a year, therefore it is more reliable to calculate the percentage of individuals exposed according to the year of birth rather than age. Brackets for years of birth were selected to match the age brackets used in this report as far as possible.

It is important to take note that the percentage of women exposed is higher than the percentage of men for all years of birth. This difference is particularly apparent for women born between 1940 and 1980 (aged 36-77 in 2017). This effect is mostly due to mammography, as shown in ***Figure 12b***, which excludes this type of examination. One exception applies for children born after 2013 (aged 4 or less in 2017) for whom the percentage of young boys exposed is higher than the percentage of young girls. This matches previous observations in the report on the paediatric population **[9]** and is probably caused by health problems which mostly affect the male perinatal population more than the female perinatal population, as proven by the higher level of perinatal mortality for young boys compared with young girls.

Figure 11

Percentage of individuals exposed in 2017 per gender and year of birth.



The percentage of individuals exposed in the population increases with age, from approximately 15% for very young children to slightly less than 70% for women born in the 1940's (aged approx. 65-75 in 2017) and approx. 55% for men born in the 1930's and 1940's (aged approx. 65-85 in 2017). A higher percentage is recorded for children and teenagers born between 1998 and 2007 (aged 9-19 in 2017), which confirms the observations in the aforementioned report **[9, p. 19]** and is very probably due to the mandatory preventive oral-dental examination at the age of 12 defined in the French Code of Public Health.

Figure 12a shows the percentage of individuals exposed to at least one imaging procedure, excluding dental radiology. The general reduction in the percentage of individuals exposed has very little effect on the overall age distribution, with one key exception for the years corresponding to children and teenagers aged 10-20 in 2017, for whom this percentage is halved. This category of the population is in fact characterised by extensive use of dental radiology, as indicated in the previous chapter. By comparing ***Figure 11*** and ***Figure 12a***, it appears that the difference between the percentages of exposed men and women, which is most noticeable for people born between 1940 and 1980, is partially attributable to dental radiology, as this difference is even greater if this type of imaging is excluded. This point would appear to indicate that more men in this age bracket exclusively participate in this type of radiological examination (dental radiology) than women during the year. On the other hand, it appears that more women born between 1983 and 2007 exclusively participate in this type of examination than men during the year, as the differences shown in ***Figure 11*** are almost non-existent in ***Figure 12a*** for these years of birth.

Figure 12

Percentage of individuals exposed in 2017 per gender and year of birth, excluding dental radiology or mammography.

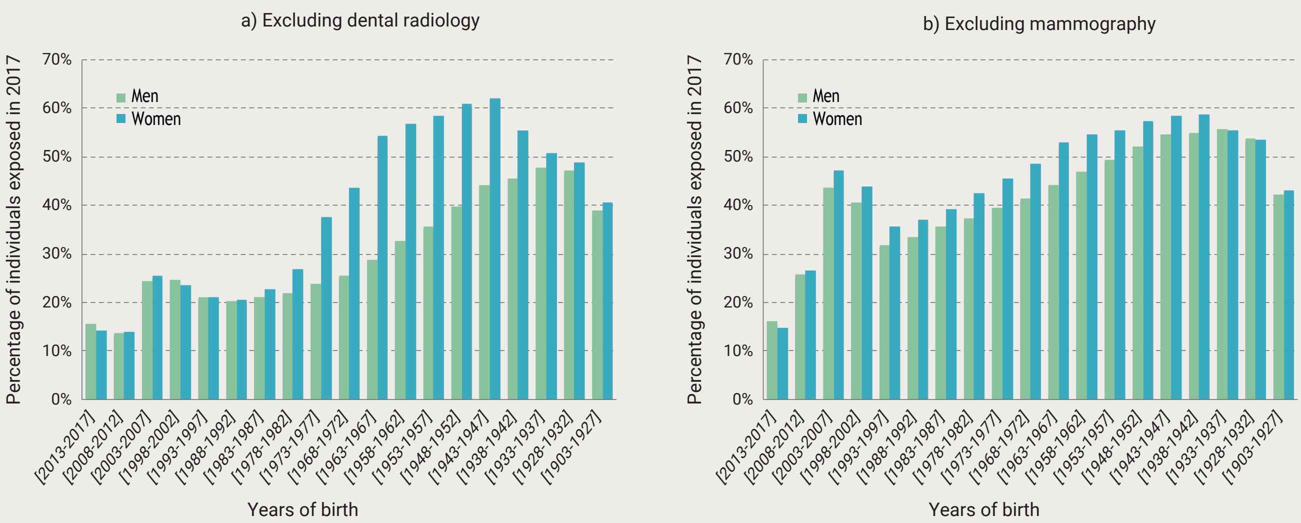


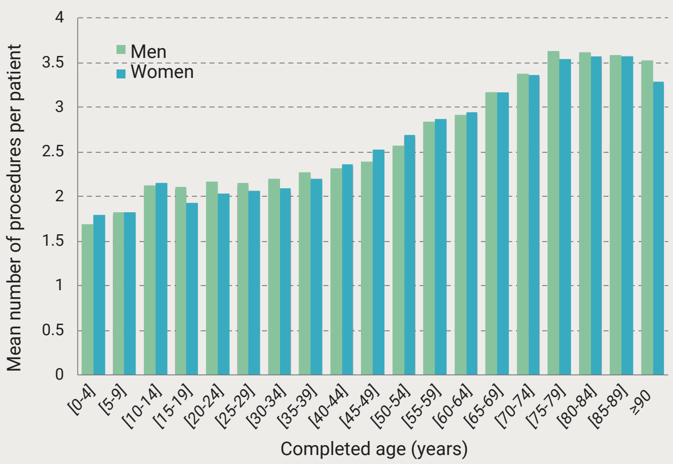
Table XII

Statistics on the number of procedures per patient, per gender and per year.

Number of procedures per patient	Men	Women	Overall
Mean	2.57	2.65	**2.61**
Mean (dental radiol. excl.)	2.61	2.52	**2.56**
25th percentile	1	1	**1**
Median	2	2	**2**
75th percentile	3	3	**3**
95th percentile	7	7	**7**
Maximum			**132**

Figure 13

Mean number of diagnostic procedures per patient in 2017, per gender and age.



5.1.2 Number of procedures per patient

The 319,187 individuals on the sample panel exposed to at least one imaging procedure in 2017 participated in 834,444 imaging procedures, representing a mean figure of 2.61 procedures per patient. ***Table XII*** shows details of the different statistics for the number of procedures involving patients each year. On average, female patients participated in slightly more examinations than male patients. This trend is reversed if dental radiology is not considered when determining the exposed population. The distribution of the number of procedures is highly asymmetrical, as shown by the different percentiles calculated in ***Table XII***: 50% of patients benefitted from one or two annual procedures, 75% of patients from one to three procedures, and 5% from over 7 diagnostic procedures in 2017. 132 is the maximum number of procedures recorded in the sample panel for one single patient. It is important to realise that this distribution remains constant if dental radiology is excluded.

The distribution of the mean number of diagnostic procedures depends on the age of the patient, as illustrated in ***Figure 13***: on average, young children (age < 10) participate in less than 2 procedures annually; on average, the elderly (≥ 75) participate in approx. 3.5 procedures. The mean number of procedures increases almost linearly with age, except the 1-14 age bracket, and, to a lesser extent, the 15-39 age brackets for men, for whom a higher level of procedures is recorded. The mean number of procedures stabilises above the age of 75 for men and 80 for women.

The distribution of the number of procedures according to age and gender clearly differs depending on the type of imaging performed, as shown in ***Figure 14*** for four types:

- The mean number of conventional radiological procedures (***Figure 14a***) is relatively high for the youngest children[11] (1.5 per patient for children aged under 5) and then stabilises around 1, up to the age of 40. A significant difference is recorded in these age brackets between women and men, to the benefit of the latter[12]. From the age of 40, the mean number of procedures increases almost linearly up to the highest ages. This increase is particularly noticeable for women, who participate in more annual examinations than men, on average, for all age brackets. This observation is clearly dependent on screening mammography for breast cancer.
- The distribution of the mean number of dental radiology procedures (***Figure 14b***) follows the reverse trend to conventional radiology: on average, the youngest patients (except children aged under 5) participate in approximately one dental procedure in the year, and this value then steadily decreases with age, with a steeper drop from age 85. It also appears that, on average, young female patients benefit from slightly more dental radiological examinations than young male patients, with the trend reversing from the age of 35.
- With computed tomography (***Figure 14c***), the distribution of the mean number of procedures is noticeably offset towards older ages, particularly for men. Before the age of 15, the mean number of computed tomography procedures per patient is very low (between approx. 0.03 and 0.06); this figure then increases slowly, before adopting a steeper trend and reaching a maximum of 0.7 for women and 0.9 for men in the oldest patients. The difference between men and women peaks for the

[11] Probably due to chronic pathologies affecting young children (bronchiolitis, etc.).

[12] This figure must be compared with the higher frequency of radiography procedures of the limbs of young men (cf. Figure 6), probably due to traumatology.

60-75 age brackets: male patients benefit from 1.8 times more computed tomography examinations than female patients.

- Finally, the distribution for nuclear medicine (***Figure 14d***) is also strongly centred on more elderly patients. The mean number of procedures is very low before the age of 35-40, and then rapidly rises to peak between 70 and 80, and then falls off. The difference between men and women reaches significant values in the 55+ age bracket.

Due to the inadequate number of procedures in the sample panel, the results obtained for diagnostic interventional radiology are not shown here.

5.2 Individual effective dose

If the cumulative effective dose calculated for 2017 is compared with the number of patients (reminder: patients are considered as individuals in the sample panel who are actually exposed), **a cumulative mean individual effective dose of approx. 3.4 mSv is obtained**. To a greater extent than for the number of procedures, the dose distribution varies widely (cf. ***Table XIII***): half of patients absorb a dose which is less than or equal to 0.1 mSv, 75% absorb 1.5 mSv or less, while 5% of the most exposed patients absorb a dose of greater than 18.1 mSv, with a maximum value of 380 mSv recorded for a given patient in this study.

Figure 14

Distribution of the mean number of procedures per patient, per age and gender, per type of imaging.

Table XIII

Statistics on cumulative annual effective doses per patient, according to gender, including and excluding dental radiological procedures.

Annual effective dose per patient (mSv)	Including dental			Excluding dental		
	Men	Women	Overall	Men	Women	Overall
Mean value	3.95	2.94	**3.38**	5.84	3.88	**4.68**
25th percentile	0.009	0.019	**0.014**	0.010	0.068	**0.058**
Median	0.04	0.31	**0.10**	0.61	0.31	**0.33**
75th percentile	1.60	1.40	**1.53**	5.85	2.45	**3.80**
95th percentile	20.3	15.5	**18.1**	27.6	18.6	**21.4**
Maximum value			**380**			**380**

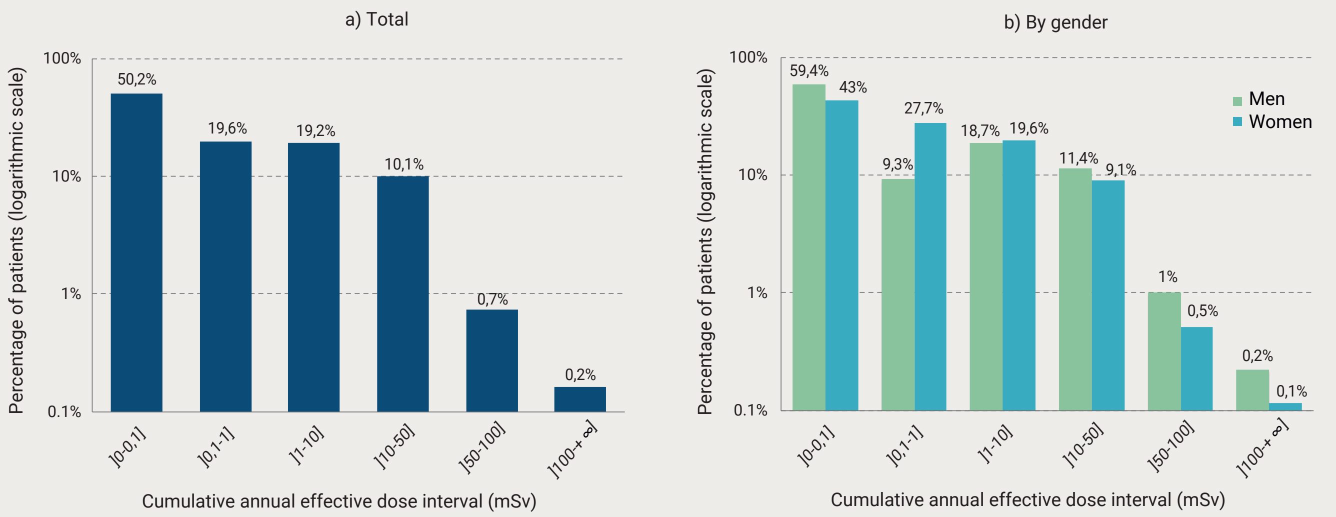
Unlike the conclusions of section 5.1.2 on the number of procedures, a very noticeable difference is apparent in *Table XIII* between men and women in terms of cumulative individual effective dose: men absorbed approx. 1 mSv more than women in 2017 on average. By analysing the different percentiles, we can confirm that the distribution for the effective dose of men is clearly offset towards higher dose levels compared to women. This observation must be compared with the mean number of computed tomography and nuclear medicine procedures per patient, which is higher for men (cf. *Figure 14c* & *d*): these two types of imaging record the highest effective doses for each examination, therefore it is logical for the cumulative effective dose per patient to be higher for men than for women.

