REPORT

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INSTITUT
DE RADIOPROTECTION
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Enhancing nuclear safety

Exposure of children to ionising radiation due to diagnostic medical imaging procedures performed in France in 2015

2015 ExPRI Paediatric Study

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Health and Environment Unit

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Résumé

Ce rapport a pour objectif d'établir pour l'année 2015 les données relatives à l'exposition des enfants de moins de 16 ans aux examens d'imagerie médicale diagnostique utilisant les rayonnements ionisants (radiologie conventionnelle, dentaire et interventionnelle diagnostique, scanographie et médecine nucléaire). L'étude a été réalisée à partir des actes d'imagerie diagnostique extraits de l'échantillon généraliste des bénéficiaires de l'Assurance maladie, représentatif au 1/97ème de la population française.

Environ 604 actes diagnostiques pour 1000 enfants ont été réalisés en 2015, chiffre en relative stabilité (+1,5 %) par rapport à l'année 2010. La proportion d'enfants ayant bénéficié d'au moins un acte diagnostique atteint 31 %, en hausse de 2 points. La dose efficace annuelle moyenne s'élève à 0,135 mSv par enfant, exposé ou non, en baisse de 25 % par rapport à l'année 2010, tandis que la dose efficace moyenne par enfant exposé atteint la valeur de 0,43 mSv, en baisse de 34 %. L'exposition est extrêmement hétérogène puisque la moitié des enfants exposés a reçu une dose efficace annuelle cumulée inférieure ou égale à 0,02 mSv. Les enfants âgés de moins de 1 an sont, en proportion de l'effectif exposé de leur classe d'âge, la catégorie la plus exposée, avec une dose efficace annuelle médiane de 0,55 mSv.

L'exposition des enfants aux rayonnements ionisants due aux actes d'imagerie médicale diagnostique a très sensiblement diminuée entre 2010 et 2015 en France et cela alors que la fréquence moyenne de ces actes est restée relativement stable sur la même période. Cette baisse de l'exposition est donc exclusivement due à la diminution globale des doses moyennes par acte d'imagerie médicale, liée à l'amélioration des techniques et des pratiques.

Abstract

The purpose of this report is to establish data for the year 2015 on the exposure of French children aged under 16 years to diagnostic medical imaging procedures involving ionising radiation (conventional and dental radiology, diagnostic interventional radiology, computed tomography and nuclear medicine). The study was conducted using 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.

Around 604 diagnostic procedures per 1000 children were performed in 2015, a near stable figure (+1.5%) compared to the year 2010. The proportion of children who had at least one diagnostic procedure was 31%, up by 2 points from 2010. The annual mean effective dose is 0.135 mSv per child, exposed or not, down 25% from 2010, while the mean effective dose per exposed child is 0.43 mSv, down 34% from 2010. Exposure is extremely varied among exposed children, since half of them received a cumulative annual effective dose of 0.02 mSv or less. Relative to the number of children exposed in their age group, children aged under 1 year are the most highly exposed category, with a median annual effective dose of 0.55 mSv.

Children's exposure to ionising radiation originating from diagnostic medical imaging procedures decreased markedly in France between 2010 and 2015, even though the mean frequency of these procedures remained nearly stable over the same time period. This reduction in exposure is therefore due solely to an overall decrease in the mean dose per medical imaging procedure, which is related to improvements in technologies and practices.

Glossary

ASP	Abdominal X-ray without preparation
ATIH	French Technical Agency for Information on Hospitalisation
CCAM	Common Classification of Medical Procedures
ICRP	International Commission on Radiological Protection
CNAM	French national health insurance scheme
EGB	Representative sample of the French population protected by health insurance
FDG	Fluorodeoxyglucose
HAS	French national health authority
MSA	Social security scheme for agricultural workers
NIR	National registration number (social security number)
DRL	Diagnostic reference level
PMSI	Diagnosis categorisation system for calculating hospital treatment costs
RSI	Social security scheme for the self-employed
SFIPP	French-speaking society for paediatric and prenatal imaging
SFR	French radiology society
SLM	Social security scheme for public sector workers
SNIIRAM	National information system for health insurance schemes
T2A	Activity-based funding system for French hospitals
PET	Positron emission tomography

1 INTRODUCTION

Medical imaging, though undeniably beneficial in patient treatment, is the main contributor to the French population's exposure to ionising radiation of artificial origin [1]. It is therefore important to characterise this medical exposure regularly, as required by the European Union since 1997 [2]. This requirement was reinforced in 2013 by European Directive 2013/59/Euratom [3], which was recently transposed into French law. Article R1333-67 of the French Public Health Code, as amended by decree on 4 June 2018, stipulates that *"The mean exposure of the population to ionising radiation by imaging modality, anatomical area, age and sex, linked to medical diagnostic procedures, shall be estimated and analysed periodically by the Institute for Radiological Protection and Nuclear Safety (IRSN) and shall be the subject of a public report that can be consulted on IRSN's website."*

This has been done by IRSN since 2003, when it took part with InVS, the French Institute for Public Health Surveillance (now part of Santé Publique, the French public health agency) in setting up the national ExPRI (Exposure of the Population to Ionising Radiation) system, which is designed to provide the authorities and professionals with up-to-date data for exposure of the French population to diagnostic medical imaging procedures. Since 2012 the ExPRI system has been entirely the responsibility of IRSN. Three reports have been produced on exposure of the French population, at five-year intervals (2002, 2007 and 2012) [4]-[6]. In 2015 IRSN brought together a team of experts consisting of representatives of the competent authorities and of relevant learned societies and professional bodies. Among other things, the committee recommended repeating the special study of exposure of the paediatric population in 2010 because of the particular radiosensitivity and long life expectancy of this section of the population [7].

This report aims to establish data for 2015 on the medical exposure of France's paediatric population due to diagnostic imaging. First of all it discusses the methods used to select the diagnostic imaging procedures and to estimate their frequency of use and the doses associated with them. The results are then presented by imaging modality, by anatomical area investigated, by type of procedure and by type of healthcare establishment, for the whole paediatric population. All the results are characterised by the age and sex of the individuals. Finally, the results are compared with international data.

2 SELECTION OF THE TYPES OF PROCEDURE AND DETERMINATION OF THEIR FREQUENCY

The exposure of children to ionising radiation linked to diagnostic imaging procedures in France is studied, for 2015, using the following indicators:

- the frequency of each type of diagnostic imaging procedure using ionising radiation in 2015 for children aged under 16 years on the date of the procedure;
- the share of the population of children actually exposed in 2015, i.e. who underwent at least one diagnostic imaging procedure using ionising radiation during the year;
- the contribution of each type of procedure to the mean effective dose per child, for the whole paediatric population;
- the annual effective dose received by the children actually exposed in 2015.

2.1 Selection of diagnostic imaging procedures for the study

Only imaging procedures that use ionising radiation for diagnostic purposes are included, i.e.:

- conventional radiology procedures, including dental radiology;
- computed tomography procedures (CT scans);
- nuclear medicine procedures for diagnostic purposes;
- interventional radiology procedures for diagnostic purposes[1].

These procedures are referred to as "diagnostic procedures" in the rest of this report.

2.1.1 Identification of procedures: the Common Classification of Medical Procedures (CCAM)

The CCAM is a unique system of reference codes for all technical medical procedures covered by health insurance in France. It is used nationally and its use has been mandatory since 31 December 2005 by all general practitioners and medical specialists working either in the outpatient sector (local doctors' surgeries and health clinics) or in public or private hospitals (inpatient stays and outpatient consultations). The codes are used for activity pricing and description.

With the CCAM, diagnostic procedures can be unambiguously distinguished from one another. Each type of procedure is identified by a full description and a code consisting of four letters and three numbers. For example, the CCAM code ZBQK002 corresponds to the description "Chest X-ray". For the requirements of this study, a keyword search was carried out on version 49 of the CCAM: 632 different codes were found. Having eliminated therapeutic procedures, biopsies and ex-vivo examinations, 401 codes were retained, including 24 new codes that were not covered in the study for 2010 [7].

The use of the codes in the CCAM nomenclature by dental surgeons, which did not apply at the time of the 2010 study, was becoming widespread in 2015. Consequently, only some dental X-rays are associated with a CCAM code. The rest can still be identified using a particular service reference (see section 2.2.3 for more details).

[1] Radioguided biopsies are not included in this study because representative dosimetric data are rare for these procedures that are highly dependent on the operator's skill as well as on the complexity of the intervention.

2.1.2 Grouping of procedures

The procedures selected for this study were grouped for analysis in two ways:

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

b. **By anatomical area explored**: the anatomical areas defined in the report are based on radiation protection criteria, i.e. by looking at the organs situated within the radiation field, using the methodology recommended by European Radiation Protection Report 154 [8]. For example, X-rays of the lumbar spine are grouped in the anatomical area "abdomen". In the study, some of the anatomical areas rarely explored in children have been grouped together: procedures concerning the digestive system are included in the *head and neck*, *chest* or *abdomen-pelvis* areas, depending on the organ concerned; those concerning the genitourinary system are grouped into the *abdomen-pelvis* area. Conversely, procedures concerning the pelvic girdle are grouped in a specific area, because of their particular importance in paediatric radiology. Similarly, procedures concerning a section of the spine are included in the areas *head and neck*, *chest* or *abdomen-pelvis* areas, depending on the part of the spinal column being studied, whereas those concerning the whole spine have their own special category. In dental radiology, procedures are grouped into two categories, which are not strictly anatomical areas. The *extraoral* category includes procedures where the image receptor is outside the patient's mouth (panoramic X-ray, cone-beam CT, cephalometric projection), whereas the *intraoral* category includes procedures where the image receptor is inside the patient's mouth (periapical, bitewing and occlusal X-rays).

Table I: Anatomical areas associated with each imaging modality and number of CCAM codes actually used.

Imaging modality *Anatomical area*	Number of CCAM codes
Conventional radiology	**93**
Head and neck	*8*
Chest	*13*
Abdomen and pelvis	*16*
Pelvic girdle	*10*
Whole spine	*4*
Limbs	*31*
Other	*11*
Dental radiology	**22**
Extraoral	*5*
Intraoral	*17*
Computed tomography	**37**
Head and neck	*13*
Chest and heart	*4*
Abdomen and pelvis	*5*
Spine	*4*
Limbs	*9*
Trunk	*2*
Nuclear medicine	**27**
Head and neck	*3*
Chest and heart	*4*
Abdomen and pelvis	*10*
Whole body	*7*
Other	*3*
Diag. interventional radiology	**9**
Cardiac	*1*
Vascular	*8*
All modalities	**188**

Table I lists the anatomical areas taken into account for each imaging modality, and the number of CCAM codes used for this study (i.e. the codes covering at least one procedure for the sample population in question). A full list of the CCAM codes included in this study is given in Appendix 1.

2.2 Estimation of the frequency of diagnostic imaging procedures

The frequency of procedures for the "Whole of France" paediatric population was estimated for this study on the basis of the observed frequency for the paediatric population in SNIIRAM's EGB sample, the database of anonymised data managed by CNAM containing billing information for healthcare procedures.

2.2.1 EGB sample

The SNIIRAM order of 20 June 2005 authorised the creation of a national representative sample of 1/97th of all health insurance scheme beneficiaries (general scheme excluding the SLM public sector schemes). This sample is known as the *Échantillon Généraliste des Bénéficiaires* or EGB sample. It is a permanent sample of beneficiaries and it links their administrative and sociodemographic characteristics to their healthcare "consumption" over time (this consumption may be zero). A study published in 2009 by Roquefeuil *et al.* [9] demonstrated the EGB sample's internal validity, i.e. the sample's representativeness and lack of bias in respect of the population protected by the general health insurance scheme (excluding the SLM schemes) and the reimbursed healthcare consumption of this population:

- the sex and age distribution of the EGB sample is very similar to that of the population as a whole;
- the mean reimbursed expenditure per EGB sample beneficiary who underwent at least one healthcare procedure during the year of study (2007) is very similar to that of the population as a whole.

After that study was carried out, the EGB was extended in 2011 to beneficiaries of the MSA (agricultural) insurance scheme and the RSI (self-employed) insurance scheme, and then in 2015 to the beneficiaries of 10 SLM (public sector) schemes. It therefore represents 94.5% of the population covered by a social security scheme in France and will eventually encompass all French social security schemes. Its representativeness has therefore been improved since the study by Roquefeuil *et al.* The results in this report, calculated on the basis of the paediatric population in the EGB sample for 2015, can therefore be extrapolated to the whole population of France with a high degree of confidence.

The EGB sample data is accessed via a secure Internet portal run by CNAMTS. Since the end of 2016, IRSN has had permanent access by decree for the purposes of its public service missions, particularly the preparation of this report [10].

Approximately 120,000 beneficiaries born between 2000 and 2015 were included in the EGB sample in 2015, regardless of whether they were "consumers" or "non-consumers" of healthcare during that period[2]. In particular, in the field of interest of this study, these beneficiaries may have undergone one or more diagnostic procedures, or none at all in the year 2015. The composition of the EGB sample in 2015 for beneficiaries born from 2000 onwards is presented in Table II. The population was studied by in 5-year age ranges (or by year where the number of procedures was sufficiently high), in accordance with the recommendations of European Radiation Protection Report 154 [8], with a special class for infants aged under one year because of the particular morbidity of this age group.

[2] In this study, the population of the 2015 EGB sample is calculated only with the beneficiaries of the general healthcare scheme, the agricultural scheme and the self-employed scheme. The beneficiaries of the 10 SLM schemes were incorporated during the year, but their past history was not included so their healthcare consumption does not cover 12 months in 2015. Taking them into account would therefore have introduced bias into the study.

Table II: Number of beneficiaries[2] in the 2015 EGB sample by year of birth between 2000 and 2015

	Year of birth				Total
	2015	2010-2014	2005-2009	2000-2004	
Boys	3 362	19 683	19 932	19 203	**62 180**
Girls	3 161	18 790	19 031	18 275	**59 257**
Total	**6 523**	**38 473**	**38 963**	**37 478**	**121 437**

2.2.2 Procedure count

The healthcare consumption of each beneficiary is periodically fed into the EGB sample from SNIIRAM's billing data. Since June 2011, SNIIRAM has had reimbursement data for healthcare services (non-hospital healthcare) and data from public and private hospitals, thanks to the inclusion of additional data from the PMSI programme (diagnosis categorisation system for calculating hospital treatment costs) run by ATIH, the French Technical Agency for Information on Hospitalisation. The CCAM is used to code the procedures performed. Each beneficiary included in the EGB sample is identified by their encrypted NIR number[3], so it is possible to reconstruct healthcare pathways while maintaining patient anonymity, regardless of whether the care was received in the private or public sector, or at home, at a clinic or in hospital. The EGB sample therefore enables all diagnostic procedures on the sample's beneficiaries to be counted.