The contribution of dental radiology to the collective effective dose is very low (see chapter 4), therefore it is worthwhile characterising the cumulative effective dose per patient integrating all imaging procedures other than dental radiology. This approach will reduce the population considered as exposed (n = 229,790 instead of 319,187) as patients having exclusively participated in dental radiological procedures during 2017 are not included. The mean cumulative effective dose for this reduced population increases significantly (+38%), and reaches approximately 4.7 mSv. Differences previously recorded between the exposure of men and women are confirmed and enhanced: the mean cumulative effective dose per male patient is almost 2 mSv higher than for female patients.

Figure 15 shows another means of approaching the distribution of cumulative annual effective doses per patient. The percentage of patients having absorbed a cumulative dose in a specified dose interval is shown in this figure, with a logarithmic scale, covering both

Figure 15

Percentage of patients having absorbed a cumulative annual effective dose in the specified interval.



genders (a) and per gender (b). It appears that roughly half (50.2%) of patients absorbed a cumulative effective dose of less than or equal to 0.1 mSv in 2017. Slightly under 20% of patients absorbed a cumulative effective dose of between 0.1 and 1 mSv, and an additional 20% absorbed a dose between 1 and 10 mSv. Finally, 10.1% of patients absorbed between 10 and 50 mSv and 0.9% over 50 mSv. These figures illustrate one point that the mean dose per patient alone tends to mask: **most (81.6% precisely) patients absorbed a dose of less than the mean dose of 3.4 mSv in 2017**.

The distribution of the cumulative effective dose clearly differs depending on gender as shown in ***Figure 15b***: three times more women absorb a cumulative annual dose of between 0.1 and 1 mSv, which corresponds to the mammography dose range. In the highest dose intervals, the percentage of men is the double of that of women, due to their more frequent need for computed tomography and nuclear medicine.

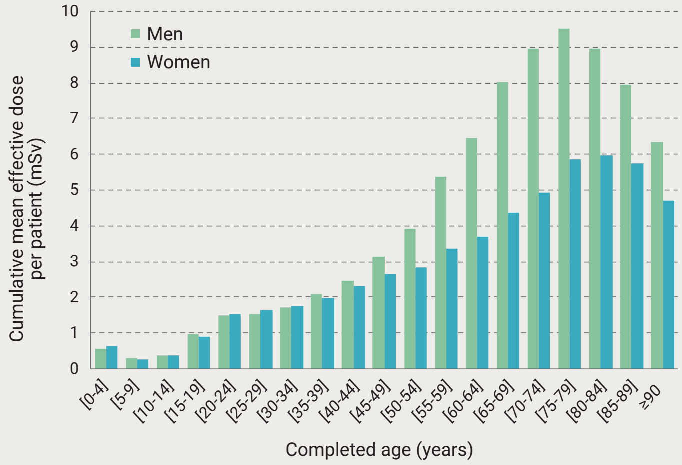
The cumulative mean effective dose also depends on the age of the patients, and to an even greater extent, as shown in ***Figure 16***. This figure shows the distribution of this dose according to age bracket for each gender. This distribution varies in a very similar manner for men and women up to the age of around 40: less than 1 mSv for children and very young adults (0.6 mSv before the age of 5; approx. 0.4 mSv between 5 and 15; 0.9 mSv before the age of 20), without any noticeable difference between boys and girls, climbing with age to reach approximately 2 mSv before the age of 40. Above this age, on average, annual exposure will be substantially higher for men than for women (approx. 9 mSv vs 5 mSv between the ages of 70 and 74). This difference is explained by the results given in the previous chapter, which particularly demonstrate that men participate in more computed tomography and nuclear medicine procedures than women after the age of 45. In fact, most of the effective doses associated with computed tomography and diagnostic nuclear medicine procedures exceed the effective doses associated with conventional radiology examinations.

5.3 Focus article: The issue of cumulative computed tomography examinations

As indicated in chapter 4, computed tomography is the type of imaging with the greatest contribution to the collective effective dose in France. This observation is valid for all countries with a similar healthcare system to France. The cumulative effective dose for patients

Figure 16

Cumulative mean effective dose per patient, according to gender and age.



participating in several computed tomography examinations must therefore be considered at international level. A recent study by the Massachusetts General Hospital in Boston **[33]** concluded that 1.3% of patients having benefitted from at least one computed tomography examination over a period of 1 to 5 years had absorbed a cumulative effective dose in excess of 100 mSv. Similar conclusions were reached by an international study led by the International Atomic Energy Agency (IAEA) **[34].**

On this basis, this section of the ExPRI study focuses on patients having participated in at least one diagnostic computed tomography procedure (as previously explained in chapter 2, interventional procedures and computed tomography used for radiotherapy planning purposes are not taken into consideration), in 2017 and, retrospectively, over a cumulative 3- and 6-year period. ***Table XIV*** shows various statistics for the number of computed tomography procedures and associated individual effective dose. It is important to specify that any doses absorbed in imaging procedures other than computed tomography are not considered. Depending on the cumulative duration considered, on average, patients benefitted from between 1.64 and 2.56 computed tomography examinations for periods of 1 and 6 year respectively, corresponding to a mean cumulative effective dose of 12 to 18 mSv. Most patients by far undergo computed tomography examinations infrequently: 75% of patients recorded a maximum of two examinations over one or three years, and three over six years, with cumulative effective doses of less than 15 mSv, 18 mSv and 20 mSv, respectively. However, it also appears that, within the population for each of the periods considered, 1% of patients participated

Table XIV

Number of diagnostic computed tomography procedures and associated individual effective dose for the population of patients exposed to computed tomography and over three cumulative periods.

Cumulative period considered		Mean value	Median	Percentiles 75th	Percentiles 95th	Percentiles 99th	National population* of the 99th percentile
2017 (1 year)	N° of procedures	1.64	1	2	4	7	67,000
	Effective dose (mSv)	12.2	9.3	14.6	37.8	77.0	
2015-2017 (3 years)	N° of procedures	2.10	1	2	6	11	148,000
	Effective dose (mSv)	15.4	9.7	18.0	51.7	117.7	
2012-2017 (6 years)	N° of procedures	2.56	2	3	8	14	225,000
	Effective dose (mSv)	18.2	10.0	20.0	62.8	145.0	

* Estimated national population, rounded to the nearest thousand.

in more than 7 examinations in 2017, 11 examinations between 2015 and 2017 and 14 examinations between 2012 and 2017, which leads to cumulative effective doses in excess of 77 mSv, 118 mSv and 145 mSv, respectively. The national population corresponding to this 1% of patients having benefitted from computed tomography procedures is indicated, rounded to the nearest thousand, in ***Table XIV:*** it represents over 200,000 patients over 6 cumulative years.

It would be worth considering patients having accumulated an effective dose in excess of 100 mSv from the population having benefitted from computed tomography procedures during the cumulative periods studied. In fact, the various international organisations such as ICRP **[16]** or UNSCEAR **[10]** have reached a consensus on considering that above this effective dose, stochastic risks exist for ionising radiation. ***Table XV*** shows a few characteristics of this population of patients subject to high exposure, hereafter referred to as "100mSv+". **In 2017, approximately 0.5% of patients having participated in at least one computed tomography scan absorbed a cumulative effective dose of more than 100 mSv, which represents approximately 33,000 patients at national level. Over the 2012-2017 period, i.e. a total of 6 years, this percentage reached 2.25%, which is slightly over 500,000 patients throughout France.** The mean effective dose absorbed by patients represented approx. 130 mSv for 2017 and 160 mSv in total over 6 years. The maximum values recorded for the sample panel represented 30 computed tomography procedures and a cumulative 313 mSv in 2017 and 65 computed tomography procedures and cumulative 694 mSv over 6 years in the 2012-2017 period. Due to the limited representativeness of the sample panel, the maximum values at national level are very probably higher than the peak panel values.

Figure 17 shows some characteristics of the "100 mSv+" population over a cumulative 3-year period, compared with base 100 in 2012-2014, showing variation

Table XV

Characterisation of the population of patients exposed to computed tomography and absorbing more than 100 mSv, in terms of number of procedures and associated individual effective dose, over three cumulative periods.

Cumulative period considered		Mean value	Median	Percentiles 75th	Percentiles 95th	% patients exposed*	National population#
2017 (1 year)	N° of procedures	10.1	9	12	18	0.49	33,000
	Effective dose (mSv)	133.5	122.6	144.0	199.7		
2015-2017 (3 years)	N° of procedures	12.2	11	15	22	1.44	212,000
	Effective dose (mSv)	153.0	134.6	172.1	270.6		
2012-2017 (6 years)	N° of procedures	14.1	13	17	26	2.25	506,000
	Effective dose (mSv)	160.0	138.2	179.5	296.2		

* Compared with the population having benefitted from at least one diagnostic computed tomography procedure in the period studied.
# Estimated national population, rounded to the nearest thousand.

over time. The percentage of "100 mSv+" patients in the population having benefitted from at least one computed tomography procedure in the period considered (red line) increased by 40% from 1.01% in 2012-2014 (for around 136,000 patients) to 1.44% in 2015-2017 (for around 212,000 patients). Over the same period, the cumulative mean effective dose for these same patients (green line) increased by around 10%, to reach approximately 153 mSv. The mean number of computed tomography examinations for these patients (blue line) is relatively stable at around 12 examinations over 3 years. These results appear to indicate that the population exposed to over 100 mSv due to cumulative computed tomography examinations has steadily and relatively rapidly increased, since 2012

The mean age[13] of the "100mSv+" patient sub-group over the 2012-2017 period is approximately 62. Most of this sub-population is male (60.5% men versus 39.5% women). ***Figure 18*** shows the age pyramid for this sub-group. No significant difference between men and women is apparent in the age distribution. Half of patients are aged between 55 and 71 at the time of the first computed tomography examination. However, this strongly exposed sub-group includes a small, but significant, percentage of young patients. The general shape of this age pyramid can be extrapolated at national level, however, it is important to show caution with the youngest patients due to the inherent statistical uncertainty for a panel-based study, including if the panel is fairly large, as is the case here. In particular, the "100 mSv+" sub-group only includes 9 children aged under 15, which implies high levels of uncertainty for any extrapolation to the national level.

Figure 17

Variation in the cumulative "100mSv+" population over 3 sliding years between 2012 and 2017 (base 100 for 2012-2014).

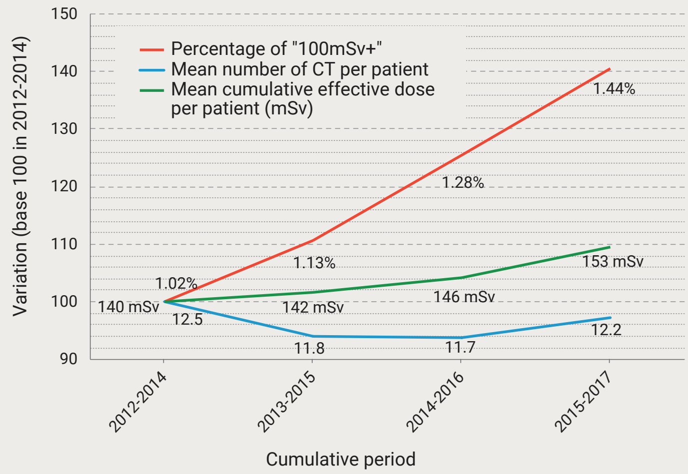


Figure 18

Distribution per age bracket and per gender of patients exposed to more than 100 mSv over the 2012-2017 period.

The age is calculated on the date of the first computed tomography scan.

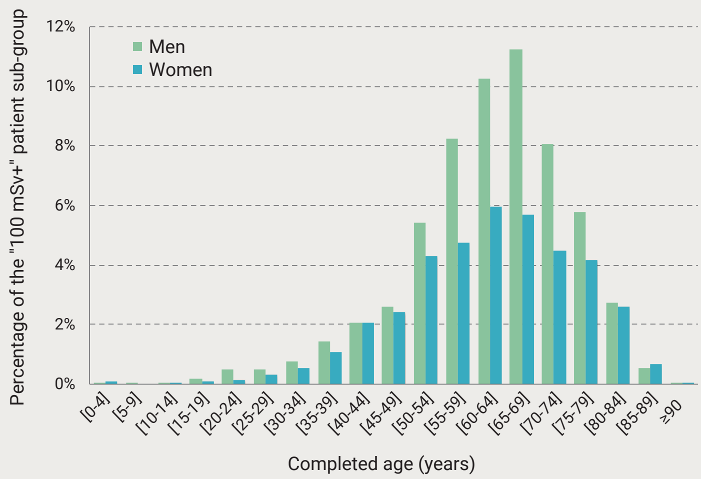
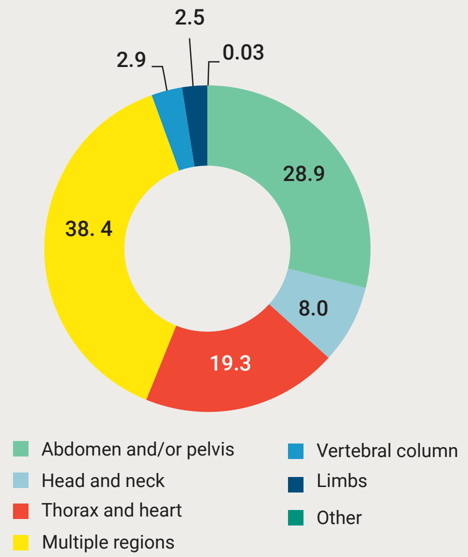


Figure 19

Distribution per anatomical region of CT scans on "100mSv+" patients over the 2012-2017 period.