Compared to the study for 2010 [7], the representativeness of the SNIIRAM data available in 2015 has improved in several respects:

– The PMSI data for public hospitals is much more comprehensive. The T2A system (activity-based funding system for French hospitals), introduced in 2004 and gradually expanded since then, is now almost the only funding method for medicine, surgery, obstetrics and dentistry at both public and private establishments. All imaging carried out at these establishments therefore appears in the PMSI and it can therefore be considered in 2015 to give a practically exhaustive picture of hospital activity.

– The inclusion of the beneficiaries of the agricultural and self-employed schemes makes the EGB sample more representative of the diversity of the French population's health habits. This representativeness will be further improved in future studies by the inclusion of a large number of SLMs, including the student healthcare schemes.

– Many private dental healthcare services are associated with CCAM codes, enabling a more detailed description of this activity.

The data extracted from the EGB sample for this study can therefore be considered comprehensive enough to describe population exposure linked to diagnostic procedures performed in the private sector or during stays or outpatient treatment at public hospitals. Nevertheless, because the EGB is a 1/97th sample of the population, there may be only very tiny numbers of some uncommon procedures for children, such as interventional radiology, nuclear medicine, and to a lesser extent computed tomography. Extrapolation to the whole population becomes statistically problematic in these cases.

[3] National registration number of physical persons, usually referred to as their social security number. It is unique to each beneficiary.

2.2.3 Extraction of parameters of interest for the study

Queries were made via the SAS Enterprise Guide 7.1 software to the SNIIRAM and PMSI databases to extract all diagnostic procedures in the EGB sample carried out between 1 January and 31 December 2015 on children aged under 16 years at the time of the procedure. In practice, because the beneficiary's date of birth is not available in the EGB sample, to prevent re-identification, the beneficiary's age at the time of the diagnostic procedure is calculated to the nearest month and rounded up, so a child born in February 2014 who underwent a procedure in February 2015 is considered to be aged 12 months at the time of the examination, though their real age could be 11 or 12 months depending on whether the examination date was before or after their birthday. The diagnostic procedures extracted include:

- procedures performed in the private sector, i.e. by "*practitioners working in private practice*", "*full-time hospital practitioners working privately*", and "*practitioners working as employees in a private establishment*", which therefore includes procedures performed in doctor's surgeries and private clinics, including dental care with a CCAM code;
- procedures performed during hospital stays in public establishments;
- procedures performed as outpatient treatments in public healthcare establishments;
- procedures performed by dental surgeons in the private sector without a CCAM code.

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

- the demographic characteristics of the beneficiary: encrypted NIR, sex, month and year of birth;
- the characteristics of the procedure:
  - reference service type[4],
  - healthcare sector (private, dental without CCAM code, public sector inpatient and outpatient),
  - CCAM code and procedure description, for all procedures except some dental radiology,
  - month and year performed.

The analysis looked at:

- the frequency of performance in 2015 of each of these types of diagnostic procedure, for children aged 0 to 15 years, according to the two groups defined (imaging modalities and anatomical areas examined), and according to the age and sex of the beneficiaries;
- the distribution of imaging procedures between the public and private sectors;
- the share of the population of children actually exposed in 2015, i.e. who underwent at least one procedure during the year, characterised by age and sex.

Finally, the exposure of children given at least one pelvic X-ray before they were 6 months old in 2015 was also studied. This is because the ongoing use of this type of X-ray on very young children, against the recommendations of the French

[4] The reference service type is a variable defining the type of healthcare service in SNIIRAM, for procedures performed privately. There are 10 values of this variable that are associated with radiology procedures. In practice only 4 codes returned a non-zero number of procedures (listed by decreasing number of procedures): 1351 (CCAM imaging procedures [excluding ultrasound]), 1331 (X-rays), 9423 (oral disease prevention – 4 X-ray plates) et 9422 (oral disease prevention – 2 X-ray plates). Code 1351 is used for all radiology procedures with CCAM codes, including dentistry procedures. Codes 1331, 9422 and 9423 are used solely for dental radiology procedures without CCAM codes.

national health authority (HAS) [11], is of particular interest to the French-speaking society for paediatric and prenatal imaging (SFIPP).

3 ESTIMATION OF THE DOSES ASSOCIATED WITH DIAGNOSTIC IMAGING PROCEDURES

3.1 Dosimetric indicator: effective dose

In accordance with the recommendations of European Radiation Protection Reports°154 [8] and 180 [12], the dosimetric indicator used in this study to assess the exposure of children to ionising radiation linked to diagnostic procedures is the effective dose (expressed in millisieverts, mSv). Effective dose is an indicator of the risk of long-term damage to health (potential to cause cancers and hereditary effects) linked to exposure to ionising radiation. This indicator is used to assess the overall risk for the whole body, regardless of whether or not the whole body was exposed, taking account of the type of radiation (type and energy), and the radiosensitivity of each organ exposed [13]. Because it is calculated using weighting factors defined for the general population, all ages and sexes combined, **the effective dose should not be used to give an absolute quantification of the risk for a specific population such as the paediatric population, or of course for estimating the risk to an individual.** However, it can be used to compare the relative radiological risks associated with the imaging of different anatomical areas or the risks associated with different imaging modalities used for the same examination. As a standardised indicator, it can also be used for comparisons between different countries and for studying how the exposure resulting from a particular procedure changes over time.

The effective doses were calculated using the tissue weighting factors defined in International Commission on Radiological Protection (ICRP) Publication 103 [13]. The annual individual effective dose is obtained by adding together the effective doses associated with the different procedures performed on a single patient during the period of interest.

3.2 Estimation of the mean effective doses associated with each type of procedure

Various different sources of available data have been used to associate a mean effective dose with each type of procedure:

- the data sent to IRSN by all imaging services for the update of the radiology and nuclear medicine diagnostic reference levels [14], [15];
- procedure guides prepared by professionals, radiologists, nuclear medicine doctors and dental surgeons [16]-[18];
- dosimetric studies performed by IRSN or professional bodies in France [19]-[23];
- private communications with professionals [24].

These data are considered to be representative of French practice in radiology and nuclear medicine in 2015. The mean effective doses by procedure type for 2015 are presented in Appendix 1, categorised by imaging modality, anatomical area and CCAM code. The doses by procedure type have fallen overall compared to 2010, in line with the reduction in dosimetric indicators already identified in IRSN's report published in 2016 analysing data related to the update of the DRLs [15].

It is important to remember that the mean effective doses used for each procedure are for examinations of adults. Paediatric data are relatively rare in the literature, so it is very difficult to estimate exhaustively the doses for all the diagnostic procedures in this study. Moreover, the data that are available are heavily dependent on children's body size, and therefore their age. Additionally, even in cases where exposure parameters specific to children are available, the small physical stature of children means that there is less radiation attenuation and that the organ doses received are therefore not necessarily lower than for adults. Finally, as explained in section 3.1 above, the tissue weighting factors in ICPR Publication 103 are for the general population, which means that they should not be used to estimate the risk for a specific population. Because the study is not a risk study but only a study to characterise the exposure of the paediatric population for national and international comparison purposes, it is therefore better to use the effective doses calculated for adults, as recommended by European Radiation Protection Report 154 [8] and ICRP Publication 103 [13, Paragr. 340], and as the previous study [7] did.

3.3 Uncertainty of the effective dose values

The main sources of uncertainty when it comes to estimating the mean effective dose by type of procedure were described and discussed in the report for 2010 [7]. They concern:

- the national dispersion of effective doses delivered for a given type of procedure;
- inconsistencies that can persist for certain types of procedure between actual clinical practice and the CCAM classification;
- the rarity of certain types of procedure, which affects the reliability of their dosimetric assessment.

European Radiation Protection Report 180 [12] estimated the uncertainty of the mean effective doses per procedure calculated by each of the countries that took part in the Dose Datamed 2 study. The mean uncertainty of this estimate, based on the method proposed by Hart and Wall [25], is in the range 20-40% for all the procedures being looked at.

The uncertainty for the calculation of the annual mean effective doses per child is mainly due to the uncertainty for the mean effective doses per procedure, which in this type of study is much higher than the uncertainty for the frequency of the procedures or the population count. European Radiation Protection Report 180 [12] considers that the uncertainty of the estimates for population dose is between 12% and 25% depending on whether the mean effective doses by type of procedure are calculated on the basis of real clinical practice or are estimated from the literature. Because the mean effective doses by type of procedure in this study are partly calculated on the basis of real data (DRL survey or specific studies) and partly extrapolated from the literature, the uncertainty of the annual mean effective doses per child calculated in this study should fall within this range.

Summary

The 2015 ExPRI Paediatric Study was conducted on the EGB sample, which represents 1/97th of the French population protected by the CNAM general health insurance scheme, the self-employed scheme and the agricultural scheme. All diagnostic imaging procedures using ionising radiation (conventional radiology, dental radiology and diagnostic interventional radiology, computed tomography and nuclear medicine), performed in 2015 on children aged under 16 years at the time of the procedure, were taken into account. The frequency of performance of the procedures was determined for the public and private sectors and was studied on the basis of the child's age and sex. The mean effective doses associated with each type of procedure were determined and were used to calculate the annual mean effective dose per child. The share of the population of children actually exposed, i.e. who underwent at least one procedure during the year, was characterised by age and sex. The number of procedures and the annual individual effective dose were calculated for the population of children actually exposed.

4 EXPOSURE OF THE WHOLE PAEDIATRIC POPULATION IN 2015

This chapter describes the results of the study concerning the whole paediatric population studied, regardless of whether or not a child underwent a diagnostic procedure. The results are given in the form of frequency of performance, i.e. the number of procedures per 1000 children in the population studied, and in the form of an annual mean effective dose per child. Where the information available for the study permits, the main results are interpreted.

A total of 73,325 diagnostic procedures were performed during 2015 on children in the EGB sample aged under 16 years. When related to the 121,437 children in the EGB sample born between 2000 and 2015, that represents a **mean of 604 procedures per 1000 children**. The mean effective dose per child in the EGB sample due to diagnostic procedures carried out during 2015 is **0.135 mSv per child**. This mean can be extrapolated to the whole paediatric population of France. It therefore provides an indicator of the exposure of French children to ionising radiation of medical origin (excluding therapeutic uses). However, the real exposure of children is extremely diverse because only a fraction of the children in the sample underwent one or more diagnostic procedures in 2015. This population of children actually exposed will be studied in chapter 0.

4.1 Distribution of exposure by imaging modality

Figure 1 presents by imaging modality the frequencies of performance of procedures and the distribution of the associated total effective dose for all ages and sexes combined.

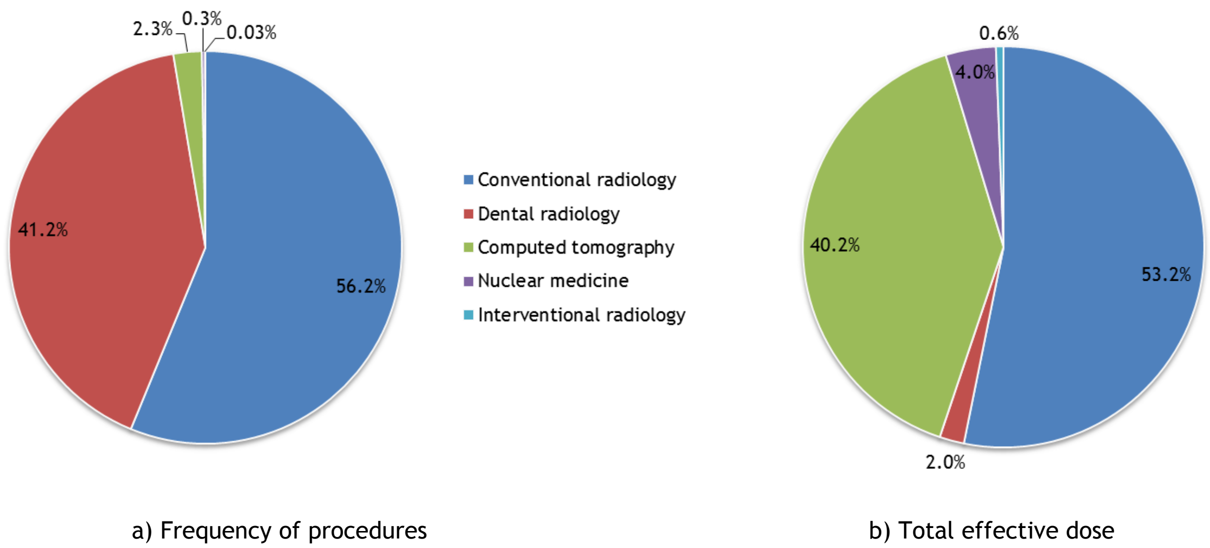

Figure 1. Distribution by imaging modality of diagnostic procedures and of the associated effective dose.

Conventional radiology accounts for both the majority of procedures performed and the majority of the total effective dose. Dental radiology is the second largest contributor in terms of frequency of procedures but only the fourth largest for total effective dose. Conversely, computed tomography is the third most frequent modality, a long way behind dental radiology, but is in second place for effective dose with a contribution of more than 40%. Nuclear medicine and diagnostic interventional radiology procedures are infrequent and contribute little to the overall dose of the paediatric population.

4.1.1 Frequency of procedures by imaging modality according to the child's age and sex

The frequencies of procedures vary according to the child's age and, to a lesser extent, sex. Table III shows the frequencies of procedures by age range and sex, calculated per 1000 children in each age range.