In %



[13] The age of the patient is calculated on the date of the first computed tomography examination in the cumulative period considered.

Figure 19 shows the anatomical regions covered by the computed tomography procedures performed on patients in the "100mSv+" sub-group during the 2012-2017 period. The distribution of these procedures is very clearly different to that recorded for the entire sample panel (cf. chapter 4.2.3). In particular, the percentage of computed tomography scans imaging multiple regions (mostly thorax-abdomen-pelvis) has almost tripled (38.4% vs 13.4%). Abdominal and/or pelvic imaging procedures are also slightly more frequent (29% vs 25%), as well as thorax and cardiac imaging (19.3% vs 17.5%). On the other hand, computed tomography examinations of the head and neck (8% vs 25%), and of the vertebral column and limbs, are much rarer than for the general population.

To conclude, a population estimated at over 30,000 patients nationwide was exposed to a cumulative effective dose of over 100 mSv in 2017 due to multiple computed tomography examinations. This figure rises to 500,000 if a cumulative period of 6 years is considered. This strongly exposed population appears to be steadily increasing since 2012. Most members of this population are elderly, however one quarter is aged under 55. On this basis, potential long-term radio-induced effects must be considered for this specific population. It is worth remembering that these patients are very certainly treated for serious pathologies, and that computed tomography examinations are probably an essential part of this treatment. Specific investigations would be required to confirm this point and potentially identify any unnecessary or redundant examinations. The description of this group of patients strongly exposed to medical examinations requiring ionising radiation could be rendered more precise by considering other types of diagnostic procedures.

6 VARIATION IN DIAGNOSTIC MEDICAL EXPOSURE FOR THE FRENCH POPULATION FROM 2002 TO 2017

This study follows on from the three previous studies focusing on 2002, 2007 and 2012 [5]–[7]. The method used to estimate the number of diagnostic procedures changed significantly between the different studies.

For the year 2002, the EGB sample panel was not yet available and the number of procedures was therefore determined based on multiple data sources: CNAMTS, DREES, regional hospitalisation agency for greater Paris, etc.

For the year 2007, the EGB sample panel was used for procedures in the private sector, however data for the public sector was not yet included in this sample panel. Public sector data was therefore extrapolated based on a survey of 50 public healthcare establishments. In addition, dental radiology data had not been updated and data from 2002, obtained during a CNAM survey, had been re-used.

The same method was used in 2012 as for the current study. However, the progressive withdrawal of the NGAP codes for dental radiological procedures, replaced by CCAM codes, has greatly boosted the reliability of the data collected. In addition, dental CCAM codes have been extensively modified (cf. section 2.2.2). For both of these reasons, comparing figures for this type of imaging between 2017 and previous years is a delicate process.

The mean effective doses for each type of procedure in this study were updated compared to the previous study for 2012, mainly on the basis of the analysis of diagnostic reference levels data, to match changing medical practices. However, the same method was used for this study and previous editions.

This chapter compares the results for 2017 with the results of previous studies, and comments on changes, considering changing methods.

6.1 Variation in the mean number of annual procedures

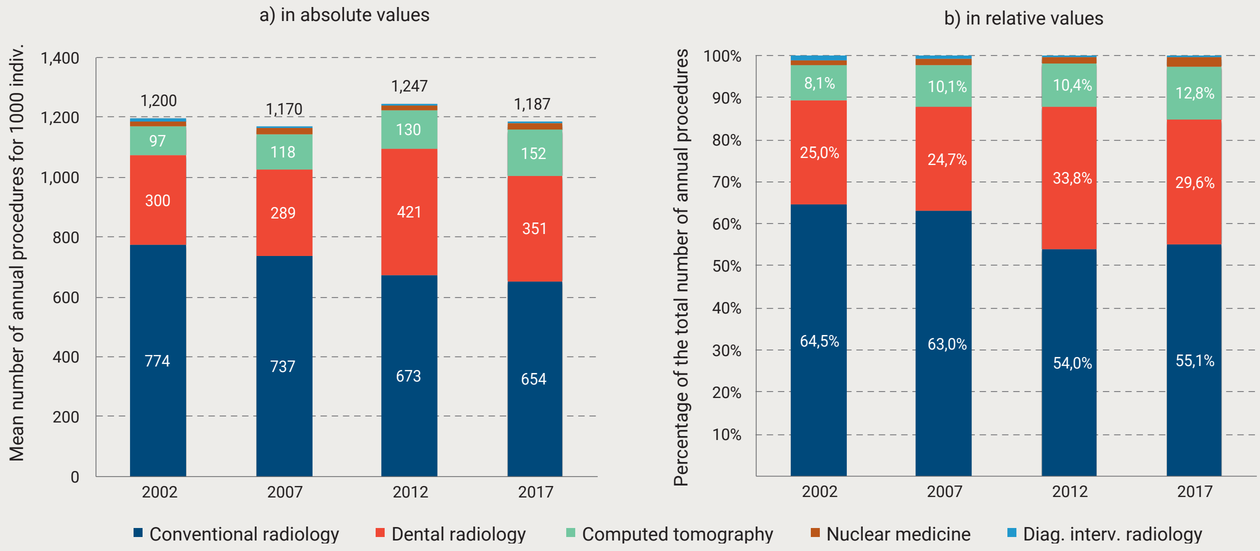
The mean number of annual procedures decreased from 1,247 to 1,187 for 1,000 beneficiaries between 2012 and 2017, which is a 4.8% decrease. However, the mean number of annual procedures, excluding dental radiology (836 for 1,000 beneficiaries) is 1.3% higher than in 2012.

Details of variation since 2002 for each type of imaging can be found in ***Figure 20***. It appears that the frequency of dental procedures varies widely between the different studies, which strongly affects total figures for diagnostic procedures. In fact, this type of imaging is generally responsible for the reduction in the mean annual number of diagnostic procedures between 2012 and 2017. The frequency of dental procedures indeed fell steeply (by 16.8%), over 5 years. However, it is important to consider these figures with plenty of caution. On the one hand, as explained in the corresponding ExPRI report [6], dental data for 2007 is very probably underestimated14. On the other hand, two major changes occurred during the 2012-2017 period: the percentage of dental radiology procedures with CCAM codes increased substantially as dental surgeons switched from NGAP codes to CCAM codes; new CCAM codes were introduced, some covering several

[14] The number of intra-oral dental procedures in 2007 was taken as equal to the 2002 figure, as no more recent data was available [6, tab. III].

Figure 20

Variation in the number of annual diagnostic procedures between 2002 and 2017, per type of imaging.

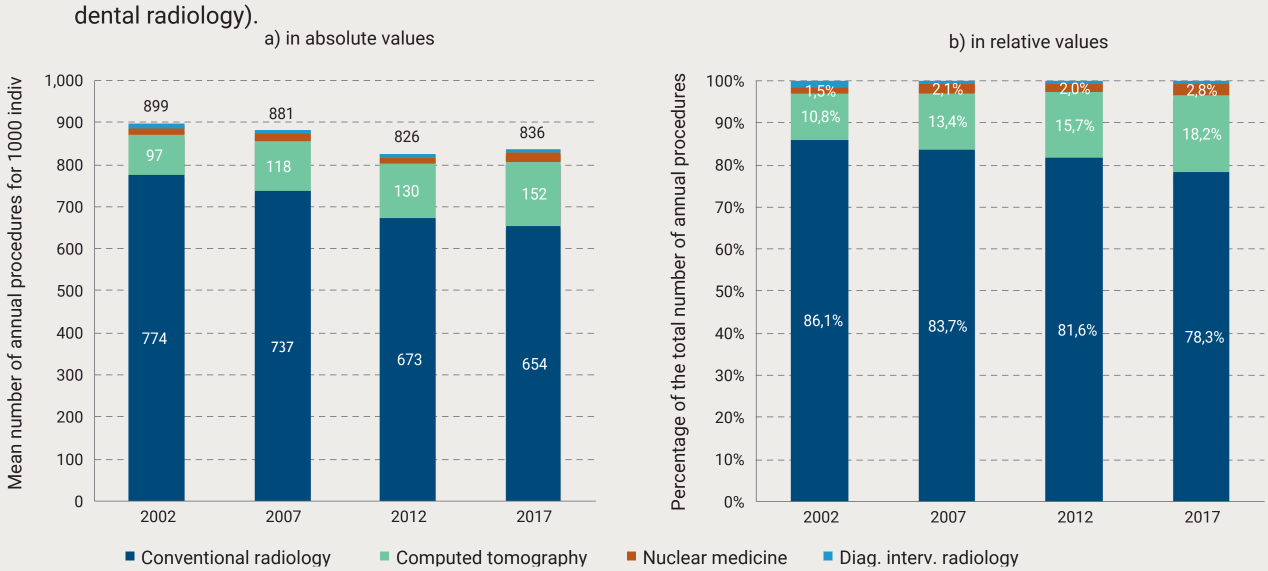


images (cf. section 2.2.2 for more detailed explanations). Comparing the frequency of dental procedures between 2012 and 2017 is therefore affected by these sources of uncertainty and reliability must be considered as inadequate. For this reason, it is more appropriate to exclude dental radiology when considering variation in diagnostic procedures.

As shown in ***Figure 21***, if dental procedures are excluded, the downward trend in the number of procedures, recorded since 2002, disappears in 2017: **the mean number of annual procedures, excluding dental radiology (836 for 1,000 beneficiaries) is 1.3% higher than in 2012**. The frequency of conventional radiological procedures dropped by 2.8% (a smaller decrease than in previous periods) and still represent the vast majority (78.3%) of all annual examinations, excluding dental radiology. Computed tomography expanded substantially over the period, climbing from 130 to 152 annual procedures for 1,000 beneficiaries, i.e. a 17% increase. The percentage of

Figure 21

Variation in the number of annual diagnostic procedures between 2002 and 2017, per type of imaging (excluding dental radiology).



computed tomography versus all diagnostic procedures, excluding dental procedures, has been constantly rising since 2002, from 10.8% to 18.2% over 15 years. Nuclear medicine procedures remain infrequent (23 for 1,000 beneficiaries), but have expanded strongly by approximately 44% since 2012, and the percentage versus all non-dental diagnostic procedures (2.8%) has almost doubled in 15 years. The frequency of diagnostic interventional radiological procedures has not varied substantially (6 for 1,000 beneficiaries in 2017). Due to this low figure and existing limitations already mentioned (cf. section 4.2.5) for this type of imaging in this study, no conclusions can be reached with respect to variation in this type of imaging since 2002.

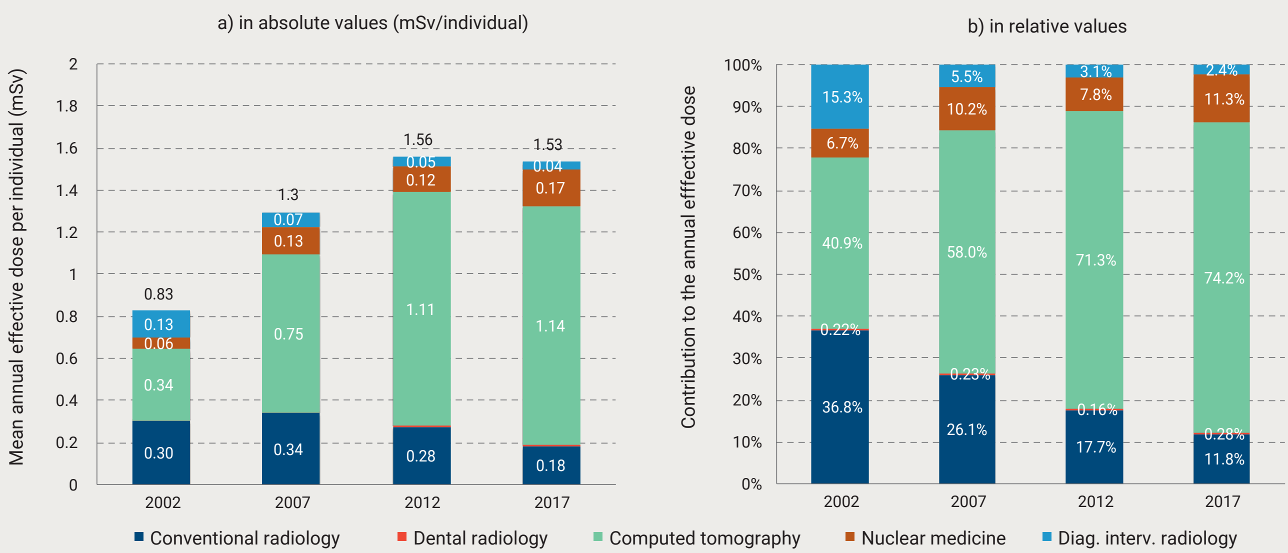
It is worth comparing these figures with the periodic review by the CNAM of the activity of independent doctors. The last edition of this review focuses on 2016 **[35]**. The decrease in the relative share of conventional radiology is also mentioned: "*the percentage of conventional radiology in imaging as a whole*[15] *dropped from 25% in 2012 to 22% in 2016*". Variation in nuclear medicine and computed tomography procedures also matches these conclusions: "*scintigraphy (reimbursements up +7.2% in 2016) and, to a lesser extent, computed tomography, contribute to the overall increase in imaging procedures*". The increase in imaging procedures (excluding dental procedures) recorded in this study is more moderate than the increase indicated in the CNAM review: "*Between 2007 and 2016, reimbursements for imaging recorded mean annual growth of 2.4%*". It is, however, important to take note that this study excludes all types of imaging which do not use ionising radiation, such as ultrasound, which represents over 40% of imaging procedures, and MRI, which is rapidly expanding in use (+7 % between 2015 and 2016). In addition, the comparison is limited as the procedures performed in the public sector are not integrated in the CNAM review.