Table III. Frequency of procedures by age range according to imaging modality (number of procedures per 1000 children in the age range in question)

Imaging modality	< 1 year	1 to 5 yrs	6 to 10 yrs	11 to 15 yrs	All ages
Sex	/1000 child. (%)	/1000 child. (%)	/1000 child. (%)	/1000 child. (%)	/1000 child. (%)
Conventional radiology	**521 (95.8%)**	**214 (85.5%)**	**288 (48.9%)**	**490 (49.3%)**	**339 (56.2%)**
Boys	*562 (95.1%)*	*224 (85.2%)*	*272 (48.4%)*	*501 (51.6%)*	*343 (57.6%)*
Girls	*476 (96.8%)*	*204 (85.9%)*	*305 (49.5%)*	*478 (47%)*	*336 (54.7%)*
Dental radiology	**0.5 (0.1%)**	**26.7 (10.7%)**	**289 (49.1%)**	**478 (48.1%)**	**249 (41.2%)**
Boys	*0.3 (0.1%)*	*28.8 (11%)*	*278 (49.6%)*	*444 (45.7%)*	*235 (39.6%)*
Girls	*0.6 (0.1%)*	*24.6 (10.4%)*	*300 (48.6%)*	*514 (50.5%)*	*262 (42.8%)*
Computed tomography	**17 (3.2%)**	**7.6 (3.1%)**	**11 (1.8%)**	**24 (2.4%)**	**14 (2.3%)**
Boys	*22 (3.7%)*	*8.2 (3.1%)*	*11 (1.9%)*	*25 (2.5%)*	*15 (2.5%)*
Girls	*12 (2.5%)*	*7.0 (3%)*	*11 (1.7%)*	*23 (2.2%)*	*13 (2.2%)*
Nuclear medicine	**3.4 (0.6%)**	**1.7 (0.7%)**	**0.8 (0.1%)**	**1.8 (0.2%)**	**1.5 (0.3%)**
Boys	*5.1 (0.9%)*	*1.5 (0.6%)*	*0.8 (0.1%)*	*1.6 (0.2%)*	*1.5 (0.3%)*
Girls	*1.6 (0.3%)*	*1.9 (0.8%)*	*0.9 (0.1%)*	*1.9 (0.2%)*	*1.6 (0.3%)*
Diag. interventional radiology	**1.5 (0.3%)**	**0.2 (0.1%)**	**0.1 (0%)**	**0.1 (0%)**	**0.2 (0%)**
Boys	*1.8 (0.3%)*	*0.3 (0.1%)*	*0.1 (0%)*	*0.1 (0%)*	*0.2 (0%)*
Girls	*1.3 (0.3%)*	*0.1 (0%)*	*0.2 (0%)*	*0.2 (0%)*	*0.2 (0%)*
All modalities	**543 (100%)**	**250 (100%)**	**588 (100%)**	**993 (100%)**	**604 (100%)**
Boys	*592 (100%)*	*262 (100%)*	*562 (100%)*	*971 (100%)*	*595 (100%)*
Girls	*492 (100%)*	*238 (100%)*	*616 (100%)*	*1017 (100%)*	*613 (100%)*

Large variations can be observed for different age ranges:

- Children aged 1 to 5 years have the lowest frequency of exposure to diagnostic procedures, at around 4 times less than children aged 11 to 15 years, who are the most frequently exposed with a frequency of nearly 1 procedure per child.
- Conventional radiology accounts for nearly 96% of diagnostic procedures performed on children aged under 1 year, which makes this age range the one most frequently exposed to this imaging modality.
- The conventional radiology and dental radiology proportions are equivalent for children aged 6 years and over.
- Girls are exposed slightly more often than boys (1.8%); this trend is enhanced in children aged over 6 years, mainly because of dental radiology. Conversely, girls aged under 6 years are less often exposed than boys aged under 6 years, particularly in the under 1 year age range, where the frequency of diagnostic procedures is 10% higher for boys, mainly due to conventional radiology. This difference between the sexes in very young children is probably linked to perinatal mortality, which in developed countries is 20% to 30% higher for boys than girls [26]. Indeed, it seems logical to consider that more common perinatal pathologies in small boys translate into a larger number of imaging procedures.

These trends can also be observed in Figure 2, which represents the frequency of procedures according to the child's age and the imaging modality for both sexes combined.

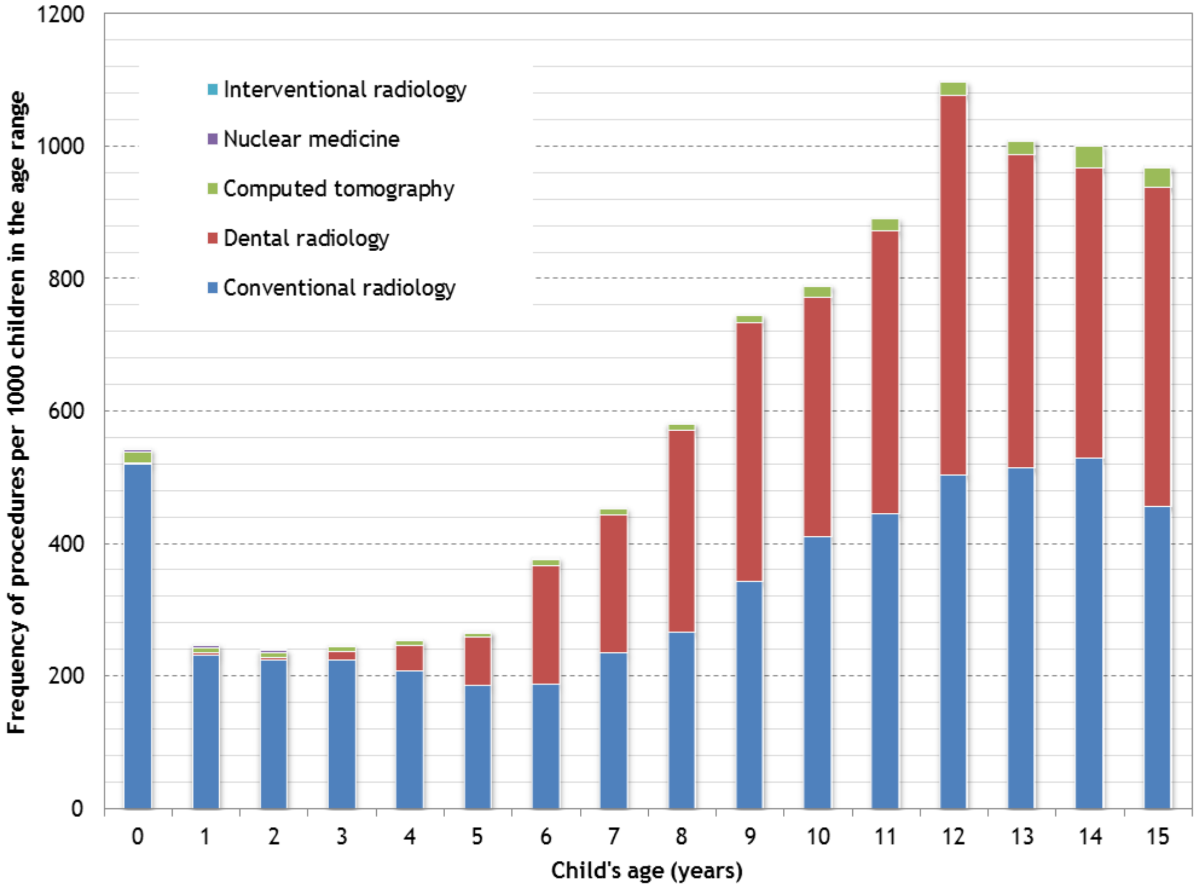

Figure 2. Frequency of procedures by imaging modality according to the child's age, both sexes combined.

It can be seen that:

- After the peak observed before the age of 1 year, the frequency of procedures is minimal and fairly stable from 1 to 5 years, with the conventional radiology proportion gradually decreasing in favour of dental radiology. From 6 years of age, the frequency of procedures gradually increases up to 12 years of age, where the maximum is reached with approximately 1100 procedures per 1000 children. It then declines slightly, stabilising at approximately 1 procedure per child aged 13 to 15 years.
- The proportions of conventional and dental radiology are almost the same from 6 years of age, except at 12 years of age when an increase in dental procedures produces the maximum observed in the frequency of procedures, for all modalities combined. This peak in procedures is probably related to the compulsory oral disease prevention examination required at 12 years of age by the Public Health Code [27].
- The proportion of computed tomography procedures varies between 1.3% and 3.5%, with maximum values observed in both the youngest children and the oldest.

– Nuclear medicine and even more so diagnostic interventional radiology only account for a significant share of the frequency of procedures in the youngest children.

4.1.2 Mean effective dose by imaging modality according to the child's age and sex

Table IV presents the mean effective dose per child and per imaging modality, by age range and sex.

Table IV. Annual mean effective dose per child by age range and imaging modality (µSv).

Imaging modality	< 1 year	1 to 5 yrs	6 to 10 yrs	11 to 15 yrs	All ages
Sex	µSv/child (%)	µSv/child (%)	µSv/child (%)	µSv/child (%)	µSv/child (%)
Conventional radiology	**220 (78.5%)**	**45 (57.6%)**	**47 (49.7%)**	**101 (47%)**	**72 (53%)**
Boys	*243 (75.9%)*	*44 (54.1%)*	*44 (46.5%)*	*86 (42.3%)*	*67 (49.7%)*
Girls	*196 (82.3%)*	*45 (61.7%)*	*50 (53%)*	*118 (51.4%)*	*77 (56.4%)*
Dental radiology	**-- (0%)**	**<1 (0.4%)**	**3 (3.3%)**	**5 (2.4%)**	**3 (2%)**
Boys	*-- (0%)*	*<1 (0.4%)*	*3 (3.2%)*	*5 (2.4%)*	*3 (1.9%)*
Girls	*-- (0%)*	*<1 (0.4%)*	*3 (3.4%)*	*6 (2.4%)*	*3 (2.1%)*
Computed tomography	**50 (17.6%)**	**27 (34.6%)**	**40 (42.6%)**	**101 (46.7%)**	**55 (40.4%)**
Boys	*63 (19.8%)*	*31 (38%)*	*44 (46.6%)*	*103 (50.5%)*	*59 (43.4%)*
Girls	*35 (14.5%)*	*23 (30.8%)*	*36 (38.4%)*	*99 (43.1%)*	*51 (37.3%)*
Nuclear medicine	**7 (2.6%)**	**5 (6.6%)**	**4 (3.9%)**	**8 (3.5%)**	**6 (4%)**
Boys	*12 (3.8%)*	*5 (6.3%)*	*3 (3.4%)*	*9 (4.4%)*	*6 (4.5%)*
Girls	*2 (0.8%)*	*5 (6.8%)*	*4 (4.3%)*	*6 (2.7%)*	*5 (3.6%)*
Diag. interventional radiology	**4 (1.3%)**	**<1 (0.8%)**	**<1 (0.5%)**	**<1 (0.4%)**	**<1 (0.6%)**
Boys	*2 (0.5%)*	*1 (1.3%)*	*<1 (0.3%)*	*<1 (0.4%)*	*<1 (0.6%)*
Girls	*6 (2.4%)*	*<1 (0.4%)*	*<1 (0.8%)*	*<1 (0.4%)*	*<1 (0.7%)*
All modalities	**280 (100%)**	**77 (100%)**	**94 (100%)**	**216 (100%)**	**136 (100%)**
Boys	*321 (100%)*	*80 (100%)*	*94 (100%)*	*203 (100%)*	*136 (100%)*
Girls	*238 (100%)*	*74 (100%)*	*94 (100%)*	*229 (100%)*	*137 (100%)*

The mean effective dose per child, regardless of sex or imaging modality but by the child's age, is presented in Figure 3.

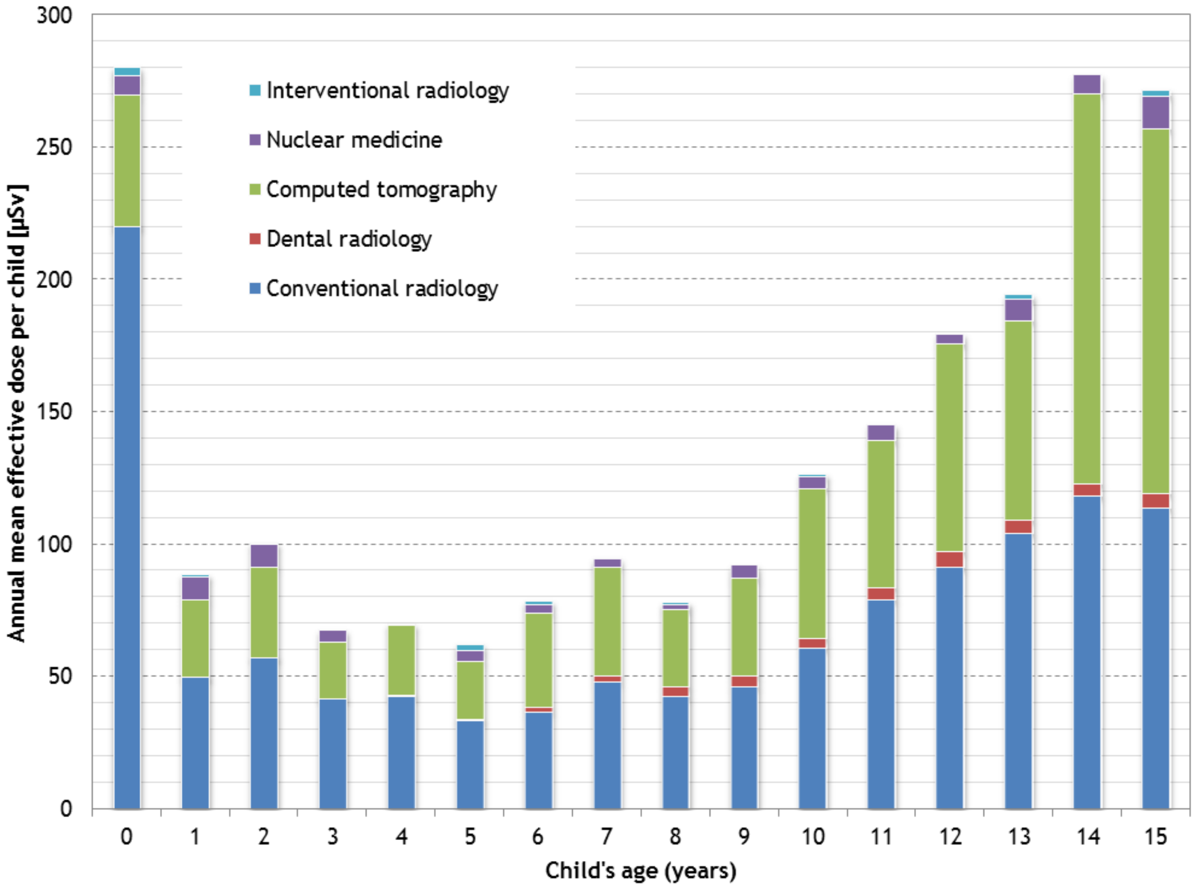

Figure 3. Annual mean effective dose per child in µSv by imaging modality and age, both sexes combined.

The large variations in the frequency of procedures based on the child's age are confirmed and amplified when assessing the annual mean effective dose:

– Children aged under 1 year and children aged 11 to 15 years have the highest annual mean effective dose, at 280 µSv per child for the former and 216 µSv for the latter (up to 270-275 µSv for children aged 14 and 15 years). Conventional radiology is by far the biggest contributor for children aged under 1 year, and gives the highest mean effective dose for all ages combined (220 µSv), whereas computed tomography is responsible for around half of the exposure of the oldest age groups. Children aged 1 to 10 years receive mean doses that are 3 to 4 times lower.

– Overall, the mean doses of boys and girls are equivalent, though computed tomography scans make a larger contribution for boys and conventional radiology makes a larger contribution for girls. On the other hand, boys aged under 1 year receive on average a distinctly higher dose (35%) than girls of the same age, which is linked to the difference in the frequency of procedures mentioned in the previous section. Conversely, the effective dose of girls aged 11 to 15 years is on average 13% higher than that of boys in the same age range, related entirely to conventional radiology.

– With the notable exception of children aged under 1 year, the effective doses linked to conventional radiology and computed tomography are fairly small and relatively stable for children aged from 1 to 10 years, but they then gradually increase up to the ages of 14 and 15 years. The most frequent procedures observed in Figure 2 for children aged 12 years are dental procedures, which involve very low doses and therefore have no impact on the mean dose per child. The contribution of nuclear medicine to the mean effective dose per child remains low for all age groups (10 µSv or less). The contribution of diagnostic interventional radiology is only significant for children aged under 1 year, but it remains very low.

<u>**Summary of results and comparison with the previous study**</u>

In France in 2015, approximately 604 diagnostic procedures were carried out per 1000 children aged under 16 years, which is relatively stable (+1.5%) compared to the figure for 2010. Conventional radiology and dental radiology account for 56% and 41% of procedures respectively, computed tomography accounts for just over 2%, nuclear medicine and diagnostic interventional radiology account for less than 1%. This distribution is substantially equivalent to the distribution for 2010. By age group, it is children aged 11 to 15 years who are the most frequently exposed, with 993 procedures per 1000 children (down 10% on 2010), whereas those aged 1 to 5 years are the least frequently exposed, with 250 procedures per 1000 children (up 24%). The frequency of procedures on children aged under 1 year (543 procedures per 1000 children) has fallen by 26% compared to 2010. Girls are exposed slightly more often than boys, for all age groups combined (+1.8%).

The annual mean effective dose is 0.135 µSv per child; this is down 25% compared to 2010. Conventional radiology contributes about 53% to this dose, or 72 µSv per child, which is a 53 µSv reduction compared to 2010. CT scans account for about 40% of the total dose, or 55 µSv per child, which is a slight increase of 7 µSv since 2010. Dental radiology, nuclear medicine and diagnostic interventional radiology together contribute less than 7%, or 9 µSv, which is a 2 µSv increase since 2010. Children aged under 1 year have the highest annual mean effective dose: 0.28 mSv per child. For all age groups combined, the annual mean effective doses of girls and boys are identical.

4.2 Frequency of diagnostic imaging procedures by anatomical area explored

The distribution of the imaging procedures extracted from the EGB sample for 2015 is described in Table V. The number of procedures is shown there by imaging modality, broken down by anatomical area. The frequencies of the procedures performed on the EGB sample population are also given for each sex and for both sexes combined. The results of this table are broken down by imaging modality in the next few pages.

4.2.1 <u>Conventional radiology</u>

The absolute majority of procedures concern examinations of the limbs, followed by chest X-rays. Boys undergo conventional radiology procedures overall slightly more often than girls (+0.7%). The difference is mainly due to X-rays of the limbs and chest, where there is a significant difference in favour of boys (+1.4% for limbs, +1.1% for the chest). Conversely, girls more frequently undergo examinations of the pelvic girdle (+0.3%), the abdomen and pelvis (+0.3%) and especially the whole spine, for which the difference is 1.3%.

Table V. Distribution of imaging procedures by imaging modality and anatomical area explored, expressed as the number of procedures and the frequency of procedures per 1000 children.

Imaging modality *Anatomical area*	Number of procedures in EGB 2015	Frequency of procedures: Overall /1000 child.	(%)	Boys /1000 child.	(%)	Girls /1000 child.	(%)
Conventional radiology	**41210**	**339.4**	**(56.2%)**	**342.9**	**(57.6%)**	**335.6**	**(54.7%)**
Head and neck	*1540*	*12.7*	*(3.7%)*	*13.6*	*(4%)*	*11.7*	*(3.5%)*
Chest	*8733*	*71.9*	*(21.2%)*	*77.1*	*(22.5%)*	*66.5*	*(19.8%)*
Abdomen and pelvis	*2124*	*17.5*	*(5.2%)*	*16.3*	*(4.7%)*	*18.8*	*(5.6%)*
Pelvic girdle	*3046*	*25.1*	*(7.4%)*	*23.6*	*(6.9%)*	*26.6*	*(7.9%)*
Whole spine	*2673*	*22.0*	*(6.5%)*	*15.8*	*(4.6%)*	*28.6*	*(8.5%)*
Limbs	*22148*	*182.4*	*(53.7%)*	*189.0*	*(55.1%)*	*175.4*	*(52.3%)*
Other	*946*	*7.8*	*(2.3%)*	*7.7*	*(2.2%)*	*7.9*	*(2.4%)*
Dental radiology	**30190**	**248.6**	**(41.2%)**	**235.4**	**(39.6%)**	**262.5**	**(42.8%)**
Extraoral	*10585*	*87.2*	*(35.1%)*	*79.9*	*(34%)*	*94.7*	*(36.1%)*
Intraoral	*19605*	*161.4*	*(64.9%)*	*155.5*	*(66%)*	*167.7*	*(63.9%)*
Computed tomography	**1714**	**14.1**	**(2.3%)**	**14.8**	**(2.5%)**	**13.4**	**(2.2%)**
Head and neck	*1010*	*8.3*	*(58.9%)*	*8.8*	*(59.4%)*	*7.8*	*(58.3%)*
Chest and heart	*160*	*1.3*	*(9.3%)*	*1.6*	*(10.7%)*	*1.0*	*(7.7%)*
Abdomen and pelvis	*229*	*1.9*	*(13.4%)*	*1.8*	*(12.5%)*	*1.9*	*(14.4%)*
Spine	*86*	*0.7*	*(5%)*	*0.7*	*(4.9%)*	*0.7*	*(5.2%)*
Limbs	*205*	*1.7*	*(12%)*	*1.6*	*(10.5%)*	*1.8*	*(13.6%)*
Trunk	*24*	*0.2*	*(1.4%)*	*0.3*	*(2%)*	*0.1*	*(0.8%)*
Nuclear medicine	**186**	**1.5**	**(0.3%)**	**1.5**	**(0.3%)**	**1.6**	**(0.3%)**
Head and neck	*4*	*<0.1*	*(2.2%)*	*--*	*(0%)*	*0.1*	*(4.3%)*
Chest and heart	*4*	*<0.1*	*(2.2%)*	*<0.1*	*(3.2%)*	*<0.1*	*(1.1%)*
Abdomen and pelvis	*75*	*0.6*	*(40.3%)*	*0.6*	*(37.6%)*	*0.7*	*(43%)*
Whole body	*97*	*0.8*	*(52.2%)*	*0.9*	*(58.1%)*	*0.7*	*(46.2%)*
Other	*6*	*<0.1*	*(3.2%)*	*<0.1*	*(1.1%)*	*0.1*	*(5.4%)*
Diag. interventional radiology	**25**	**0.2**	**(<0.1%)**	**0.2**	**(<0.1%)**	**0.2**	**(<0.1%)**
Cardiac	*2*	*<0.1*	*(8%)*	*--*	*(0%)*	*<0.1*	*(18.2%)*
Vascular	*23*	*0.2*	*(92%)*	*0.2*	*(100%)*	*0.2*	*(81.8%)*
All modalities	**73325**	**603.8**	**(100%)**	**594.9**	**(100%)**	**613.2**	**(100%)**

Figure 4 represents the change in the frequency of procedures by child's age, for each anatomical area explored.

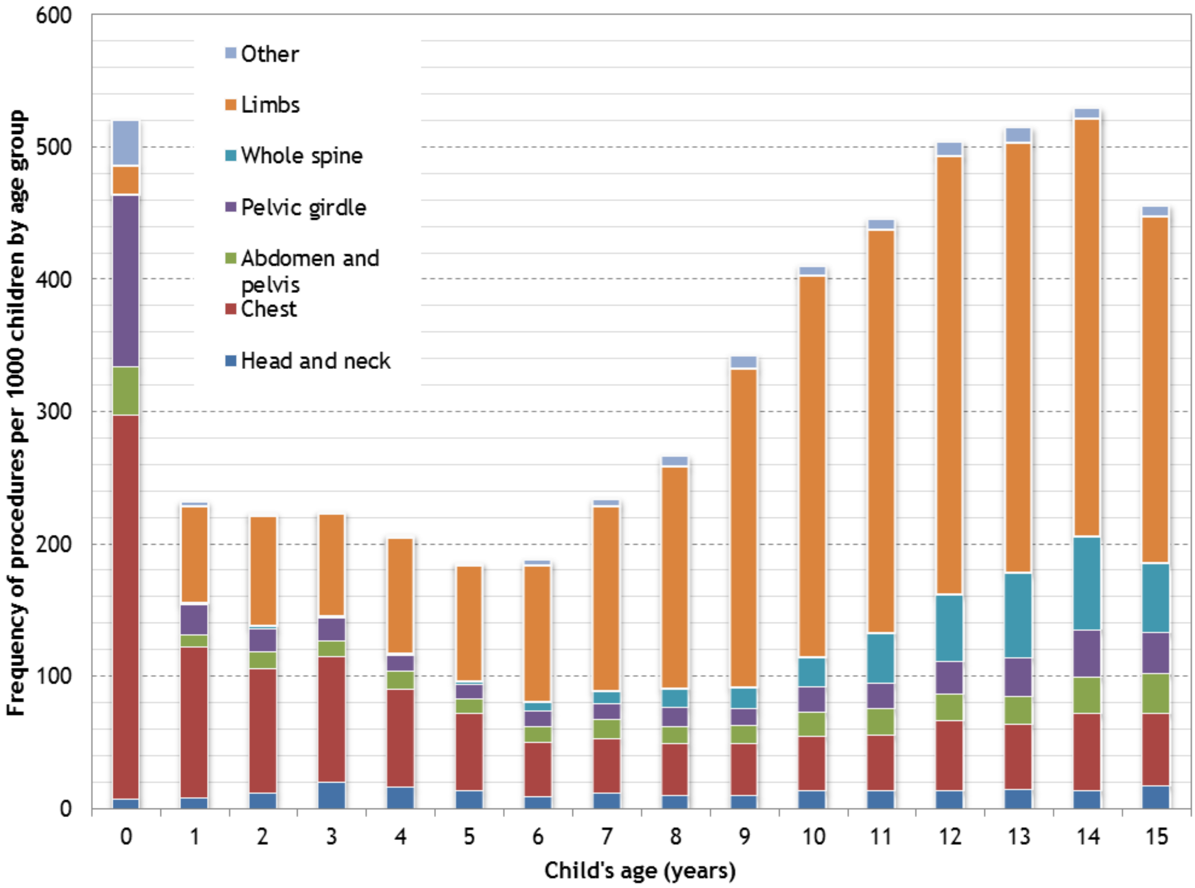

Figure 4. Frequency of conventional radiology procedures by anatomical area according to the child's age (both sexes combined).

This graph shows that the anatomical areas explored vary significantly with the child's age:

- Chest X-rays are very frequent in children aged under 1 year, where they account for more than half of conventional radiology procedures. Their frequency is much lower in older children but they still account for 30 to 50% of conventional radiology procedures in children aged 1 to 5 years, falling to about 10% in children aged over 10 years.
- Conversely, X-rays of limbs are infrequent in children aged under 1 year but are very frequent in older children: they account for the majority of procedures from the age of 6 years.
- The frequency of procedures concerning the pelvic girdle varies little with age, with the notable exception of children aged under 1 year for whom this is the second most frequently explored area with a proportion of about 25%. This will be studied in more detail in a focus on page 35.
- Procedures carried out on the whole spine are in a small minority in young children; their proportion gradually increases until they become as frequent as chest X-rays in children aged 12 years and over.
- Procedures carried out on the head and neck remain in a minority, regardless of the children's age, which is consistent with the small number of recommended indications for this examination [28].

– The frequency of procedures on the abdomen and pelvis is low from 1 to 9 years, but significantly higher thereafter and in children aged under 1 year. Abdominal X-rays without preparation (ASPs) form the bulk of conventional radiology procedures on this area (see Appendix 1). Paediatric indications for ASP are limited as a first-line examination but remain relatively frequent as a second-line examination after an ultrasound scan [29].

Figure 5 shows by age range the differences in exposure frequency between boys and girls already observed overall in Table V.

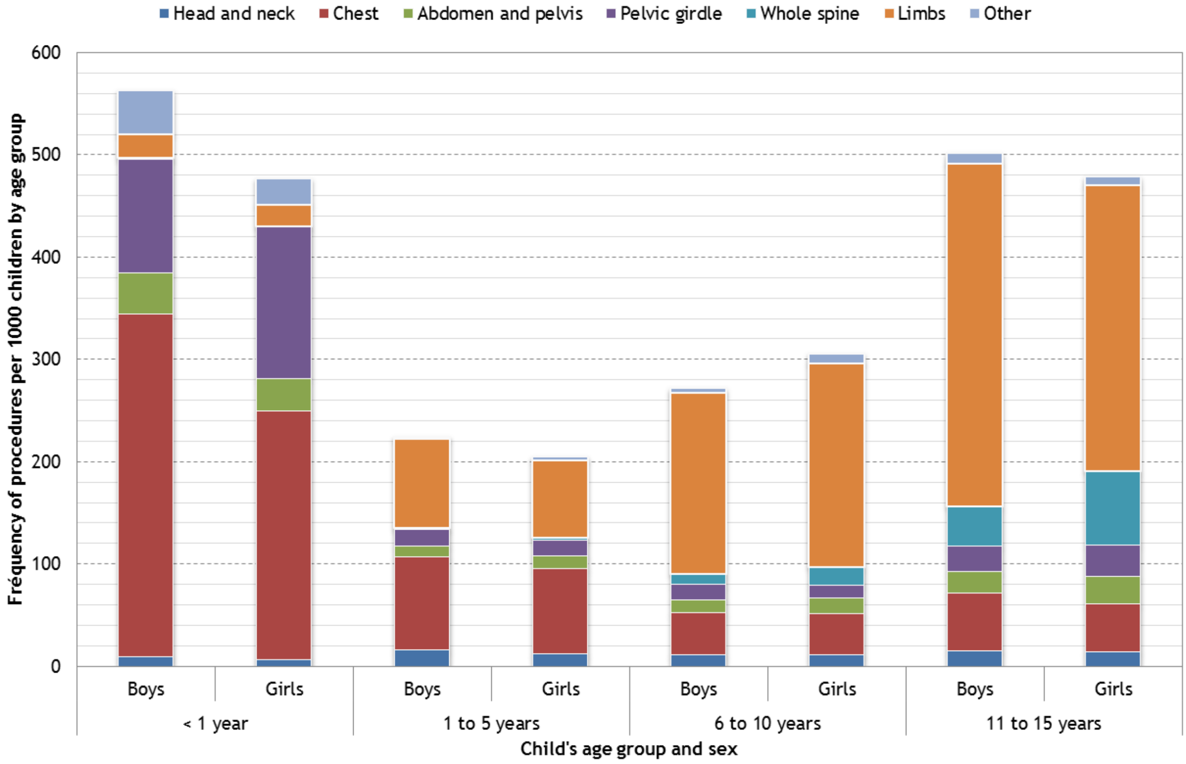

Figure 5. Frequency of conventional radiology procedures according to anatomical area explored, and child's age group and sex.

It can be seen that:

– The higher frequency of chest X-rays among boys is particularly significant in children aged under 1 year and much less marked for other age groups. This observation confirms the explanation put forward in section 4.1.1 that the difference is linked to the higher mortality of newborn boys, with respiratory syndromes among the most common perinatal pathologies [26]. The difference in the frequency of limb X-rays between girls and boys is also very marked for children aged 11 to 15 years.