6.2 Variation in mean annual per caput effective doses

If we consider variation in the mean annual effective doses associated with diagnostic procedures during the different ExPRI studies (cf. ***Figure 22***), **it appears that the increase recorded between 2002 and 2012 (+88 %) disappears between 2012 and 2017: the mean annual per caput effective dose decreased by 1.9% from 1.56 to 1.53 mSv between 2012 and 2017.** This decrease is mainly attributable to **conventional radiology, for which the contribution (0.18 mSv in 2017) dropped by over 34%**, which substantially exceeds the 2.8% reduction in the frequency of procedures recorded over this period. **The contribution of computed tomography to the annual effective dose increases moderately (+2.4%)** when compared with the increase of over 17% recorded for the frequency of this type of imaging procedure. The contribution of nuclear medicine to the annual effective dose increased by around 44% from 0.12 mSv to 0.17 mSv,

Figure 22

Variation in the mean annual per caput effective dose between 2002 and 2017, per type of imaging.



[15] In this case, the term imaging covers all types of imaging, whether ionising or non-ionising, such as MRI and ultrasound, which explains the different percentages versus this study.

which is equivalent to the increase recorded for the frequency of this type of imaging procedure.

These results are attributable, in addition to variation in the frequency of the different types of imaging procedures, to variation in mean doses per examination between 2012 and 2017. Significant decreases in the mean doses of conventional radiological examinations (7% globally) and computed tomography examinations (-12% globally) were recorded over this period as part of the study on DRL **[19]**. With nuclear medicine, the doses absorbed by patients are relatively stable as they mainly depend on the activity of the radiopharmaceutical administered.

6.3 Variation in the distribution of procedures per examination category

Table XVI contains the number of imaging procedures performed in France in 2007 and 2012, as published in appendix 5 of the previous report **[7]** and those in this study focusing on 2017. The distribution of procedures is indicated for each examination category used in the previous ExPRI study, and not those defined in this study, in order to compare the three years studied using the same basis for classification (cf. 2.1.2). Refer to appendix 1 of the previous report for details of this classification **[7]**.

For **conventional radiology**, in 2007, thorax examinations were the most frequent procedure; their number has dropped by over 10% in ten years, downgrading this category from the top rank in 2007 to the second most frequent rank in 2017. On the other hand, limb x-rays have increased noticeably (+27% since 2007) and rank as the most frequent category of procedures in 2017, representing over one third (33.7%) of conventional radiology procedures. Spine x-rays have increased substantially (+39% since 2007), but only represent a small percentage of procedures (1.5% in 2017). It is important to take note that, according to this classification, this category only includes radiograms of the entire spine. Radiograms which only cover part of the vertebral column are recorded under the corresponding anatomical regions (e.g. radiography of the dorsal vertebral column is recorded under the thorax category). The percentages of other conventional radiology procedure categories are relatively stable (pelvic bone, breast, bone density testing, whole skeleton, biliary duct), or have very noticeably dropped (abdomen, head and neck, urogenital system, digestive tract, bed-ridden x-rays). The number of procedures in these latter categories have also decreased since 2012, and even since 2007 for some categories (particularly the abdomen).

The percentage of extraoral categories (dental panoramic imaging, cone-beam CT, skull teleradiography) climbed steeply, particularly between 2012 and 2017, from 14% to almost 32% of **dental radiological** procedures. For the reasons explained in the introduction to this chapter, large-amplitude variation was recorded between 2007 and 2017 for the number of intraoral dental radiological procedures, which led to a mechanical, but artificial, decrease in the percentage of these procedures in dental radiology as a whole in 2017 compared with previous years. However, the extraoral group procedures, which were not affected by changes to CCAM codes and only slightly impacted by the withdrawal from the NGAP codes (cf. start of this chapter), have expanded substantially since 2012 (+107%). Therefore, the notable increase in the percentage of extraoral procedures in dental radiology is very real and very significant.

The most hard-hitting change for **computed tomography** examinations over the 2007-2017 decade involved the pronounced increase in procedures imaging the entire trunk or the head and trunk (chest-abdomen-pelvis (CAP) or Head+CAP category): these procedures represent 13.4% of all computed tomography procedures in 2017, versus 1.4% in 2007 and 4.2% in 2012. This observation must be paralleled with the augmented mean annual per caput effective dose attributable to computed tomography over the period (cf. 6.2). The percentages of the two most frequent examination categories (abdomen and/or pelvis, head and neck) have markedly decreased since 2007 and each represent one quarter of all computed tomography procedures in 2017. The percentage of thorax examinations has also dropped (17.5% in 2017) although the absolute number of such procedures has climbed (+21% over 10 years) and thorax imaging ranks third procedure category in terms of frequency. The percentages of vertebral column and limb categories are relatively stable.

In a context where **nuclear medicine** procedures are becoming considerably more frequent (cf. 6.1), clear variation appears in terms of their distribution. In particular, the percentage of the whole body PET category out of all nuclear medicine procedures has tripled over a decade, rising from less than 10% in 2007 to over 32% in 2017, and reached the top rank in terms of frequency of nuclear medicine procedures in 2017. On the other hand, the percentage of procedures imaging the skeleton (bone scintigraphy) fell significantly over the same period, from approximately 42% to around 25%. However, these procedures remain the most frequent (over 410,000 in 2017) after the whole body PET. Procedures imaging the thyroid, lungs or the urogenital system have also dropped noticeably since 2007, in terms of both percentage and absolute numbers. The percentage of cardiac scintigraphy examinations remains generally constant, between 24% and 25% over the period in question. The relatively steep increase recorded for the category including other nuclear medicine procedures, rising from 2.5% to 6.3% over ten years, is also notable. This increase is mainly attributable to pre- or peri-surgical radio-isotopic detection procedures, which are closely imbricated in cancer treatment, just like whole body PET.

Finally, the percentage of cardiac procedures in **diagnostic interventional radiology** climbed substantially between 2007 and 2017, when it reached 70% of all procedures. However, this observation must be carefully qualified as many peripheral vascular procedures are frequently performed for both diagnostic and therapeutic reasons, and are not included in the study for this reason, as previously mentioned in section 4.2.5. Neither must this observation be assumed to represent actual variation for this type of imaging.

Table XVI

Distribution of diagnostic procedures in France in 2007, 2012 and 2017 (rounded values) depending on the categories defined for the study focusing on 2012 [7].

	Procedures in 2007		Procedures in 2012		Procedures in 2017	
	absolute	%	absolute	%	absolute	%
Conventional radiology	**47,012,200**	**100%**	**44,175,500**	**100%**	**46,680,600**	**100%**
Thorax	13,999,080	29.8%	12,356,600	28.0%	12,476,300	26.7%
Limbs	12,363,870	26.3%	13,224,000	29.9%	15,719,200	33.7%
Pelvis (bone)	5,801,540	12.3%	5,289,300	12.0%	5,613,700	12.0%
Abdomen	5,184,450	11%	4,023,300	9.1%	3,623,200	7.8%
Breast	5,085,190	10.8%	5,102,500	11.6%	5,289,300	11.3%
Head and neck	1,399,870	5.7%	1,980,600	4.5%	1,710,900	3.7%
Bone density testing	717,950	1.5%	644,900	1.5%	673,200	1.4%
Spine	514,480	1.1%	595,000	1.3%	715,500	1.5%
Urogenital system	309,750	0.7%	182,600	0.4%	165,200	0.4%
Digestive tract	288,870	0.6%	219,600	0.5%	171,100	0.4%
Entire skeleton	74,290	0.2%	75,200	0.2%	112,800	0.2%
Biliary duct	20,720	0.04%	24,700	0.1%	28,800	0.1%
Other	3,090	0.01%	457,200	1.0%	381,400	0.8%
of which bed-ridden x-rays	not counted separately		455,400	1.0%	380,300	0.8%
Dental radiology	**18,430,150**	**100%**	**27,616,000**	**100%**	**25,022,900**	**100%**
Intra-oral	15,739,050	85%	23,756,000	86%	17,033,400	68.1%
Extra-oral	2,691,100	15%	3,860,000	14%	7,989,400	31.9%
Computed tomography	**7,563,920**	**100%**	**8,483,900**	**100%**	**10,865,800**	**100%**
Abdomen and/or pelvis	2,256,820	29.9%	2,548,500	30.0%	2,720,800	25.0%
Head and neck	2,088,010	27.6%	2,278,600	26.9%	2,719,200	25.0%
Thorax	1,569,080	20.8%	1,654,400	19.5%	1,898,900	17.5%
Vertebral column	926,350	12.3%	1,028,000	12.1%	1,212,300	11.2%
Limbs	602,950	8%	615,300	7.3%	854,300	7.9%
Chest-abdomen-pelvis (CAP) or Head+CAP	115,280	1.4%	355,300	4.2%	1,457,400	13.4%
Other	5,430	0.1%	500	<0.01%	2,800	0.03%
Nuclear medicine	**1,177,120**	**100%**	**1,103,200**	**100%**	**1,662,200**	**100%**
Skeleton	493,590	41.9%	352,800	32.0%	413,900	24.9%
Heart	285,810	24.3%	277,300	24.8%	398,900	24.0%
whole body PET	113,730	9.8%	229,300	20.8%	534,700	32.2%
Thyroid	96,980	8.2%	62,300	5.6%	62,100	3.7%
Lungs	71,360	6.1%	51,700	4.7%	53,200	3.2%
Urogenital system	31,870	2.7%	15,100	1.4%	18,600	1.1%
Head and neck (excluding the thyroid)	28,350	2.3%	29,200	2.6%	49,600	3.0%
Whole body (excluding skeleton and PET)	20,520	1.7%	16,600	1.5%	20,800	1.3%
Abdomen and/or digestive tract	4,910	0.4%	3,000	0.3%	5,200	0.3%
Other	30,000	2.5%	65,900	6.0%	105,300	6.3%
Diagnostic interventional radiology	**439,610**	**100%**	**376,900**	**100%**	**434,900**	**100%**
Cardiovascular	277,900	63%	254,000	67%	304,300	70%
Perivascular	161,710	37%	122,900	33%	130,600	30%
TOTAL	74,623,000		81,755,500		84,666,400	

7 CONCLUSIONS AND PROSPECTS

This study is the 4th edition of the ExPRI system launched in 2003 [5]. This approach updated information on the exposure of the French population in 2017 compared with the most recent view focusing on 2012 data [7]. The method used for the study, which has not changed substantially since the previous edition, is based on the SNIIRAM generalist sample panel of beneficiaries (EGB) when determining the frequency of imaging procedures, and mainly on the analysis of the data collected by IRSN as part of diagnostic reference levels when estimating the effective doses for these procedures. The representativeness of EGB data available in 2017 has improved significantly since the report on 2012, with respect to several points:

- Medical data for public hospitals is far more comprehensive, as per procedure invoicing system is now near exclusively applied for financing purposes. The EGB can therefore be considered as practically exhaustive for hospital activities in 2017.
- As beneficiaries for ten local health insurance firms have been integrated in the sample panel, it is more representative of the wide range of healthcare habits of the French population, particularly students, even if the representativeness of data for students still remains well below that of the rest of the population.
- The reliability of dental radiology data has been greatly enhanced thanks to the general use of CCAM codes for independent doctors, ensuring a detailed description of this sector.