– Certain procedures are performed more frequently on girls, and for X-rays of the pelvic girdle this is particularly true for children aged under 1 year and to a lesser extent for children aged 11 to 15 years. Girls aged 6 years and over receive X-rays of the whole spine more frequently than boys of the same age; this type of examination is extremely rare in younger children.

4.2.2 Dental radiology

Table V and Figure 6 can be used to study the frequency of dental radiology procedures according to the sex and age of the children.

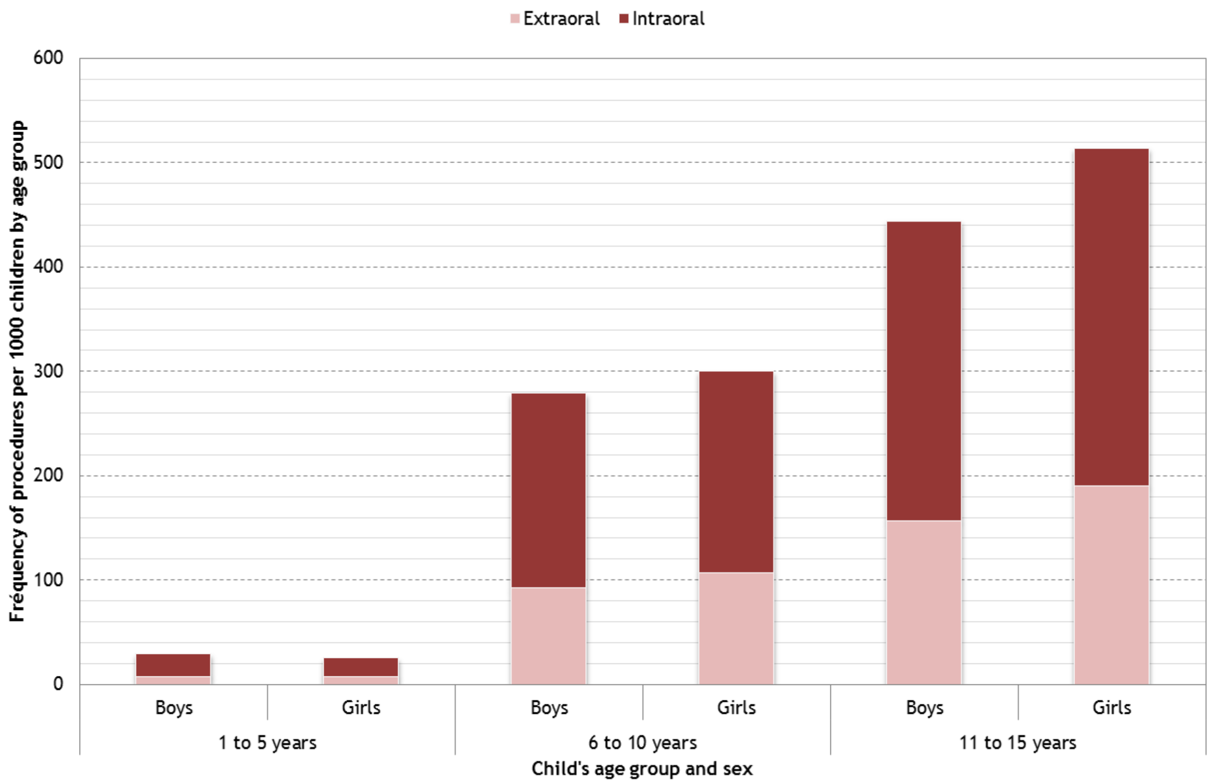

Figure 6. Frequency of intraoral and extraoral dental radiology procedures according to child's age group[5] and sex.

Overall, about two thirds of dental radiology procedures performed in 2015 on the population studied are intraoral X-rays. Dental radiology procedures are performed more frequently on girls than on boys, with a difference of 27 procedures per 1000 children, of which 15 are extraoral X-rays (panoramic X-ray, cone-beam CT, etc.). This difference is only apparent from the 6-10 year age group upwards and is particularly significant in children aged 11 to 15 years. The difference can probably be explained by the fact that orthodontic treatment on girls is more frequent than on boys [30].

4.2.3 Computed tomography

In the case of scans, head and neck examinations are dominant and account for nearly 60% of procedures, for all age groups combined (see Table V). The frequency of CT scans, for all anatomical areas combined, is 10% higher in boys than in girls, though girls undergo scans of the limbs or abdomen and pelvis slightly more often than boys.

The frequency of computed tomography procedures by anatomical area explored is shown in Figure 7 according to child's age and sex.

[5] Children aged under 1 year are not shown in this graph because for them the number of procedures is insignificant.

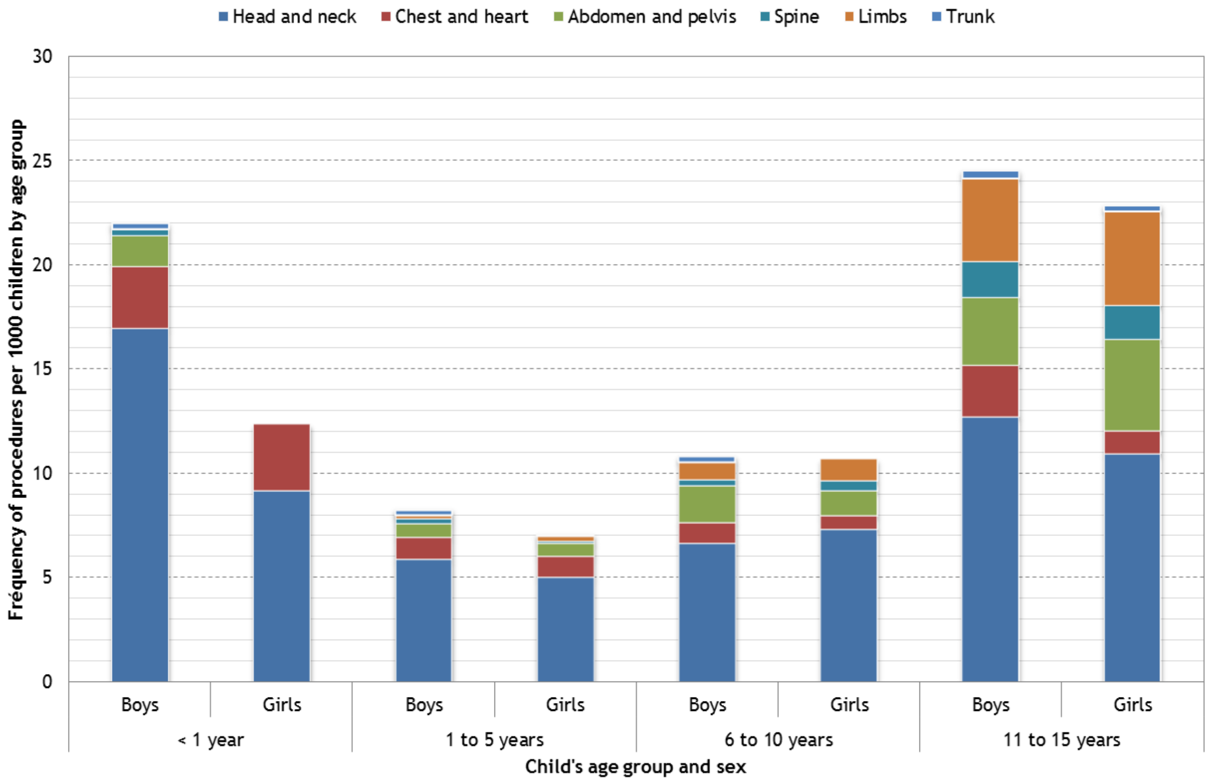

Figure 7. Frequency of computed tomography procedures according to anatomical area explored, and child's age and sex.

It can be considered that:

- differences between boys and girls can be observed in all age groups, but they are particularly marked for children aged under 1 year: boys have computed tomography scans almost twice as often as girls, mainly on the head and neck;
- examinations of the head, neck, chest and heart also seem to be significantly more frequent in boys aged 11 to 15 years than girls of the same age.

These observations should, however, be viewed in the light of the fact that relatively few of these scans were identified for the EGB sample (1,714 in total), which means the statistics are insufficient in some age groups and for some types of examination.

4.2.4 Nuclear medicine

The number of nuclear medicine procedures extracted from the EGB sample is small; only the frequency of procedures concerning the whole body (mainly bone scintigraphy and PET scans with FDG) and the abdominal/pelvic area (mainly renal scintigraphy) can be interpreted statistically. Boys seem to be given whole body examinations slightly more frequently than girls, and vice versa for examinations of the abdominal/pelvic area, but these differences are probably not statistically significant. Figure 8 shows that examinations of the abdomen/pelvis are more frequent in young children, particularly those aged under 1 year, whereas whole body scans are performed mostly on older children, particularly those aged 11-15 years.

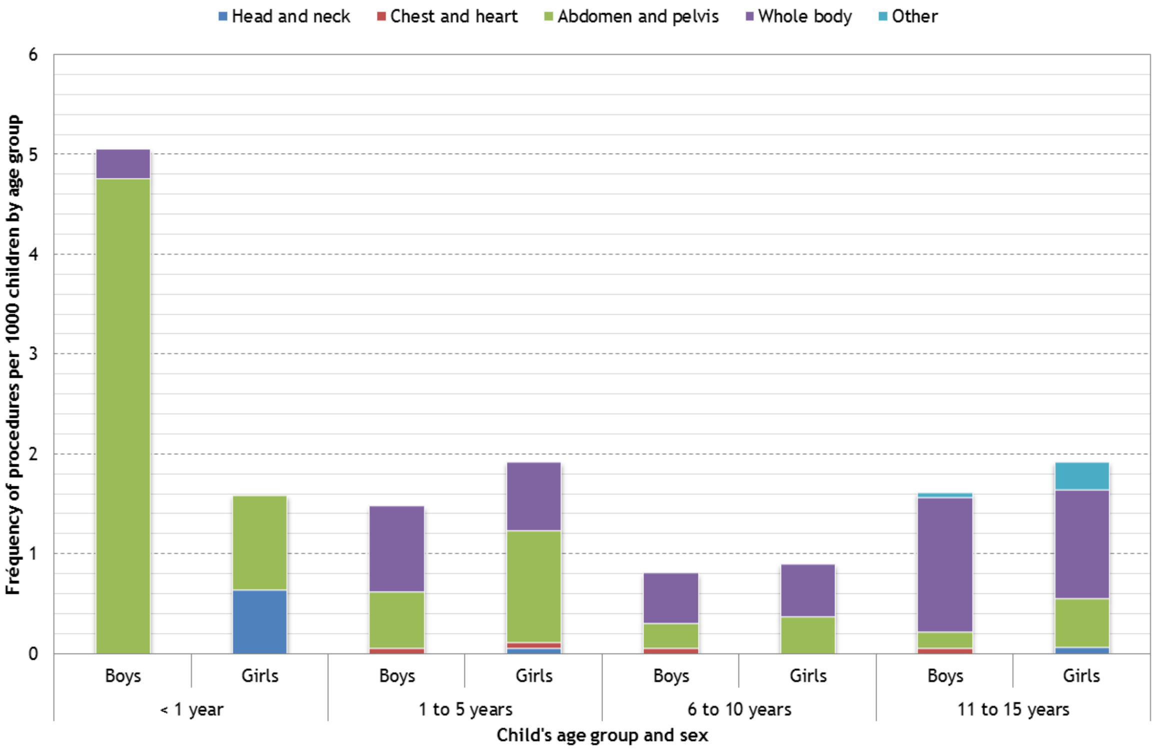

Figure 8. Frequency of nuclear medicine procedures according to anatomical area explored and child's age group.

4.2.5 Diagnostic interventional radiology

The number of procedures identified is extremely small, which prevents analysis of these procedures. Vascular examinations seem to dominate by far, but it is worth remembering that diagnostic interventional cardiology procedures such as coronary arteriography are commonly combined with therapeutic procedures in children and are therefore not counted in this study.

<u>Summary of results and comparison with the previous study</u>

With conventional radiology, more than half of procedures are on the limbs. Children aged over 6 years and especially boys aged 11 to 15 years are the categories that undergo these procedures most frequently. The chest is the second most frequently exposed anatomical area, particularly in children aged under 1 year and especially boys in this age range.

With dental radiology, two thirds of examinations carried out in 2015 are intraoral X-rays. Girls undergo dental radiology procedures significantly more often than boys, particularly extraoral X-rays.

With computed tomography, head and neck examinations are dominant and account for nearly 60% of procedures. Children aged under 1 year and children aged 11 to 15 years are the most frequently exposed, boys more than girls.

With nuclear medicine, the majority of procedures concern the abdomen and pelvis, particularly for children aged under 1 year, and the whole body, particularly for children aged 11 to 15 years.

These observations correspond overall to those of the previous study for 2010.

Focus on the CCAM codes associated with the highest frequencies and the highest doses

The queries run on the EGB sample database for 2015 supplied a total of 73,325 diagnostic imaging procedures performed on children aged under 16 years. Out of this total, 61,219 procedures had a CCAM code (83.5%) and 12,106 did not (16.5%). The procedures without codes are considered to be intraoral X-rays, as explained in section 2.1.2. A detailed list of the CCAM codes, with their description, frequency of performance and contribution to the annual mean effective dose per child is given in Appendix 1. In total, 188 CCAM codes out of the 401 included in this study are represented, i.e. had a non-zero frequency in queries run on the 2015 EGB sample database.

Of the 23 most frequent codes, 5 concern dental radiology and 18 conventional radiology. The most frequently coded procedure is the dental panoramic radiograph (referred to hereafter as the panoramic X-ray), with a frequency of performance in the EGB sample of approximately 63 procedures per 1000 children. Then comes the chest X-ray (58 procedures/1000 children), intraoral periapical and/or bitewing X-rays of a sector of 1 to 3 adjacent teeth (38 procedures/1000 children), then X-rays of the hand or finger (31 procedures/1000 children), the foot (21 procedures/1000 children) and the wrist (20 procedures/1000 children). It should be noted that, when all the CCAM codes related to intraoral periapical and/or bitewing X-rays are grouped together, this becomes the second most frequent type of radiological examination (61 procedures/1000 children) of the examinations with codes, and therefore the largest overall since procedures without codes are also intraoral X-rays.

The highest code for computed tomography (CT scan of the skull with injection) is in 24th place with a performance frequency of 5 procedures/1000 children. The highest code for nuclear medicine is the whole body bone scintigraphy scan in several stages, in 76th place with 0.5 procedures/1000 children. Finally, there are no codes for diagnostic interventional radiology in the top 100.

If CCAM codes are ranked by relative contribution to the total effective dose, the procedure contributing most to the exposure of the paediatric population of the EGB sample in 2015 is the abdominal/pelvic CT scan with injection, which accounts for 15.7 µSv per child on average. Next come four conventional radiology procedures: abdominal X-ray without preparation, pelvic girdle (1 view), whole spine (2 views), and oesophageal/gastric/duodenal transit, which contribute between 7 and 12.4 µSv/child on average. Computed tomography scans of the skull and spine without injection are in 6th and 7th place. The highest nuclear medicine code is for bone scintingraphy in stages, at 18th position with a contribution to the annual mean effective dose per child of 2.1 µSv.

To conclude, it is interesting to note that the 12,106 procedures not coded in the CCAM, which are dental procedures, contribute only 0.39% to the total effective dose, which only represents about 0.5 µSv per child on average in 2015.

4.3 Distribution of imaging procedures by type of healthcare establishment

The sector performing the diagnostic procedures was analysed using the EGB sample data for 2015, since the available information includes the type of healthcare facility. Two facility types were identified: private facilities, comprising doctor's surgeries, private clinics and hospitals and private non-profit facilities (e.g. cancer centres); and public hospital facilities, for which it is possible to find out whether the examination was performed during an inpatient stay or on an outpatient basis.

The results of this analysis are shown in Table VI.

Table VI. Distribution between the public sector and private sector of paediatric diagnostic procedures[6] listed in the EGB sample database in 2015.

Imaging modality	Number of procedures	Distribution of procedures		
			Public	
		Private	Outpatient treatment	Inpatient treatment
Conventional radiology	41 210	51.1%	38.3%	10.5%
Dental radiology	30 190	98.1%	1.8%	0.1%
Computed tomography	1 714	35.1%	27.0%	37.9%
Nuclear medicine	186	30.1%	45.2%	24.7%
All modalities	**73 325**	**70.0%**	**23.0%**	**6.9%**

Overall, 70% of the procedures counted in this study were performed in the private sector, compared to 30% in the public sector, of which 23% were on an outpatient basis and 7% during a hospital stay. If dental radiology procedures, which are very numerous and more than 98% of which are performed in the private sector, are excluded, the distribution is more balanced: 50.4% in the private sector and 49.6% in the public sector, of which 37.9% are performed on an outpatient basis and 11.7% during hospital stays.

If dental radiology is excluded, the distribution between the public and private sectors depends heavily on patient age, as shown in Figure 9 in the case of computed tomography and conventional radiology.

[6] The public/private distribution of diagnostic interventional radiology procedures is not shown in this table because it is not statistically representative.

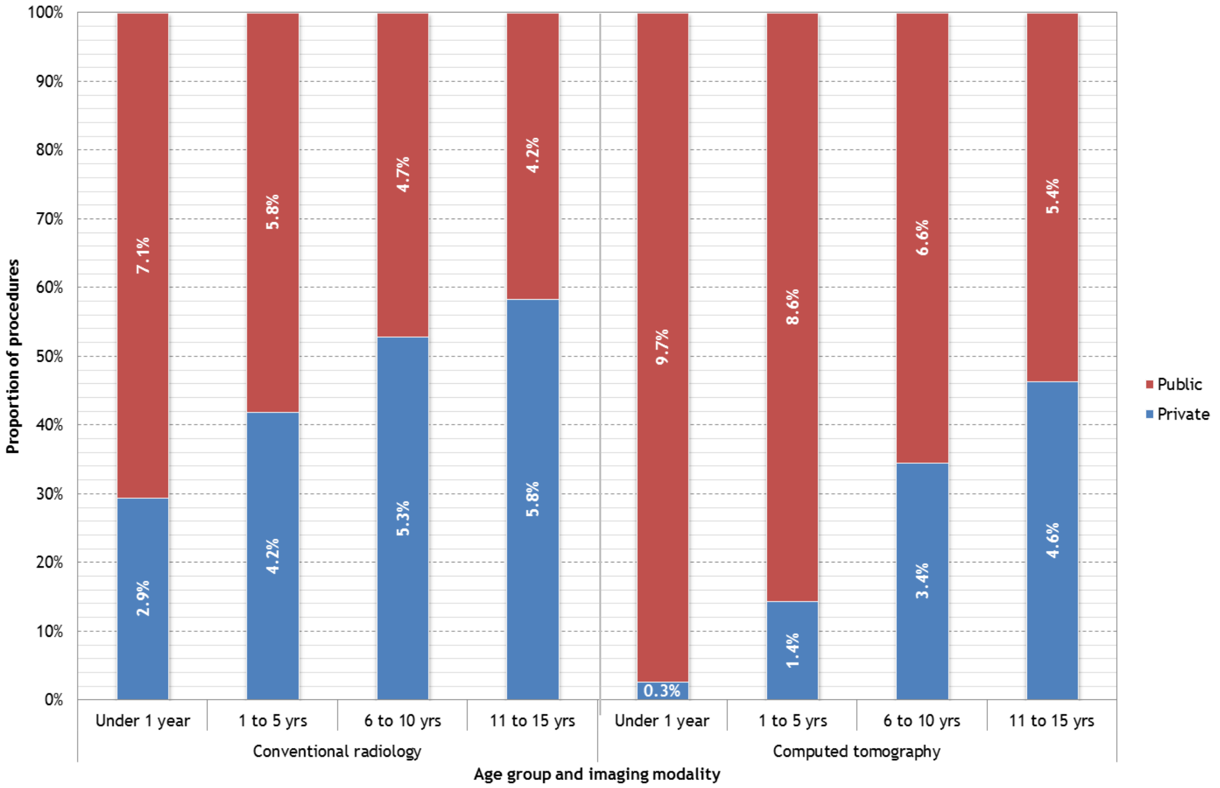

Figure 9. Distribution of procedures between the public and private sectors by child's age group, for conventional radiology and computed tomography.

The proportion of conventional radiology procedures performed in the private sector increases with patient age, rising from 29% for children aged under 1 year to 58% for children aged 11 to 15 years, i.e. twice as many. For computed tomography, the private sector proportion is always lower than for conventional radiology but the change as a function of patient age is even more marked: the private sector proportion for children aged 11 to 15 years is 17 times larger than for children aged under 1 year, for whom the private sector accounts for only 2.7% of procedures. Because scans of young children are almost always associated with complex pathologies or emergency treatment, they are mainly performed by specialist hospital departments, which are mostly public.

By comparison with the previous study for 2010 [7], when these figures were calculated only for computed tomography procedures, the public sector proportion was slightly higher in 2015, at 65% compared to 59%. This increase is due almost entirely to outpatient treatments. The change by patient age is comparable, with a greater public sector share than in 2010 for children aged 6 to 10 years and 11 to 15 years (66% compared to 59% and 54% compared to 39% respectively), but a slightly lower public sector share for younger children (97% compared to 100% for children aged under 1 year and 86% compared to 91% for children aged 1 to 5 years).

5 PAEDIATRIC POPULATION ACTUALLY EXPOSED IN 2015

Because the EGB sample data come from the SNIIRAM database for the private sector and the PMSI database for inpatient and outpatient treatments in the public sector, it was possible to determine the share of the population studied that was actually exposed in 2015, i.e. that underwent at least one imaging procedure using ionising radiation for diagnostic purposes during the year. For each patient exposed, it was possible to characterise their exposure in terms of the number and type of procedures.

5.1 Characterisation of the exposed population

Of the 121,437 children aged 0 to 15 years in the EGB sample in 2015, 38,024 or 31.3% underwent one or more diagnostic procedures in 2015. They are referred to as exposed children or the exposed population in the rest of this report. Figure 10 shows the proportion of children exposed according to sex and age[7].

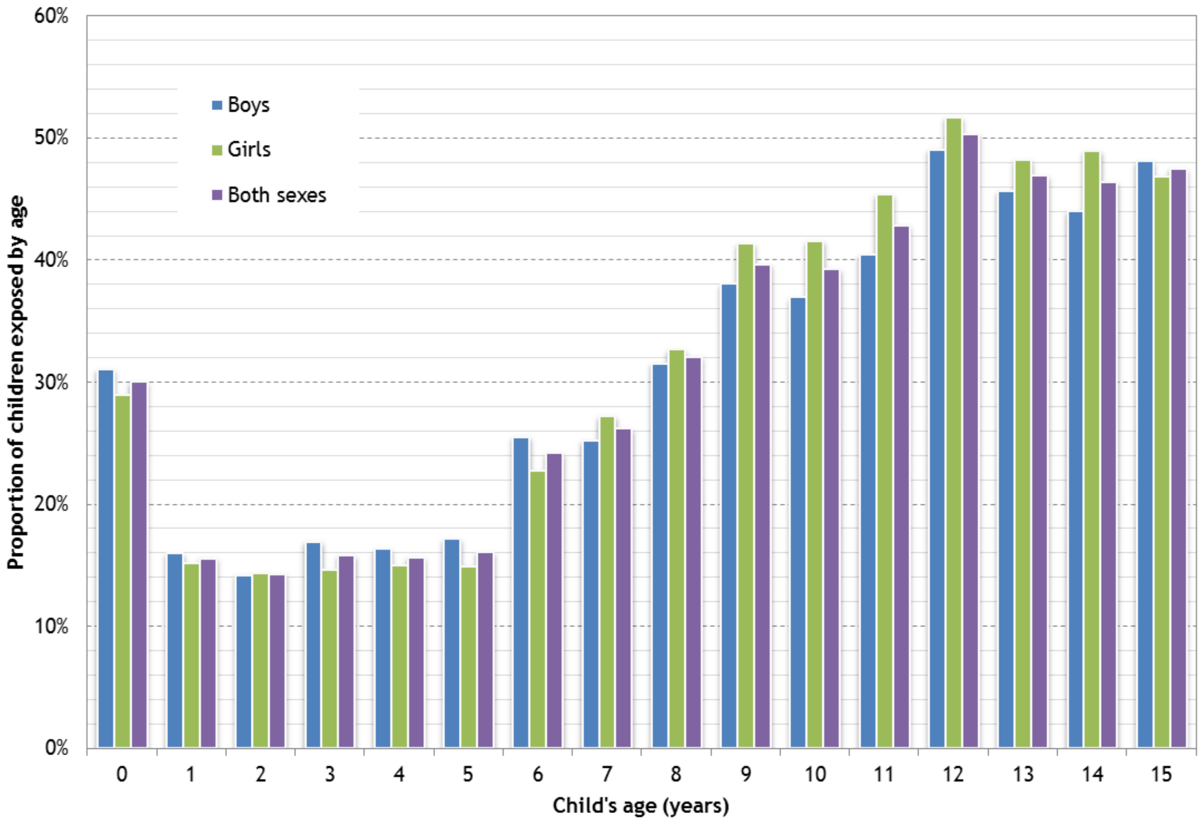

Figure 10. Proportion of children who underwent at least one diagnostic procedure in 2015, by age and sex

The proportion of exposed children varies widely with age and, to a lesser extent, with sex:

- 30% of children aged under 1 year underwent one or more procedures.
- Between 1 and 5 years, the proportion is relatively stable at around 15%.
- The proportion then gradually increases to 50% at the age of 12 years, and then stabilises at around 47%.

[7] Where multiple procedures are carried out, the child's age is calculated on the date of the first diagnostic procedure.

These results should be compared with the change in the frequency of procedures, shown in Figure 2 on page 19. In particular, the peaks observed for children aged under 1 year and children aged 12 years are explained by the fact that the higher frequencies of procedure in these two age groups are due more to a larger number of children being exposed than to a larger number of examinations per exposed child. It is highly likely that the very specific case of medical care of the neonatal population explains why, proportionally, twice as many children aged under 1 year undergo diagnostic procedures than children aged 1 to 5 years. The high proportion of children aged 12 years exposed is probably due to the compulsory oral disease prevention examination, as mentioned earlier in section 4.1.1 on page 19.

The differences between boys and girls are less marked than those linked to age. However, it can be seen that from the age of 7 years, the proportion of girls who undergo at least one procedure is significantly higher than the proportion of boys, except at the age of 15 years. Conversely, boys aged 6 years and under are more frequently exposed than girls of the same age.

In 2015, the exposed population of the EGB sample underwent a total of 73,325 diagnostic procedures (see Table V on page 23). The exposed children therefore underwent on average 1.93 procedures. Table VII presents statistical indicators for the number of procedures per exposed child by age group.

Table VII. Statistics for the annual number of procedures per exposed child by age group.

	< 1 year	1 to 5 yrs	6 to 10 yrs	11 to 15 yrs	All ages
Number of children exposed in EGB sample	1 960	5 960	12 570	17 534	38 024
ber of procedures per child					
Mean	1.88	1.62	1.88	2.08	1.93
Minimum	1	1	1	1	1
25th percentile	1	1	1	1	1
Median	1	1	1	2	1
75th percentile	2	2	2	3	2
95th percentile	5	4	4	5	5
Maximum	92	25	42	31	92

It shows, for example, that 50% of exposed children underwent only one diagnostic procedure during the year; 75% underwent one or two procedures and 95% had 5 procedures or fewer. The distribution of the number of procedures per child is therefore very asymmetrical: the vast majority of children underwent only one procedure during the year, whereas a very small number of children had a large number of procedures. This is explained by the fact that the procedures included in the study are both common radiological examinations, such as dental X-rays affecting a large number of children in the general population, but not recurrent, and more specialised radiological examinations, such as abdominal/pelvic CT scans, which affect a small number of children and are generally used to monitor a disease.

The distribution of the number of procedures per child, within the exposed population, is shown in Figure 11, according to the 4 age groups used previously.

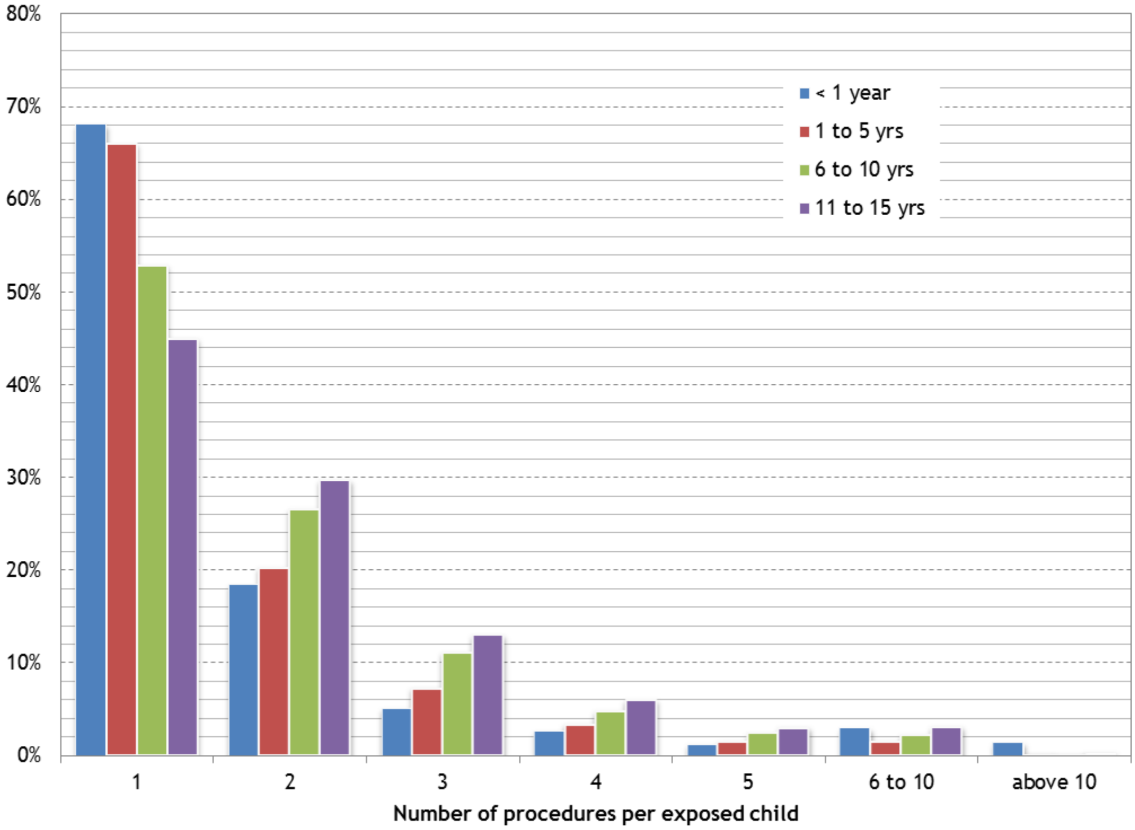

Figure 11. Histogram of the numbers of procedures per child exposed during the year, for each age range.