The main characteristics of the exposure of the population to ionising radiation from diagnostic medical imaging procedures in France in 2017 are as follows:

- The mean number of annual procedures recorded decreased from 1,247 to 1,187 for 1,000 beneficiaries between 2012 and 2017, which is a 4.8 % decrease. CCAM codes used to record dental radiological imaging were substantially changed over the 2012-2017 period and these modifications generally led to this variation. Indeed, when dental radiology is excluded, **the mean number of annual procedures is equal to 836 for 1,000 beneficiaries, which is 1.3% higher than in 2012 (826 for 1,000 beneficiaries)**.
- The mean annual per caput effective dose decreased by 1.9% from 1.56 to 1.53 mSv between 2012 and 2017. This decrease is mainly attributable to conventional radiology, for which the contribution (0.18 mSv) dropped by over 34%. The contribution of computed tomography to the annual effective dose (1.14 mSv) increases moderately (+2.4%) when compared with the increase of over 17% recorded for the frequency of this type of imaging procedure. The contribution of nuclear medicine increased by around 44% from 0.12 mSv to 0.17 mSv, which is equivalent to the increase recorded for the frequency of this type of imaging procedure.
- Computed tomography ranks third in terms of frequency of procedures, representing slightly under 13% of diagnostic procedures, but it contributes approximately 75 % of the collective effective dose attributable to the diagnostic medical imaging sector. Procedures imaging the entire trunk or the head and trunk are expanding rapidly and represent 13.4% of all computed tomography procedures, versus 1.4% in 2007.
- Dental radiology represents just under 30% of diagnostic procedures and does not significantly contribute to the collective effective dose. The percentage of extraoral procedures (including dental panoramic imaging and cone-beam CT) has climbed steeply since 2012, from 14% to almost 32% of all dental radiological procedures.
- Nuclear medicine only represents 2% of procedures, but ranks 3rd in terms of contributions to the collective effective dose at over 11 %, just behind conventional radiology. Positron emission tomography (whole body PET) is the most frequent type of procedure and its contribution to nuclear medicine examinations tripled over a decade, rising from less than 10% in 2007 to over 32%.
- Diagnostic interventional radiology, which represents very few procedures in terms of number for this study (0.5%), contributes 2.4 % of the collective dose. It is important to remember that diagnostic interventional radiological procedures are very frequently associated with a therapeutic procedure and, in this case, are not considered in this study. On this basis, these figures are probably well underestimated and must not be considered as representative of clinical practice.

- 45.4% of the population has benefitted from one or several diagnostic procedures, representing a slight increase since 2012 (43.8%). A much higher percentage of women is exposed than men: 50.2 % versus 40.4 %. If we exclude dental radiological procedures, which only make a very minor contribution to the collective effective dose, the exposed percentage of the population falls to 32.7%; it can therefore be considered that approximately one third of the French population has benefitted from at least one diagnostic procedure other than dental radiology. The percentage of individuals exposed in the population varies widely with age, from approximately 15% for very young children to slightly less than 70% for women aged 65-75 and approx. 55% for men aged 65-85.

- Patients (*i.e.* the population having benefitted from at least once diagnostic procedure and therefore actually exposed) participated in 2.6 procedures during the year, on average. This number varies depending on the age of these patients: children aged under 10 participate in less than 2 procedures annually, on average, while adults aged over 75 participate in approx. 3.5 procedures. No significant difference was detected between men and women for the mean number of annual procedures.

- The cumulative individual effective dose for patients in 2017 represented a mean value of 3.4 mSv. The distribution of this dose is extremely heterogeneous: half of patients absorbed a dose of less than or equal to 0.1 mSv, most patients (approx. 82%) absorbed a dose of less than the mean dose of 3.4 mSv, while the top 5% in terms of exposure absorbed a dose of more than 18.1 mSv. A very noticeable difference is apparent between men and women: men absorbed approx. 1 mSv more than women in 2017 on average. The cumulative individual effective dose varies widely with the age of patients: less than 1 mSv for children and very young adults (aged 20 or less), climbing with age to reach approximately 2 mSv before the age of 40. Above this age, on average, annual exposure will be substantially higher for men than for women (approx. 9 mSv vs 5 mSv between the ages of 70 and 74).

A more specific study of the population of patients having benefitted from at last one annual diagnostic computed tomography procedure in 2017, and retrospectively over a cumulative period of up to 6 years, was also completed. It would appear that a population estimated at over 30,000 patients nationwide was exposed to a cumulative effective dose of over 100 mSv in 2017 due to multiple computed tomography examinations. This figure rises to 500,000 patients over a cumulative period of 6 years (2012-2017). This strongly exposed population appears to be steadily increasing since 2012. Most members of this population are elderly, however one quarter is aged under 55.

In general, exposure of the French population to ionising radiation from diagnostic medical imaging procedures, excluding dental radiology, was relatively constant in 2017 compared with 2012. Variation detected in terms of the mean frequency of imaging procedures and the average per caput annual effective dose is generally minor. In particular, the almost 90% increase recorded between 2002 and 2012 for the average per caput annual effective dose was no longer evident between 2012 and 2017. Nuclear medicine recorded the greatest increase over this 5-year period (+44%), in terms of both frequency and contribution to the collective effective dose. Computed tomography remains the most significant contribution to the exposure faced by the population by far. However, the increase in collective effective dose attributable to this type of imaging (+2.4%) remains well below that of computed tomography procedures, which became far more frequent over the period in question (+17%). These observations reflect the decrease in doses per computed tomography procedure recorded in the most recent review of diagnostic reference levels for the 2016-2018 period [19]. Only a small percentage of patients – but representing several hundreds of thousands of patients throughout France – combined high effective doses, and approximately 25% of these patients were aged under 55. Although these patients are very certainly treated for serious pathologies, potential long-term radio-induced effects must be considered.

Finally, with respect to the analysis of data in this study, it would appear that improvements are required in the interventional radiological sector, for which diagnostic procedures are differentiated from therapeutic procedures. The study is currently limited to diagnostic procedures, which prevents any reliable representation of the exposure of patients benefitting from this type of medical treatment, which has been extensively expanding throughout France in recent years, as well as internationally. On this basis, it would appear that the scope of the analysis of the ExPRI system and the study methods used must be modified. However, two difficulties must be faced when expanding the scope of the study to therapeutic interventional radiology procedures: firstly, it will probably be complicated to identify procedures using CCAM codes due to the fact that some codes are rather generalist, secondly, the doses associated with some interventional procedures vary widely, which will make it complicate to assign a specific dose to a given procedure. However, changing the ExPRI system in this way would ensure compliance with the recommended guidelines of international bodies such as UNSCEAR.

This periodic report will be completed by complementary studies focusing on specific topics in the coming years. To begin with, the data in this report will be compared with all available European and international data. Other topics could be covered at a later time, such as changes to some specific imaging procedures in recent years, e.g. cone-beam CT for dental radiology or radiography imaging the entire vertebral column. Available data on the exposure of children to computed tomography scans could be detailed pending the future publication of the final results of the international epidemiological EPI-CT study **[36]**.

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APPENDIX

LIST OF CCAM CODES PER TYPE OF IMAGING AND EXAMINATION CATEGORY. EFFECTIVE DOSE PER PROCEDURE, FREQUENCY OF PROCEDURES AND CONTRIBUTION TO THE MEAN PER CAPUT ANNUAL DOSE

Details of all of the 343 CCAM codes actually used for this study (i.e. codes for which at least one procedure was recorded) can be found below, in ***Table XVII*** to ***Table XXI*** for each of the types of imaging. They represent a total of 816,052 diagnostic procedures, i.e. 97.8% of all procedures counted for in the EGB sample panel in 2017. CCAM codes are classified by examination category for each type of imaging, as defined in section 2.1.2 of this report. The "E / proc" column indicates the mean effective dose for the CCAM code, in mSv. The "Freq of proc" column indicates how often the procedure is performed yearly, as a number of procedures for 1,000 beneficiaries. The "E_{mean} / indiv." indicates the contribution of the procedure to the mean per caput annual effective dose in µSv, calculated for the entire population of the EGB sample panel in 2017. N.S. (not significant) is indicated if the code was recorded less than 20 times.

Dental radiology procedures without CCAM codes (cf. section 2.1.1) only represent 2.2% of all of the procedures recorded and are not included in the appended tables. In order to calculate their contribution to the total effective dose, these procedures were considered as equivalent to one (two and four respectively) dental retroalveolar and/or retrocoronary radiography of a sector of 1 to 3 contiguous teeth (CCAM code: HBQK389) for the reference service code 1331 (9422 and 9423 respectively).

Table XVII

Effective dose per procedure, frequency of procedures and contribution to the mean per caput annual dose for CCAM codes for conventional radiology.

CCAM code	Description of the procedure	E / proc. (mSv)	Freq of proc (/1,000 indiv.)	E_{mean} / indiv. (µSv)
Head and neck				
BBQH001	Unilateral or bilateral lacrimal dacryocystography	0.5	0.04	0.02
HCQH001	Sialography	0.5	N.S.	N.S.
HQQH002	Dynamic radiological study of deglutition, with recording [dynamic pharyngography]	0.06	0.10	<0.01
LAQK003	Radiography of the skull and/or face bones according to 1 or 2 incidences	0.039	5.61	0.22
LAQK005	Radiography of the skull and/or face bones according to 3 or more incidences	0.79	2.60	2.05
LBQK001	Unilateral or bilateral tomography of the temporomandibular joint	0.5	0.16	0.08
LBQK005	Unilateral or bilateral radiography of the temporomandibular joint	0.012	0.38	<0.01
LCQK002	Radiography of soft neck tissue	0.06	0.53	0.03
Vertebral column				
AEQH001	Dorsal and/or lumbar myelography	9	0.08	0.70
AEQH002	Cervical myelography	0.6	N.S.	N.S.
AFQH002	Saccoradiculography	9	0.05	0.44
LDQK001	Radiography of the cervical segment of the spine according to 1 or 2 incidences	0.063	1.72	0.11
LDQK002	Radiography of the cervical segment of the spine according to 3 or more incidences	0.17	12.82	2.18
LDQK004	Radiography of the cervical segment and the thoracic segment of the spine	0.33	2.28	0.75

Table XVII cont.

Effective dose per procedure, frequency of procedures and contribution to the mean per caput annual dose for CCAM codes for conventional radiology.

CCAM code	Description of the procedure	E / proc. (mSv)	Freq of proc (/1,000 indiv.)	E_{mean} / indiv. (µSv)
LDQK005	Radiography of the cervical segment and the lumbar segment of the spine	0.95	0.84	0.80
LEQK001	Radiography of the thoracic segment of the spine	0.27	2.74	0.74
LEQK002	Radiography of the thoracic segment and the lumbar segment of the spine	1.1	11.66	12.82
LFQK001	Radiography of the lumbar segment of the spine according to 4 or more incidences	1.1	12.87	14.16
LFQK002	Radiography of the lumbar segment of the spine according to 1 to 3 incidences	0.85	11.12	9.45
LGQK001	Radiography of the sacrum and/or coccyx	0.5	1.38	0.69
LHQH001	Arthrography of the posterior spinal facet joints	0.7	0.82	0.57
LHQH003	Single intervertebral discography, by transcutaneous access	0.7	0.06	0.04
LHQH004	Multiple intervertebral discography, by transcutaneous access	1.5	N.S.	N.S.
LHQK002	Teleradiography of the entire spine according to 2 incidences	0.85	3.07	2.61
LHQK003	Teleradiography of the entire spine according to 2 incidences with supple-mentary segment incidence	1.1	1.13	1.24
LHQK004	Teleradiography of the entire spine according to 1 incidence	0.4	1.04	0.41
LHQK007	Radiography of the entire spine	0.85	4.79	4.07
Limbs				
MBQK001	Radiography of the arm	0.001	2.08	<0.01
MCQK001	Radiography of the forearm	0.001	3.21	<0.01
MDQK001	Radiography of the hand or finger	0.00018	28.99	<0.01
MDQK002	Bilateral radiography of the hand and/or wrist, according to 1 incidence in one single frontal image	0.00018	2.26	<0.01
MFQH001	Arthrography of the elbow	0.004	0.06	<0.01
MFQK001	Radiography of the elbow according to 3 or more incidences	0.0015	3.9	<0.01
MFQK002	Radiography of the elbow according to 1 or 2 incidences	0.00076	6.09	<0.01
MGQH001	Arthrography of the wrist	0.00048	0.33	<0.01
MGQK001	Radiography of the wrist according to 3 or more incidences	0.00037	10.46	<0.01
MGQK002	Dynamic radiographic imaging of the wrist for non-dissociative sprain according 7 specific incidences	0.0008	0.05	<0.01
MGQK003	Radiography of the wrist according to 1 or 2 incidences	0.0002	12.44	<0.01
MHQH001	Metacarpo-phalangeal or interphalangeal arthrography of a finger	0.0005	0.1	<0.01
MZQK001	Unilateral or bilateral frontal teleradiography of the entire upper limb	0.002	0.04	<0.01
MZQK003	Radiography of 2 segments of the upper limb	0.002	5.38	0.01
MZQK004	Radiography of 3 or more segments of the upper limb	0.003	0.64	<0.01
NBQK001	Radiography of the thigh	0.001	2.59	<0.01
NCQK001	Radiography of the leg	0.002	4.69	<0.01
NDQK001	Unilateral radiography of the foot according to 1 to 3 incidences	0.00018	24.96	<0.01
NDQK002	Bilateral radiography of the foot according to 1 to 3 incidences on each side	0.00037	5.13	<0.01
NDQK003	Radiography of the foot according to 4 or more incidences	0.00037	2.97	<0.01
NDQK004	Radiography of the foot according to 4 or more incidences, for podometric study	0.00046	3.52	<0.01
NFQH001	Arthrography of the knee	0.005	1.12	<0.01
NFQK001	Unilateral radiography of the knee according to 1 or 2 incidences	0.0016	13.27	0.02
NFQK002	Bilateral radiography of the knee according to 1 or 2 incidences on each side	0.0032	2.26	<0.01
NFQK003	Radiography of the knee according to 3 or 4 incidences	0.0024	23.78	0.06
NFQK004	Radiography of the knee according to 5 or more incidences	0.0048	23.79	0.11
NGQH001	Arthrography of the ankle	0,00048	0,3	<0,01

Table XVII cont.