This graph shows that, among the exposed children, the oldest tend to undergo a larger number of diagnostic imaging procedures than the younger children: the 11 to 15-year age group has the smallest rate for a single procedure (45%) and the highest rates for 2 procedures or more. The exception is the age group of children aged under 1 year: whereas 68% of this age group undergo only one diagnostic procedure in the year, the rate for 6 to 10 examinations is the same as the rate for children aged 11-15 years and the rate for more than 10 examinations is much higher than for the other age groups (about 3%). This probably reflects a very specific population requiring high levels of medical care, probably due to congenital disorders or premature birth.

Among the most frequent examinations performed on children aged under 1 year, X-rays of the pelvic girdle have a special place. Their frequency is high (31% of all conventional radiology procedures performed on girls aged under 1 year, 20% of those performed on boys of the same age, see Figure 5) and their appropriateness is questioned [11]. They are analysed in detail in the box on the next page.

Focus on X-rays of the pelvic girdle in children aged under 6 months

A high frequency of pelvic girdle X-rays in children aged under 1 year was identified in the report for 2010 [7, Fig. 5]. Because the appropriateness of these procedures was already in doubt, the French radiology society (SFR) and SFIPP, in partnership with paediatricians and orthopaedic surgeons, have run initiatives to raise awareness regarding appropriate justification for these X-rays [24]. To diagnose congenital hip displacements/dysplasia, ultrasound is the recommended examination method. X-ray is only necessary to monitor disorders that have already been confirmed [11]. The frequencies calculated in this report for this age range have fallen significantly: there were 112 procedures per 1000 boys compared to 205 in 2010 (a 45% reduction) and 148 procedures per 1000 girls, compared to 250 in 2010 (a 41% reduction). This reduction is encouraging but the appropriateness of the remaining procedures is still an issue. In response to this and to a question from SFIPP, the EGB sample data were queried on the following basis: for any child who had had at least one pelvic girdle X-ray[8] under the age of 6 months during 2015, the number of ultrasound procedures[9] carried out beforehand was searched. The results of this query are shown in Figure 12. These figures show that only 23% of children who had one or more pelvic girdle X-rays under the age of 6 months were given one or more ultrasound scans beforehand in line with HAS recommendations [11]. The interpretation of this figure has been refined following discussions with radiologists at the SFR and SFIPP. Because giving children several X-rays without performing an ultrasound scan first can also be considered justified (if there is confirmed dislocation seen clinically, which is then monitored by X-ray), the percentage of children for whom X-ray(s) of the pelvic girdle is(are) theoretically justified is 28%. The remaining 72% of children can be split into several categories:

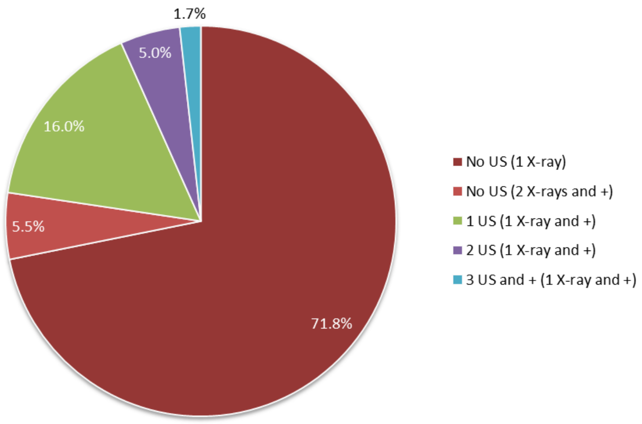

Figure 12. Proportion of children undergoing one or more ultrasound (US) scans of the hips prior to pelvic girdle X-ray performed under the age of 6 months.

- Children for whom an ultrasound examination was not performed before the age of 3 months, as recommended, and for whom an X-ray is consequently performed later on. This does not correspond to recommended best practice [11].
- Children for whom an ultrasound examination was not performed because no ultrasound scanner was available or there was no trained clinician. In theory this should not happen any more and the relevant learned societies are working to combat it.
- X-rays of the pelvic girdle other than to diagnose congenital hip displacement, such as infection, trauma, etc. There is genuine justification in these cases, but the frequency of this type of indication could only explain a small number of the 72% of children mentioned.

To conclude, the frequency of pelvic X-rays in children aged under 1 year has fallen very significantly since the 2010 study, which shows that initiatives to raise awareness among professionals have been valuable. But in a large share of cases, possibly as many as 70%, where children had a pelvic X-ray before the age of 6 months, these X-rays, subject to further investigation, could be considered unjustified.

[8] Corresponding to CCAM codes NAQK007, NAQK015, NAQK023, NAQK049, NAQK071, NEQK010, NEQK012 and NEQK035.
[9] Corresponding to CCAM codes NEQM001, PBQM001 to PBQM004.

5.2 Individual effective dose

Dividing the total effective dose calculated for 2015 by the number of children actually exposed in the EGB sample population **gives a mean individual effective dose of 0.43 mSv**. More so than for the number of procedures, the dose distribution is extremely varied (see Table VIII): half of the exposed population receives a dose of 0.02 mSv or less, 95% receives 1.6 mSv or less, whereas the remaining 5% receives a dose of 1.6 mSv or more, with a maximum observed in this study of 68 mSv.

Table VIII. Statistics for effective dose per exposed child by age group.

	< 1 year	1 to 5 yrs	6 to 10 yrs	11 to 15 yrs	All ages
Number of children exposed in EGB sample	1 960	5 960	12 570	17 534	38 024
Eff. dose/child (mSv)					
Mean	0.97	0.49	0.30	0.45	0.43
Minimum	0.0002	0.0002	0.0002	0.0002	0.0002
25th percentile	0.06	0.005	0.004	0.004	0.004
Median	0.55	0.06	0.012	0.016	0.02
75th percentile	0.6	0.12	0.04	0.06	0.06
95th percentile	2.9	1.5	1.3	1.7	1.6
Maximum	57.8	40.8	56.2	68.0	68.0

Figure 13 also illustrates this wide variation in the doses received.

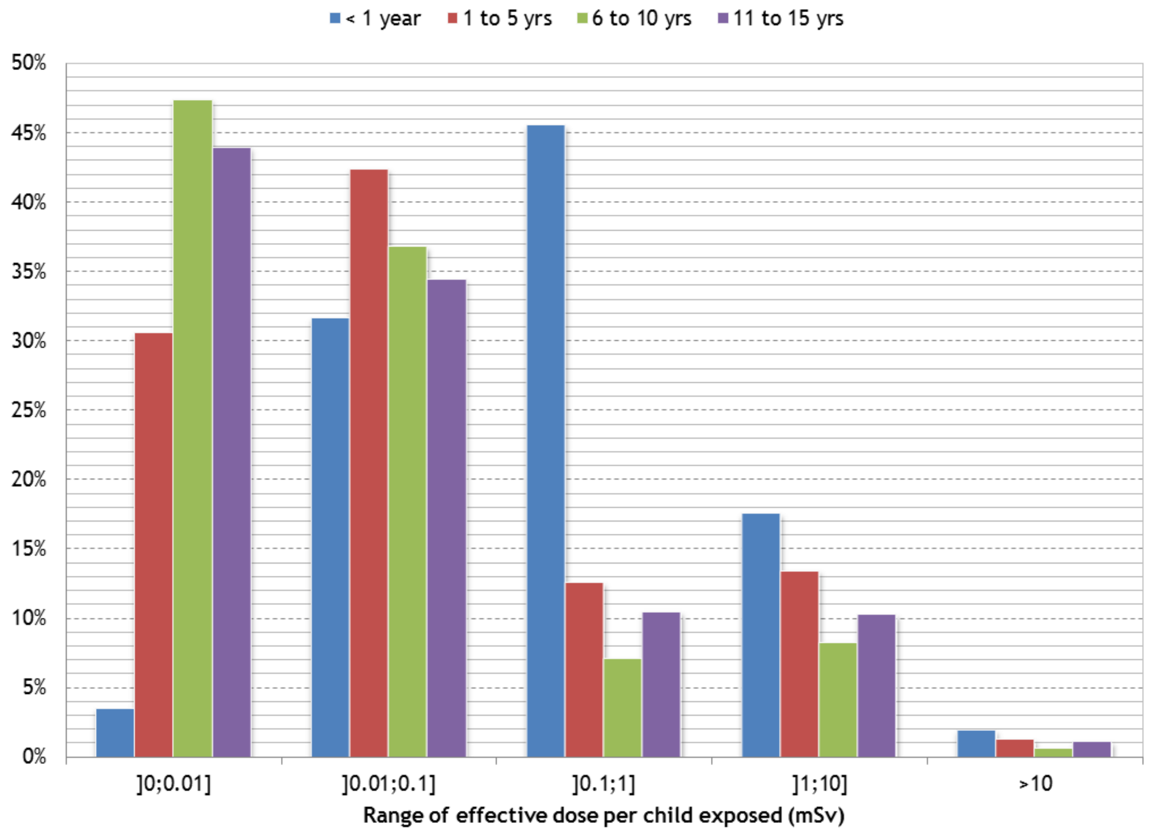

Figure 13. Histogram of the cumulative effective dose received by each child exposed during the year, for each age range.

Whereas the vast majority of children aged over 1 year received a cumulative dose well below 0.1 mSv, half of those aged under 1 year received more than 0.55 mSv. Relative to the number of children exposed in their age group, the youngest children are the most exposed category. This finding obviously agrees with the finding regarding the number of procedures for the same age group (see section 5.1 above). The reasons are therefore the same: high levels of medical care for a very specific population.

<u>Summary of results and comparison with the previous study</u>

In 2015, about 31% of children aged from 0 to 15 years underwent one or more diagnostic procedures, up 2 points compared to 2010. This proportion varies from about 15% for children aged 1 to 5 years, to about 30% for children aged under 1 year and about 45% for those aged 11 to 15 years. The mean number of procedures per exposed child, which is 1.9 in 2015, is slightly lower than in 2010 (2 procedures per exposed child).

The mean effective dose per exposed child in 2015 was 0.43 mSv, down 34% compared to 2010. Exposure is extremely varied, since half of exposed children received a cumulative effective dose of 0.02 mSV or less (compared to 0.025 mSv in 2010) and only 5% of exposed children received more than 1.6 mSv. Relative to the number of exposed children in their age group, children aged under 1 year are the most exposed, with a mean effective dose of nearly 1 mSv and a median effective dose of 0.55 mSv.

6 COMPARISON WITH THE LITERATURE

It is difficult to compare the results of this study with data published in the international literature because there are very few studies describing exposure of the paediatric population.

European Radiation Protection Report 180 [12] presents an analysis of the Dose Datamed 2 study conducted between 2007 and 2010 in 36 European countries. This is the most comprehensive study to date on exposure of the European population to ionising radiation, but it is not specific to the paediatric population and presents very few results by patient age range. In particular, the frequency of procedures and the annual mean effective doses per caput are only given for the whole population of each country. Distributions by age group and sex are given for 20 radiological examinations, but because the number of procedures is not standardised for the population of each age group and sex, the frequencies of the procedures are not comparable with those presented in this report. Qualitatively, the variation in the number of procedures by patient age for chest X-rays (*Chest* graph, p. 148) is comparable to that observed in this study in Figure 5. The high number of procedures for children aged 0 to 4 years observed in the European study is consistent with the high frequency of this type of procedure for children aged under 1 year identified in this study. The higher frequency of this procedure for boys also appears in the European study data. The same qualitative observations can be made with X-rays of the abdomen and pelvis (*Abdomen* and *Pelvis* graphs, p. 151). The graphs for CT scans (p. 154-157) also show that head and neck scans dominate by far in children, which agrees with the results of this study (see Figure 7).

An Irish study published in 2015 [31] provides elements for comparison on computed tomography and nuclear medicine examinations. This study gives a national frequency of 3.85 CT scans per 1000 children in 2012, which is much lower than the figure calculated here (14.1, see Table V). However, the Irish study only looks at examinations performed in the country's 3 paediatric hospitals, so CT scan frequency is probably underestimated, though the authors believe that few examinations of this kind are performed outside paediatric hospitals. For the record, in France about 35% of paediatric CT scans are performed in the private sector and the proportion of scans performed in paediatric hospitals compared to the whole public sector was not estimated. The frequency of nuclear medicine examinations in Ireland, which is 1.53 per 1000 children, is almost identical to the frequency calculated for France in this study. The anatomical areas to which the Irish examinations relate are, for CT scans, head and neck (about 50%), chest (15%) and abdomen (15%), which is very similar to the French distribution. In nuclear medicine, 70% of examinations concern the kidneys (40% in France) and just over 20% the bones (about 50% in France). Clinical practices in nuclear medicine therefore appear to be very different in the two countries.

A recent Italian study [32] looks at the change in the use of computed tomography scans in children and adults between 2004 and 2014 in the Lombardy region. Approximately 8.5 CT scans per 1000 children aged 0 to 17 years are counted for 2014. This is much higher than the figure in the Irish study, but it is still lower than the figure in this study (see Table V). In addition, the Italian study gives a frequency of almost zero for children aged under 5 years, unlike our results. However, it should be pointed out that the Italian study does not include hospitalised patients, which means that the examination frequency is underestimated, especially for young children, because CT scans are generally associated with high levels of medical care, and therefore hospitalisation, in this age range.

This study can also be compared with a study of exposure of the Swiss population, conducted in 2013 [33]. Regarding conventional radiology, the Swiss study indicates that chest X-rays are in a very large majority for children aged under 5 years, whereas X-rays of the limbs are very dominant for children aged 5 years and over. This matches the findings of this study. For computed tomography, the Swiss study shows a significantly higher scan frequency for boys, which agrees with this study. The anatomical area explored most is the head and neck, particularly for children aged under 5 years and to a lesser extent for children aged over 5 years, for whom the chest, abdomen/pelvis and limbs also play a large part. Once again, these results agree with the results of this study (see Figure 7).