Effective dose per procedure, frequency of procedures and contribution to the mean per caput annual dose for CCAM codes for conventional radiology.

CCAM code	Description of the procedure	E / proc. (mSv)	Freq of proc (/1,000 indiv.)	E_{mean} / indiv. (µSv)
NGQK001	Radiography of the ankle according to 1 to 3 incidences	0.00018	15.3	<0.01
NGQK002	Radiography of the ankle according to 4 or more incidences	0.00037	9.04	<0.01
NHQH001	Arthrography of the foot and/or toes	0.0005	0.1	<0.01
NZQK001	Unilateral or bilateral frontal teleradiography of the entire lower limb with bipedal support	0.005	3.79	0.02
NZQK003	Successive bilateral frontal teleradiography of the entire lower limb with monopedal support	0.01	0.43	<0.01
NZQK005	Radiography of 2 segments of the lower limb	0.003	6.02	0.02
NZQK006	Radiography of 3 or more segments of the lower limb	0.005	1.15	<0.01
PAQK001	Comparative radiography of epiphyseal cartilages of long limb bones	0.01	0.04	<0.01
Thorax				
GEQH001	Lung scans	0.2	N.S.	N.S.
LJQK001	Radiography of the thorax skeleton	0.079	2.05	0.16
LJQK002	Radiography of the thorax with radiography of the thorax skeleton	0.14	7.1	0.99
LJQK015	Radiography of the sternum and/or sternoclavicular joint	0.079	0.84	0.07
MAQK001	Radiography of the scapular belt and/or shoulder according to 3 or 4 incidences	0.017	16.83	0.29
MAQK002	Radiography of the scapular belt and/or shoulder according to 5 or more incidences	0.026	10.8	0.28
MAQK003	Radiography of the scapular belt and/or shoulder according to 1 or 2 incidences	0.0086	12.91	0.11
MEQH001	Arthrography of the shoulder	0.026	2.34	0.06
ZBQK002	Radiography of the thorax	0.058	116.74	6.77
ZBQK003	Dynamic radiological examination of the thorax, in order to study respiratory and/or cardiac functions	0.11	0.2	0.02
Mammography				
QELH001	Installation of breast reference points, by transcutaneous access with mammographic guidance	0.16	0.17	0.03
QEQH001	Galactography	0.31	N.S.	N.S.
QEQK001	Bilateral mammography	0.31	32.35	10.03
QEQK004	Screening mammography	0.31	36.29	11.25
QEQK005	Unilateral mammography	0.16	5.31	0.85
Digestive tract				
HEQH001	Radiography of the oesophagus with contrast medium [oesophageal transit]	1.2	0.16	0.19
HEQH002	Oesophageal-gastro-duodenal radiography with opacification by contrast medium [oesophageal-gastro-duodenal transit]	10	1.69	16.89
HFMP002	Secondary radiological examination of the position and/or functioning of adjustable gastric banding, with opacification by contrast medium	2.4	0.1	0.24
HGQH001	Radiography of the small intestine with contrast medium administered using a naso-duodenal probe [enteroclysis]	6	0.02	0.15
HGQH002	Radiography of the small intestine with contrast medium ingested [intestinal transit]	3.3	0.06	0.21
HHQH001	Radiography of the colon with opacification by contrast medium	9	0.25	2.21
HPMP002	Secondary radiological examination of the position and/or functioning of a peritoneal drain, a peritoneal dialysis catheter or a peritoneovenous jugular shut, with opacification by contrast medium	2.4	N.S.	N.S.
HTQH002	Defecography [dynamic rectography]	9	0.04	0.38
HZMP002	Secondary radiological examination of the position and/or functioning of a gastric probe, a biliary tube or a biliary endoprosthesis, with opacification by contrast medium	2.4	0.06	0.13
JLQH002	Dynamic colpocystorectography	9	N.S.	N.S.
ZCQK002	Radiography of the abdomen without preparation	1.1	13.28	14.61

Table XVII cont.

Effective dose per procedure, frequency of procedures and contribution to the mean per caput annual dose for CCAM codes for conventional radiology.

CCAM code	Description of the procedure	E / proc. (mSv)	Freq of proc (/1,000 indiv.)	E_{mean} / indiv. (µSv)
Urogenital system				
JBQH001	Descending urography, by transcutaneous access with ultrasound and/or radiological guidance	2.4	N.S.	N.S.
JBQH002	Ascending urography	2.4	0.53	1.28
JBQH003	Descending urography, with an existing nephrostomy	2.4	0.04	0.09
JDQH001	Ascending urethrocystography	2.4	0.41	0.98
JDQH002	Urethrocystography, with an existing cystostomy	2.4	N.S.	N.S.
JDQH003	Urethrocystography, by transcutaneous puncture of the bladder	2.4	N.S.	N.S.
JKQH001	Hysterosalpingography	1.7	1.14	1.94
JNQK001	Radiography of the contents of the gravid uterus [uterine content]	0.2	N.S.	N.S.
JZQH001	Radiological exploration of anomalies of the urogenital sinus [external genitography]	2.5	N.S.	N.S.
JZQH002	Intravenous urography without permictional urethrocystography	1.5	0.11	0.16
JZQH003	Intravenous urography with permictional urethrocystography	2.5	0.04	0.11
Pelvic bone				
NAQK007	Radiography of the pelvic girdle [hip] according to 2 incidences	0.99	2.98	2.95
NAQK015	Radiography of the pelvic girdle [hip] according to 1 incidence	0.5	37.11	18.55
NAQK023	Radiography of the pelvic girdle [hip] according to 3 or more incidences	1.5	8.04	12.06
NAQK049	Radiography of the pelvic girdle [hip] according to 1 incidence and bilateral radiography of the coxofemoral joint according to 1 or 2 incidences per side	1.1	2.91	3.20
NAQK071	Radiography of the pelvic girdle [hip] according to 1 incidence and unilateral radiography of the coxofemoral joint according to 1 or 2 incidences	0.8	8.49	6.79
NEQH001	Functional assessment of a non-traumatic hip instability with arthrography and production of a rigid cast under general anaesthetic	0.25	N.S.	N.S.
NEQH002	Arthrography of the hip	0.25	0.40	0.10
NEQK010	Radiography of the coxofemoral joint according to 1 or 2 incidences	0.3	8.69	2.61
NEQK012	Radiography of the coxofemoral joint according to 4 or more incidences	0.74	3.02	2.23
NEQK035	Radiography of the coxofemoral joint according to 3 incidences	0.45	5.63	2.54
ZCQK001	Radiographic pelvimetry	0.55	N.S.	N.S.
Bone density testing				
PAQK007	Bone density testing at 2 sites, by biphotonic method	0.001	9.23	<0.01
PAQK008	Bone density testing of the entire body by biphotonic method, for constitutional bone disorders in children	0.001	N.S.	N.S.
PAQK900	Bone density testing of the entire body by biphotonic method, for non-constitutional bone disorders	0.001	0.19	<0.01
Other				
FCQH002	Lymphography of the lower limbs	8	N.S.	N.S.
PAQK002	Radiography of the skeleton to calculate bone age, after the age of 2 years	0.0086	0.83	<0.01
PAQK003	Radiography of the entire skeleton, segment by segment, for children	1.8	0.13	0.24
PAQK005	Radiography of the hemiskeleton to calculate bone age, before the age of 2 years	0.0086	0.03	<0.01
YYYY163	Radiography of the hemiskeleton or entire skeleton for an adult	1.8	0.58	1.05
ZZQH002	Radiography of a fistula [Fistulography]	1.7	N.S.	N.S.
ZZQK001	Radiography of bed-ridden patient, according to 3 or more incidences	1.4	0.03	0.04
ZZQK002	Radiography of bed-ridden patient, according to 1 or 2 incidences	0.57	5.30	3.02

Table XVIII

Effective dose per procedure, frequency of procedures and contribution to the mean per caput annual dose for CCAM codes for dental radiology.

CCAM code	Description of the procedure	E / proc. (mSv)	Freq of proc (/1,000 indiv.)	E_{mean} / indiv. (µSv)
Intraoral				
HBQK001	Pelvibuccal radiography [occlusal]	0.025	0.69	0.02
HBQK040	Pre-interventional or peri-interventional retroalveolar intraoral radiographies over a sector of 1 to 3 contiguous teeth with final radiography for endodontics therapeutic procedure	0.0072	32.21	0.23
HBQK041	Retroalveolar and/or retrocoronary intraoral radiographies covering 14 separate sectors of 1 to 3 contiguous teeth	0.05	0.81	0.04
HBQK046	Retroalveolar and/or retrocoronary intraoral radiographies covering 9 separate sectors of 1 to 3 contiguous teeth	0.032	0.13	<0.01
HBQK061	Final retroalveolar and/or retrocoronary intraoral radiography over a sector of 1 to 3 contiguous teeth for an endodontics therapeutic procedure or peri-interventional and/or final procedure, excluding endodontics therapeutic procedures	0.0036	7.1	0.03
HBQK065	Retroalveolar and/or retrocoronary intraoral radiographies covering 10 separate sectors of 1 to 3 contiguous teeth	0.036	0.33	0.01
HBQK093	Retroalveolar and/or retrocoronary intraoral radiographies covering 13 separate sectors of 1 to 3 contiguous teeth	0.047	0.05	<0.01
HBQK142	Retroalveolar and/or retrocoronary intraoral radiographies covering 8 separate sectors of 1 to 3 contiguous teeth	0.029	0.43	0.01
HBQK191	Retroalveolar and/or retrocoronary intraoral radiographies covering 2 separate sectors of 1 to 3 contiguous teeth	0.0072	18.62	0.13
HBQK303	Pre-interventional, peri-interventional and final retroalveolar intraoral radiographies over a sector of 1 to 3 contiguous teeth for endodontics therapeutic procedure	0.011	23.8	0.26
HBQK331	Retroalveolar and/or retrocoronary intraoral radiographies covering 3 separate sectors of 1 to 3 contiguous teeth	0.011	4.31	0.05
HBQK389	Retroalveolar and/or retrocoronary intraoral radiographies covering a sector of 1 to 3 contiguous teeth	0.0036	112.94	0.41
HBQK424	Retroalveolar and/or retrocoronary intraoral radiographies covering 11 separate sectors of 1 to 3 contiguous teeth	0.04	0.09	<0.01
HBQK428	Retroalveolar and/or retrocoronary intraoral radiographies covering 5 separate sectors of 1 to 3 contiguous teeth	0.018	1.37	0.02
HBQK430	Retroalveolar and/or retrocoronary intraoral radiographies covering 7 separate sectors of 1 to 3 contiguous teeth	0.025	0.25	<0.01
HBQK443	Retroalveolar and/or retrocoronary intraoral radiographies covering 4 separate sectors of 1 to 3 contiguous teeth	0.014	8.55	0.12
HBQK476	Retroalveolar and/or retrocoronary intraoral radiographies covering 12 separate sectors of 1 to 3 contiguous teeth	0.043	0.16	<0.01
HBQK480	Retroalveolar and/or retrocoronary intraoral radiographies covering 6 separate sectors of 1 to 3 contiguous teeth	0.022	0.73	0.02
Extraoral				
HBQK002	Dentomaxillary panoramic radiography	0.019	98.37	1.87
LAQK001	Teleradiography of the skull and/or face bones according to 2 incidences	0.026	0.97	0.03
LAQK008	Teleradiography of the skull and/or face bones according to 3 incidences	0.039	0.05	<0.01
LAQK012	Teleradiography of the skull and/or face bones according to 1 incidence	0.013	4.81	0.06
LAQK027	Cone Beam Computerized Tomography (CBCT) of the maxillary, the mandible and/or dental arch	0.1	7.77	0.78

Table XIX

Effective dose per procedure, frequency of procedures and contribution to the mean per caput annual dose for CCAM codes for computed tomography.

CCAM code	Description of the procedure	E / proc. (mSv)	Freq of proc (/1,000 indiv.)	E_{mean} / indiv. (µSv)
Head and neck				
ACQH001	Computed tomography of the skull and its contents, with intrathecal injection of contrast medium	1.9	0.11	0.2
ACQH003	Computed tomography of the skull and its contents, with intravenous injection of contrast medium	2.6	5.42	14.1
ACQK001	Computed tomography of the skull and its contents, without injection of contrast medium	1.3	20.26	26.33
EAQH002	Computed tomography of brain blood vessels	2.3	0.68	1.56
EBQH004	Computed tomography of cervicocephalic blood vessels	3.6	1.32	4.76
EBQH006	Computed tomography of cervical blood vessels	3.1	0.49	1.52
LAQK002	Unilateral or bilateral computed tomography of the petrous temporal bone and the middle ear	1.3	1.17	1.53
LAQK009	Computed tomography of the face with computed tomography of soft neck tissue	1.8	0.86	1.55
LAQK011	Unilateral or bilateral computed tomography of the cerebellopontile angle and/or internal auditory canal	1.1	0.06	0.07
LAQK013	Computed tomography of the mandible/maxilla	0.61	5.99	3.66
LBQH002	Unilateral or bilateral computed tomography arthrogram of the temporomandibular joint	0.5	N.S.	N.S.
LCQH001	Computed tomography of the soft neck tissue, with intravenous injection of contrast medium	4.2	1.48	6.22
LCQK001	Computed tomography of the soft neck tissue, without intravenous injection of contrast medium	3.3	0.25	0.82
Vertebral column				
AFQH001	Saccoradiculography with computed tomography of the spine	11	0.06	0.61
AFQH003	Myelography with computed tomography of the spine	11	N.S.	N.S.
LHQH002	Computed tomography of several segments of the vertebral column, with intravenous injection of contrast medium	13	0.07	0.96
LHQH005	Single intervertebral discography by transcutaneous access with computed tomography of the spine	11	N.S.	N.S.
LHQH006	Computed tomography of one segment of the vertebral column, with intravenous injection of contrast medium	11	0.73	8.01
LHQK001	Computed tomography of one segment of the vertebral column, without intravenous injection of contrast medium	9.3	14.81	137.74
LHQK005	Computed tomography of several segments of the vertebral column, without intravenous injection of contrast medium	11	1.29	14.2
Limbs				
EKQH001	Computed tomography of blood vessels in the upper limbs	16	0.04	0.68
EMQH001	Computed tomography of blood vessels in the lower limbs	20	1.18	23.58
MZQH001	Computed tomography arthrogram of the upper limb	5.8	0.96	5.58
MZQH002	Unilateral or bilateral computed tomography of one segment of the upper limb, with injection of contrast medium	4.8	0.17	0.82
MZQK002	Unilateral or bilateral computed tomography of one segment of the upper limb, without injection of contrast medium	3.8	3.81	14.46
NZQH001	Unilateral or bilateral computed tomography of one segment of the lower limb, with injection of contrast medium	0.2	0.18	0.04
NZQH002	Computed tomography arthrogram of the lower limb	3.8	0.55	2.07
NZQH005	Computed tomography of the hip and lower limb for the integrated computer design of a customised prosthetic bone joint	10	0.11	1.05
NZQK002	Unilateral or bilateral computed tomography of one segment of the lower limb, without injection of contrast medium	0.2	4.94	0.99
NZQK004	Telemetry of the lower limbs by computed tomography	5.5	0.05	0.27

Table XIX cont.

Effective dose per procedure, frequency of procedures and contribution to the mean per caput annual dose for CCAM codes for computed tomography.

CCAM code	Description of the procedure	E / proc. (mSv)	Freq of proc (/1,000 indiv.)	E_{mean} / indiv. (µSv)
Thorax and heart				
ECQH010	Computed tomography of the thorax and/or heart	11	4.68	51.49
ZBQH001	Computed tomography of the thorax, with intravenous injection of contrast medium	4.5	9.9	44.57
ZBQK001	Computed tomography of the thorax, without intravenous injection of contrast medium	4.6	12.03	55.32
Abdomen and/or pelvis				
ELQH001	Computed tomography of the hepatic blood vessels to study vascularisation during at least 3 different phases	22	0.1	2.25
ELQH002	Computed tomography of the blood vessels in the abdomen and/or pelvis	19	0.98	18.7
ZCQH001	Computed tomography of the abdomen and pelvis, with intravenous injection of contrast medium	10	24.28	242.78
ZCQH002	Computed tomography of the abdomen or pelvis, with intravenous injection of contrast medium	11	2.06	22.65
ZCQK003	Computed tomographic pelvimetry	0.37	0.45	0.17
ZCQK004	Computed tomography of the abdomen and pelvis, without intravenous injection of contrast medium	7.3	8.86	64.69
ZCQK005	Computed tomography of the abdomen or pelvis, without intravenous injection of contrast medium	7.3	1.4	10.2
Multiple regions				
ACQH002	Computed tomography of the skull, its contents and the thorax, with intravenous injection of contrast medium	5.8	0.52	3.03
ACQH004	Computed tomography of the skull, its contents and the trunk, with intravenous injection of contrast medium	19	0.49	9.35
ECQH011	Computed tomography of the blood vessels in the thorax and/or heart with computed tomography of the abdomen and/or pelvis	18	1.22	21.96
ZZQH033	Computed tomography of 3 or more anatomical regions, with intravenous injection of contrast medium	18	16.63	299.28
ZZQK024	Computed tomography of 3 or more anatomical regions, without injection of contrast medium	11	1.56	17.21
Other				
PDQK001	Quantification of the different components of soft tissues, by computed tomography	1	N.S.	N.S.
QEQH002	Computed tomography of the breast, with intravenous injection of contrast medium	4.5	N.S.	N.S.
QEQK006	Computed tomography of the breast, without intravenous injection of contrast medium	4.6	N.S.	N.S.
ZZQH001	Computed tomography of a fistula	7,3	N.S.	N.S.

Table XX

Effective dose per procedure, frequency of procedures and contribution to the mean per caput annual dose for CCAM codes for nuclear medicine.

CCAM code	Description of the procedure	E / proc. (mSv)	Freq of proc (/1,000 indiv.)	E_{mean} / indiv. (µSv)
Cardiovascular system				
DAQL001	Myocardial perfusion emission computed tomography after physical effort or pharmacological effort, without synchronisation using an electrocardiogram	4.3	N.S.	N.S.
DAQL002	Scintigraphy of the heart chambers at rest according to 1 incidence	5.2	0.57	2.96
DAQL003	Myocardial perfusion emission computed tomography at rest, without synchronisation using an electrocardiogram	2.8	N.S.	N.S.
DAQL006	Myocardial positron emission computed tomography, with dedicated PET camera	4.8	N.S.	N.S.
DAQL007	Myocardial emission computed tomography with no perfusion marker	5	N.S.	N.S.
DAQL008	Scintigraphy of the heart chambers at rest according to several incidence	5.2	0.05	0.27
DAQL009	Myocardial perfusion emission computed tomography at rest, with myocardial perfusion emission computed tomography after physical effort or pharmacological effort, with synchronisation using an electrocardiogram	11	3.18	34.99
DAQL010	Myocardial perfusion emission computed tomography after physical effort or pharmacological effort, with synchronisation using an electrocardiogram	4.3	1.29	5.55
DAQL011	Myocardial perfusion emission computed tomography at rest, with myocardial perfusion emission computed tomography after physical effort or pharmacological effort, without synchronisation using an electrocardiogram	11	N.S.	N.S.
DAQL012	Scintigraphy of the heart chambers for a cardiac rhythm study	5.2	N.S.	N.S.
DAQL014	Myocardial perfusion emission computed tomography at rest, with synchronisation using an electrocardiogram	8.1	0.42	3.42
DAQL015	Emission computed tomography of the heart chambers at rest, with synchronisation using an electrocardiogram	6.7	0.03	0.21
Musculoskeletal system				
PAQL001	Bone scintigraphy of the entire body, segment by segment, over one phase [delayed], with complementary acquisition by a pinhole collimator	3.2	N.S.	N.S.
PAQL002	Bone scintigraphy of the entire body over several phases	3.2	2.95	9.45
PAQL003	Bone scintigraphy of the entire body over one phase [delayed]	3.2	2.39	7.66
PAQL005	Bone scintigraphy of the entire body, segment by segment, over several phases, without complementary acquisition by a pinhole collimator	3.2	0.16	0.51
PAQL006	Bone scintigraphy segment by segment, over one phase [delayed], without complementary acquisition by a pinhole collimator	3.2	N.S.	N.S.
PAQL007	Bone scintigraphy segment by segment, over several phases, with complementary acquisition by a pinhole collimator	3.2	N.S.	N.S.
PAQL008	Bone scintigraphy segment by segment, over several phases, without complementary acquisition by a pinhole collimator	3.2	0.24	0.76
PAQL009	Bone scintigraphy of the entire body, segment by segment, over one phase [delayed], without complementary acquisition by a pinhole collimator	3.2	0.03	0.09
PAQL010	Bone scintigraphy of the entire body, segment by segment, over several phases, with complementary acquisition by a pinhole collimator	3.2	N.S.	N.S.
Respiratory system				
GFQL001	Emission computed tomography of pulmonary ventilation	0.2	N.S.	N.S.
GFQL002	Emission computed tomography of pulmonary perfusion and ventilation	2.6	0.47	1.22
GFQL004	Scintigraphy of pulmonary ventilation	0.2	N.S.	N.S.
GFQL005	Emission computed tomography of pulmonary perfusion	2.4	0.06	0.14
GFQL006	Scintigraphy of pulmonary perfusion and ventilation	2.6	0.18	0.47
GFQL007	Scintigraphy of pulmonary perfusion	2.4	0.03	0.07
Urogenital system				
JAQL001	Glomerular or tubular renal scintigraphy [Isotopic nephrography] without pharmacological effort	1.3	0.03	0.04
JAQL002	Renal cortical scintigraphy	0.98	0.10	0.10
JAQL003	Glomerular or tubular renal scintigraphy [Isotopic nephrography] with pharmacological effort	1.3	0.11	0.14
JAQL005	Glomerular or tubular renal scintigraphy [Isotopic nephrography] without pharmacological effort, with retrograde scintigraphy of the bladder	1.3	N.S.	N.S.

Table XX cont.

Effective dose per procedure, frequency of procedures and contribution to the mean per caput annual dose for CCAM codes for nuclear medicine.

CCAM code	Description of the procedure	E / proc. (mSv)	Freq of proc (/1,000 indiv.)	E_{mean} / indiv. (µSv)
JAQL007	Glomerular or tubular renal scintigraphy [Isotopic nephrography] with pharmacological effort and reinjection of radio-isotopic product	1.9	N.S.	N.S.
JBQL001	Scintigraphy of pyelo-ureteral stent	0.9	N.S.	N.S.
JDQL001	Scintigraphy of the bladder, by retrograde access	0.2	N.S.	N.S.
JHQL001	Unilateral or bilateral scintigraphy of the testicle and/or scintigraphy of the penis	5	N.S.	N.S.
KGQL001	Radio-isotopic measurement of plasma and urinary clearance	0.036	0.05	<0.01
KGQL004	Radio-isotopic measurement of plasma clearance	0.02	N.S.	N.S.
Endocrine system				
KCQL001	Scintigraphy of the thyroid gland with radio-isotopic measurement of the fixation of iodine by the thyroid	1.8	0.20	0.36
KCQL002	Radio-isotopic measurement of the fixation of iodine by the thyroid	2	N.S.	N.S.
KCQL003	Scintigraphy of the thyroid gland	1.3	0.66	0.85
KDQL001	Scintigraphy of the parathyroid glands	6.1	0.18	1.10
KEQL001	Scintigraphy of the medulla of the adrenal gland	3.2	N.S.	N.S.
KEQL002	Adrenocortical scintigraphy	100	N.S.	N.S.
KGQL003	Radio-isotopic measurement of biological reservoirs	5	0.03	0.14
KZQL002	Scintigraphy of somatostatin analogues with complementary emission computed tomography, scintigraphy of the entire body to complement an image of a segment and scintigraphy of the entire body after 72 hours	9.3	0.04	0.34
KZQL003	Scintigraphy of somatostatin analogues over 2 phases	8	N.S.	N.S.
KZQL004	Scintigraphy of somatostatin analogues over 2 phases with scintigraphy of the entire body to complement an image of a segment	8.7	0.03	0.24
Immune and hematopoietic systems				
FCQL001	Lymphoscintigraphy	0.4	0.11	0.04
FDQL001	Scintigraphy of bone marrow	2.9	N.S.	N.S.
FEQL002	Radio-isotopic measurement of the life of platelets	5.5	N.S.	N.S.
FEQL007	Radio-isotopic measurement of blood volume	0.2	0.06	0.01
FFQL001	Scintigraphy of the spleen, by injecting a specific radio-isotopic marker	1	N.S.	N.S.
ZZQL006	Search for an infectious or inflammatory focus by injecting marked polynuclear leukocytes, with no separation of lymphocytes	3.6	N.S.	N.S.
ZZQL011	Search for an infectious or inflammatory focus by injecting marked polynuclear leukocytes, with separation of lymphocytes	7	0.03	0.19
ZZQL015	Search for an infectious or inflammatory focus by injecting antibodies or a marked peptide, or a non-specific radio-isotopic marker	12	0.02	0.29
Nervous system				
ACQL001	Brain emission computed tomography using a neurotransmission and/or metabolism marker	7.8	0.25	1.93
ACQL002	Brain positron emission computed tomography, with dedicated PET camera	3.8	0.20	0.77
ACQL003	Brain emission computed tomography for diagnostic purposes and brain tumour assessment	28	N.S.	N.S.
ACQL005	Emission computed tomography of cerebral perfusion with complex quantification and activation test	8	N.S.	N.S.
ACQL007	Emission computed tomography of cerebral perfusion without activation test	5.9	0.06	0.36
PET and oncology				
ZZQL002	Scintigraphic search for tumours with a specific monophotonic transmitter for tumours, with complementary emission computed tomography, scintigraphy of the entire body to complement an image of a segment and scintigraphy of the entire body after 72 hours	25	N.S.	N.S.
ZZQL005	Scintigraphic search for a tumour by monophotonic transmitter not specific to tumours	18	N.S.	N.S.
ZZQL012	Scintigraphic search for a tumour by monophotonic transmitter specific to tumours	5	N.S.	N.S.

Table XX cont.

Effective dose per procedure, frequency of procedures and contribution to the mean per caput annual dose for CCAM codes for nuclear medicine.

CCAM code	Description of the procedure	E / proc. (mSv)	Freq of proc (/1,000 indiv.)	E_{mean} / indiv. (µSv)
ZZQL013	Pre-surgical radio-isotopic detection of a lesion by intratumoral or peritumoral transcutaneous injection, with pre-surgical radio-isotopic detection	0.3	0.65	0.19
ZZQL016	Positron emission computed tomography of the entire body, with dedicated PET camera	13	7.49	97.42
Other				
HEQL001	Radio-isotopic search for gastroesophageal reflux	0.6	N.S.	N.S.
HEQL002	Scintigraphy of oesophageal transit by solid or liquid substance	0.9	N.S.	N.S.
HEQL003	Scintigraphy of oesophageal transit by solid and liquid substances	0.6	N.S.	N.S.
HFQL002	Scintigraphy of gastric or duodenal transit by solid or liquid substance with no pharmacological effort	0.3	N.S.	N.S.
HFQL004	Scintigraphy of gastric or duodenal transit by solid and liquid substances with no pharmacological effort	0.6	N.S.	N.S.
HGQL001	Radio-isotopic search for Meckel's diverticulum	2.9	N.S.	N.S.
HFQL002	Scintigraphy of the liver and spleen by a reticuloendothelial system marker	1.4	N.S.	N.S.
HFQL004	Scintigraphy of the bile ducts	2.9	N.S.	N.S.
HGQL001	Pre-surgical detection of a lesion after injecting a radio-isotopic product	0.3	0.67	0.20

Table XXI

Effective dose per procedure, frequency of procedures and contribution to the mean per caput annual dose for CCAM codes for diagnostic interventional radiology.

CCAM code	Description of the procedure	E / proc. (mSv)	Freq of proc (/1,000 indiv.)	E_{mean} / indiv. (µSv)
Cardiac				
DDQH006	Arteriography of a coronary bypass, by transcutaneous artery access	5.6	N.S.	N.S.
DDQH009	Coronary arteriography without left ventriculography, by transcutaneous artery access	5.6	3.12	17.45
DDQH010	Coronary arteriography with left ventriculography and bilateral or unilateral internal thoracic arteriography [mammary], by transcutaneous arterial access	5.6	N.S.	N.S.
DDQH011	Coronary arteriography with angiography of a coronary bypass and left ventriculography, by transcutaneous arterial access	5.6	N.S.	N.S.
DDQH012	Coronary arteriography with left ventriculography, by transcutaneous arterial access	5.6	0.94	5.27
DDQH013	Coronary arteriography with angiography of several coronary bypasses without left ventriculography, by transcutaneous arterial access	5.6	0.11	0.63
DDQH014	Coronary arteriography with angiography of a coronary bypass without left ventriculography, by transcutaneous arterial access	5.6	0.04	0.22
DDQH015	Coronary arteriography with angiography of several coronary bypasses and left ventriculography, by transcutaneous arterial access	5.6	0.03	0.18
DFQH001	Selective arteriography of the pulmonary trunk and/or branches, by transcutaneous venous access	5	N.S.	N.S.
DFQH002	Hyperselective arteriography of pulmonary arteries, by transcutaneous arterial access	5	N.S.	N.S.
Neurological				
EBQH001	General cervicocephalic phlebography, by transcutaneous venous access	5	N.S.	N.S.
EBQH002	Selective arteriography of 3 or more cervicocephalic sections, by transcutaneous arterial access	5	0.18	0.92
EBQH005	Hyperselective cervicocephalic arteriography, by transcutaneous arterial access	5	0.06	0.29
EBQH007	Supraselective cervicocephalic arteriography, by transcutaneous arterial access	5	N.S.	N.S.
EBQH008	Arteriography of several cervicocephalic sections, by multiple transcutaneous intra-arterial injections	5	N.S.	N.S.
EBQH010	Cervicocephalic arteriography, by a single transcutaneous intra-arterial injection	5	N.S.	N.S.
EBQH011	Selective arteriography of one or 2 cervicocephalic sections, by transcutaneous arterial access	5	0.06	0.28

Table XXI cont.

Effective dose per procedure, frequency of procedures and contribution to the mean per caput annual dose for CCAM codes for diagnostic interventional radiology.

CCAM code	Description of the procedure	E / proc. (mSv)	Freq of proc (/1,000 indiv.)	E_{mean} / indiv. (µSv)
ECQH012	Selective or hyperselective arteriography of the entire spinal cord, by transcutaneous arterial access	60	N.S.	N.S.
ECQH013	Selective or hyperselective arteriography of one segment of the spinal cord, by transcutaneous arterial access	60	N.S.	N.S.
ECQH014	Supraselective arteriography of the spinal cord, by transcutaneous arterial access	60	N.S.	N.S.
Biliary duct				
HMQH003	Retrograde cholangiography with infundibulectomy [punctal diathermy of the gall bladder infundibulum] or pre-cutting of the major duodenal papilla, by oesophago-gastro-duodenoscopy	1.6	0.03	0.04
HMQH004	Cholangiography, by transcutaneous injection of a contrast medium in bile ducts, with ultrasound and/or radiological guidance	1.6	0.04	0.07
HMQH005	Retrograde cholangiopancreatography without sphincter of Oddi manometry, by oesophago-gastro-duodenoscopy	1.6	N.S.	N.S.
HMQH006	Cholangiography, by injecting a contrast medium in an external biliary tube	1.6	0.12	0.20
HMQH007	Retrograde cholangiography, by oesophago-gastro-duodenoscopy	1.6	0.19	0.31
HNQH001	Retrograde pancreatography with use of a minor duodenal papilla [accessory papilla] catheter technique, by oesophago-gastro-duodenoscopy	1.6	N.S.	N.S.
HNQH003	Retrograde pancreatography with use of a major duodenal papilla catheter technique, by oesophago-gastro-duodenoscopy	1.6	N.S.	N.S.
Vascular				
DGQH001	General arteriography of the abdominal aorta and lower limbs, by transcutaneous arterial access	12	0.20	2.46
DGQH002	General arteriography of the abdominal aorta, by transcutaneous arterial access	12	0.09	1.02
DGQH003	Arteriography of the abdominal aorta and lower limbs, by lumbar transcutaneous intro-aortic injection	12	N.S.	N.S.
DGQH004	Arteriography of the aorta and its branches, by transcutaneous intravenous injection	5	N.S.	N.S.
DGQH005	General arteriography of the thoracic and abdominal aorta, by transcutaneous arterial access	12	N.S.	N.S.
DGQH006	General arteriography of the thoracic aorta, by transcutaneous arterial access	5	0.10	0.50
DGQH007	General arteriography of the arterial aorta and its cervicocephalic branches [aortic arch, by transcutaneous arterial access	5	0.05	0.27
DHQH001	Selective phlebography of several branches of the common iliac vein and/or the inferior vena cava, by transcutaneous venous access	12	N.S.	N.S.
DHQH002	Phlebography of the inferior vena cava [inferior caval venography], by transcutaneous venous access	12	N.S.	N.S.
DHQH003	Phlebography of the superior vena cava [superior caval venography], by transcutaneous intravenous injection	5	0.07	0.36
DHQH004	Selective phlebography of one branch of the common iliac vein or the inferior vena cava, by transcutaneous venous access	12	N.S.	N.S.
DHQH005	Phlebography of iliac veins and inferior vena cava [Iliac venography], by unilateral or bilateral femoral transcutaneous intravenous injection	12	N.S.	N.S.
DHQH006	General phlebography of the superior vena cava [superior caval venography], by transcutaneous venous access	5	0.03	0.15
DHQH007	Hyperselective phlebography of one branch of the common iliac vein or the inferior vena cava, by transcutaneous venous access	12	0.05	0.55
ECQH001	Bilateral arteriography of the upper limb by arterial access or transcutaneous intra-arterial injection, with positional manoeuvres	8	N.S.	N.S.
ECQH002	Supraselective arteriography of the upper limb, by transcutaneous arterial access	8	N.S.	N.S.
ECQH005	Hyperselective or selective arteriography of the upper limb, by transcutaneous arterial access	8	N.S.	N.S.
ECQH006	Arteriography of the upper limb by transcutaneous intra-arterial injection, without positional manoeuvres	8	N.S.	N.S.
ECQH007	Bilateral arteriography of the hand, by transcutaneous intra-arterial injection	8	N.S.	N.S.
ECQH015	Selective or hyperselective arteriography of the parietal and/or visceral internal thoracic artery, by transcutaneous arterial access	5	N.S.	N.S.
ECQH016	Supraselective arteriography of the parietal and/or visceral internal thoracic artery, by transcutaneous arterial access	5	N.S.	N.S.

Table XXI cont.

Effective dose per procedure, frequency of procedures and contribution to the mean per caput annual dose for CCAM codes for diagnostic interventional radiology.

CCAM code	Description of the procedure	E / proc. (mSv)	Freq of proc (/1,000 indiv.)	E_{mean} / indiv. (µSv)
EDQH001	Supraselective arteriography of an extra-intestinal branch of the abdominal aorta or internal iliac artery branch, by transcutaneous arterial access	12	N.S.	N.S.
EDQH003	Hyperselective or selective arteriography of an extra-intestinal branch of the abdominal aorta or internal iliac artery branch, by transcutaneous arterial access	12	N.S.	N.S.
EDQH005	Hyperselective and/or selective arteriography of several extra-intestinal branches of the abdominal aorta or several internal iliac artery branches, by transcutaneous arterial access	12	0.04	0.44
EDQH006	Hyperselective and/or selective arteriography of several intestinal branches of the abdominal aorta, by transcutaneous arterial access	12	0.03	0.31
EDQH007	Supraselective arteriography of the intestinal branch of the abdominal aorta, by transcutaneous arterial access	12	N.S.	N.S.
EDQH008	Hyperselective and/or selective arteriography of an intestinal branch of the abdominal aorta, by transcutaneous arterial access	12	N.S.	N.S.
EEQH001	Bilateral arteriography of the lower limb, by bilateral transcutaneous femoral intra-arterial injection	8	N.S.	N.S.
EEQH002	Hyperselective or selective arteriography of the lower limb, by transcutaneous arterial access	8	0.04	0.35
EEQH003	Arteriography of the food, by intra-arterial injection or transcutaneous arterial access	8	N.S.	N.S.
EEQH004	Supraselective arteriography of the lower limb, by transcutaneous arterial access	8	N.S.	N.S.
EEQH005	General arteriography of the lower limb, by transcutaneous arterial access	8	0.04	0.33
EEQH006	Unilateral arteriography of the lower limb, by transcutaneous femoral intra-arterial injection	8	0.08	0.61
EFQH001	Selective phlebography of the upper limb by transcutaneous venous access, with no study of the proximal veins	8	N.S.	N.S.
EFQH002	Selective phlebography of one branch of the brachiocephalic vein or the superior vena cava, by transcutaneous venous access	5	N.S.	N.S.
EFQH003	Bilateral phlebography of the upper limb by transcutaneous intravenous injection, with study of proximal veins and the superior vena cava	8	0.03	0.20
EFQH005	Unilateral phlebography of the upper limb by intravenous injection or transcutaneous venous access, with study of proximal veins and the superior vena cava	8	N.S.	N.S.
EFQH006	Unilateral phlebography of the upper limb by transcutaneous intravenous injection, with no study of the proximal veins	8	N.S.	N.S.
EFQH007	Hyperselective phlebography of one branch of the brachiocephalic vein or the superior vena cava, by transcutaneous venous access	5	N.S.	N.S.
EHQH001	Selective phlebography of a hepatic vein, by transcutaneous venous access	12	N.S.	N.S.
EJQH001	Varicography of the lower limb, by transcutaneous intravenous injection	8	N.S.	N.S.
EJQH003	Retrograde phlebography of the lower limb by ipsilateral femoral transcutaneous intravenous injection or by contralateral femoral venous access	8	N.S.	N.S.
EJQH004	Bilateral phlebography of the lower limb, by transcutaneous intravenous injection in the foot	8	N.S.	N.S.
EJQH006	Unilateral phlebography of the lower limb, by transcutaneous intravenous injection in the foot	8	N.S.	N.S.
EKQH002	Angiography of arteriovenous vascular access of an upper limb with exploration of the proximal deep veins and the superior vena cava, by transcutaneous intravascular injection	5	0.13	0.67
EZMH001	Secondary radiological examination of the permeability and/or the position of a vascular access device or a vascular endoprosthesis, by injecting a contrast medium	0.1	0.24	0.02
EZQH002	Angiography of arteriovenous vascular access in a limb, by transcutaneous vascular access	8	N.S.	N.S.
EZQH003	Angiography of arteriovenous vascular access in a limb, by transcutaneous intravascular injection	8	N.S.	N.S.
YYYY024	Full radiological assessment of the lower limbs for complex venous pathologies requiring several types of access, use of tourniquets if necessary and imaging in various positions	8	N.S.	N.S.

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Service d’études et d’expertise en radioprotection

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