There are many other studies of population exposure but very few of them contain data specific to the paediatric population. Where such data do exist, they are usually not precise enough to be compared reliably with this study. A Romanian study for 2012 [34] states that the most frequent computed tomography scans on patients aged 0 to 15 years are of the limbs and joints, the head and the cervical spine. These results only partially match the results presented here because examinations of the abdomen and pelvis are also frequent in this study and those of the head and neck dominate by a very large margin (see Table V). Another study looks at medical exposure of the South Korean population [35]. The annual number of diagnostic imaging procedures is presented for 5-year age ranges: it is stable at about 3.8 million for girls, and varies between 4.7 million for boys aged 1 to 5 years and 6.8 million for boys aged 11 to 15 years. Though not directly comparable with the procedure frequencies given in this report per 1000 children, these results nevertheless contradict the results in Table III, in which similar differences between boys and girls are not observed. One possible explanation for this contradiction is the small proportion of dental radiology procedures indicated in the Korean study (10.8% for the total population) compared to French practices (33.8% according to [6]). These considerations illustrate the difficulty of comparing studies of countries with very different medical practices and healthcare systems.

As well as the small amount of available data, the data published in the selected studies therefore vary widely. Quantitative comparisons with the results of this study are consequently necessarily limited. The qualitative correspondences observed are sufficient, however, to consider that the results of this study are consistent with those already published in other countries. Finally, this comparison highlights the uniqueness of this study: because it uses the EGB sample, it is the only study able to characterise the population of children actually exposed at a national scale. Studies that do not have a similar tool available are limited either to describing the exposure of the whole population, with no distinction between exposed and non-exposed children, or to studying a population of patients from a limited number of healthcare establishments.

7 CONCLUSION

The 2015 ExPRI Paediatric Study was conducted on the EGB sample, which represents 1/97th of the French population protected by the CNAM general health insurance scheme, the self-employed scheme and the agricultural scheme. All diagnostic imaging procedures using ionising radiation (conventional radiology, dental radiology and diagnostic interventional radiology, computed tomography and nuclear medicine), performed in 2015 on children aged under 16 years at the time of the procedure, were taken into account.

In France in 2015, about 604 diagnostic procedures were carried out per 1000 children aged under 16 years, which is relatively stable (+1.5 %) compared to the figure for 2010. Children aged 11 to 15 years are the most frequently exposed, with 993 procedures per 1000 children, whereas children aged 1 to 5 years are the least frequently exposed, with 250 procedures/1000 children. Conventional radiology and dental radiology account for 56% and 41% of procedures respectively, computed tomography accounts for just over 2%, nuclear medicine and diagnostic interventional radiology account for less than 1%. This distribution is substantially equivalent to the distribution for 2010. Girls are exposed slightly more often than boys, for all age groups combined (+1.8%). **The proportion of children that underwent at least one diagnostic procedure is 31%, up 2 points compared to 2010**. This proportion varies from about 15% for children aged 1 to 5 years to about 45% for those aged 11 to 15 years. The mean number of procedures per exposed child, which is 1.9, is slightly lower than in 2010 (2 procedures per exposed child).

The annual mean effective dose is 0.135 mSv per child, whether exposed or not, down 25% compared to 2010. Conventional radiology contributes about 53% to this dose, or 72 µSv per child, which is a 53 µSv reduction compared to 2010. CT scans account for about 40% of the total dose, or 55 µSv per child, which is a slight increase of 7 µSv since 2010. Dental radiology, nuclear medicine and diagnostic interventional radiology together contribute less than 7%, or 9 µSv, which is a 2 µSv increase since 2010. The annual mean effective doses of girls and boys are identical. **The mean effective dose per exposed child is 0.43 mSv, down 34% compared to 2010. Exposure is extremely varied, since half of exposed children received a cumulative effective dose of 0.02 mSv or less** (compared to 0.025 mSv in 2010) and only 5 % of exposed children received more than 1.6 mSv. **Relative to the number of exposed children in their age group, children aged under 1 year are the most exposed,** with a mean effective dose of nearly 1 mSv and a median effective dose of 0.55 mSv.

Generally, very few changes are observed in the frequency of diagnostic procedures in 2015 compared to 2010, as regards both number and distribution by imaging modality. On the contrary, the annual mean effective dose, calculated for the whole population as for the exposed population, is significantly lower than in the previous study. **The fact that this reduction in children's mean exposure has been observed even though the frequency of imaging procedures is stable overall means that it is directly linked to the reduction in the mean effective dose by type of procedure, identified mainly through the analysis of data sent to IRSN for diagnostic reference level purposes.** Several explanations related to better techniques and practices could be associated with this reduction, though it is not possible to determine which has the most influence. Between 2010 and 2015, a number of technological developments that reduced the dose needed to produce a high quality image became widespread in radiology departments and clinics: digital image receptors in conventional radiology and iterative reconstruction algorithms in computed tomography are two examples. Awareness has improved among professionals – both radiologists and radiographers – of the principles for justifying and optimising examinations. The involvement of medical physicists in radiology has increased and this has helped to improve practices. The learned societies concerned have published best practice guides. The authorities have stepped up their involvement, for example, ASN's action plan to manage the doses delivered to patients during medical imaging, launched in 2011.

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APPENDIX 1 List of CCAM codes by imaging modality and by anatomical area explored. Associated effective dose, frequency and contribution to the collective dose.

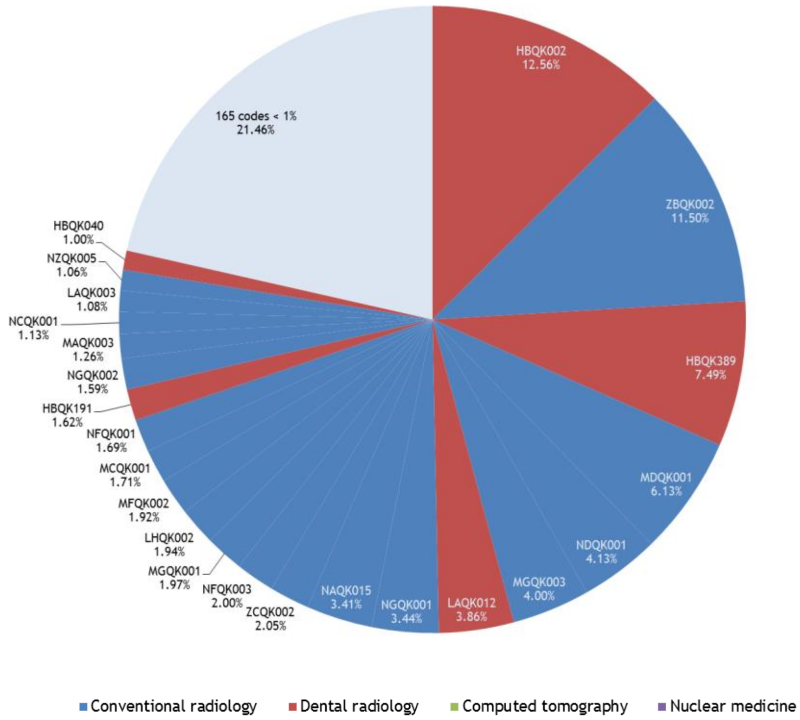
All 188 CCAM codes with a non-zero frequency in this study, representing 61,219 procedures, i.e. 83.5% of the total procedures in 2015 on the paediatric population of the EGB sample, are listed in Tables IX to XIII below. The codes are categorised by imaging modality and by anatomical area exposed. The "E/proc." column indicates the effective dose[10] associated with the CCAM code, in mSv. The "Proc. Freq." column gives the procedure frequency expressed as the number of procedures per 1000 children, and its rank in descending order. The "E_{mean}/child" column indicates the procedure's contribution to the annual mean dose per child in µSv, calculated for the whole paediatric population of the 2015 EGB sample, both exposed and non-exposed. N.S. (not significant) is entered where fewer than 10 occurrences of the code were found. [100+] indicates that the code is ranked in 100th place or more.

The distribution of the CCAM codes according to their frequency of occurrence in this study is shown in Figure 14a. The top 8 CCAM codes by frequency on their own account for more than half of the total number of coded procedures. The top 20 codes together account for three quarters of the total number of coded examinations. Finally, 165 codes each account for less than 1% of the total number of coded procedures, which corresponds to a frequency of less than 5 procedures per 1000 children. Together, these infrequent codes account for more than 21% of all coded procedures. The CCAM codes can also be studied on the basis of their relative contribution to the total effective dose, which is shown in Figure 14b. Half of the total effective dose in 2015 is due to the top 8 CCAM codes: 3 computed tomography codes and 5 conventional radiology codes. The top 20 codes account for three quarters of the total dose and consist of 10 conventional radiology codes, 9 computed tomography codes and 1 nuclear medicine code. Finally, the 164 codes that each contribute less than 1% to the total dose, which corresponds to an annual mean effective dose per child of 1.4 µSv, together make up 19% of the total dose, or nearly 26 µSv per child.

Dental radiology procedures without a CCAM code (see section 2.2.3) are not taken into account in either Tables IX to XIII or Figure 14. To calculate their contribution to the total effective dose, they were considered to be equivalent to one (or two or four respectively) intraoral periapical and/or bitewing X-rays of a sector of 1 to 3 adjacent teeth (CCAM code HBQK389) for the reference service code 1331 (or 9422 or 9423 respectively).

[10] It should be remembered that the dose is assessed on the basis of *adult* examinations for the reasons explained in section 3.2.

a)



b)

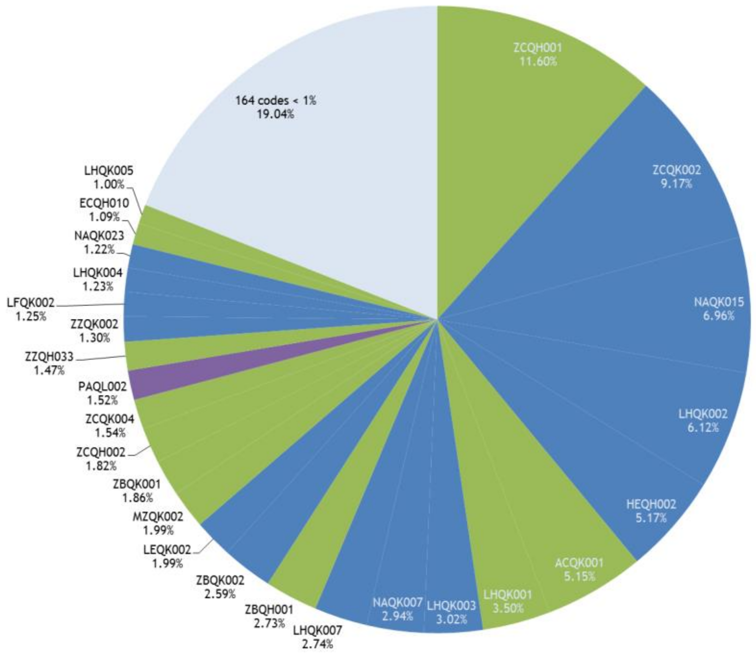


Figure 14. Classification of CCAM codes by: a) their proportion of the total coded procedures; b) their contribution to the total annual effective dose.

Table IX. List of CCAM codes for conventional radiology, categorised by anatomical area.

CCAM code	Procedure description	E/proc.	Proc. freq.		E_{mean}/child	
		mSv	/1000 child.	[rank]	µSv	[rank]
Head and neck						
HQQH002	Dynamic radiological swallowing study with recording [Dynamic pharyngography]	0.06	N.S.	[100+]	N.S.	[100+]
LAQK003	X-ray of the skull and/or facial bones, 1 or 2 views	0.04	5.44	[21]	0.22	[58]
LAQK005	X-ray of the skull and/or facial bones, 3 or more views	0.08	1.51	[48]	0.12	[77]
LBQK001	Unilateral or bilateral temporomandibular joint tomography	0.5	N.S.	[100+]	N.S.	[100+]
LBQK005	Unilateral or bilateral temporomandibular joint X-ray	0.012	0.12	[96]	<0.01	[100+]
LCQK002	Neck soft tissue X-ray	0.06	1.58	[47]	0.09	[82]
LDQK001	X-ray of the cervical segment of the spinal column, 1 or 2 views	0.07	1.01	[58]	0.07	[91]
LDQK002	X-ray of the cervical segment of the spinal column, 3 or more views	0.2	2.93	[34]	0.59	[40]
Chest						
HEQH001	Oesophageal radiography with opacification using a contrast agent [Oesophageal transit]	1.2	N.S.	[100+]	N.S.	[100+]
HEQH002	Oeso-gastro-duodenal radiography with opacification using a contrast agent [Oeso-gastro-duodenal transit]	10	0.70	[67]	7.00	[5]
LDQK004	X-ray of the cervical segment and thoracic segment of the spinal column	0.35	0.39	[79]	0.14	[73]
LEQK001	X-ray of the thoracic segment of the spinal column	0.25	0.96	[61]	0.24	[56]
LJQK001	Thoracic cage X-ray	0.08	0.71	[66]	0.06	[96]
LJQK002	Chest X-ray with thoracic cage X-ray	0.14	0.96	[60]	0.13	[74]
LJQK015	X-ray of the sternum and/or the sternoclavicular joints	0.08	0.44	[77]	0.03	[100+]
MAQK001	Shoulder girdle and/or shoulder X-ray, 3 or 4 views	0.02	2.22	[41]	0.04	[99]
MAQK002	Shoulder girdle and/or shoulder X-ray, 5 or more views	0.03	0.57	[69]	0.02	[100+]
MAQK003	Shoulder girdle and/or shoulder x-ray, 1 or 2 views	0.01	6.33	[19]	0.06	[93]
MEQH001	Shoulder arthrography	0.03	N.S.	[100+]	N.S.	[100+]
ZBQK002	Chest X-ray	0.06	57.82	[2]	3.51	[12]
ZBQK003	Dynamic chest radiography, to study respiratory and/or cardiac function	0.12	0.12	[95]	0.01	[100+]

CCAM code	Procedure description	E/proc.	Proc. freq.		Emean/child	
		mSv	/1000 child.	[rank]	μSv	[rank]
Abdomen and pelvis						
HGPH001	Meconium ileus removal from the small intestine by intestinal enema, with radiological monitoring	6	N.S.	[100+]	N.S.	[80]
HGQH002	Radiography of the small intestine with contrast medium ingestion [Small-bowel transit]	3.3	N.S.	[100+]	N.S.	[100+]
HHQH001	Radiography of the colon with opacification by contrast medium	9	0.14	[93]	1.26	[27]
HPMP002	Secondary radiological check of the position and/or operation of a peritoneal drain, peritoneal dialysis catheter or peritoneovenous shunt, with opacification by contrast medium	2.4	N.S.	[100+]	N.S.	[100+]
HZMP002	Secondary radiological check of the position and/or operation of a naso-gastric tube, bile drain or biliary endoprosthesis, with opacification by contrast medium	2.4	N.S.	[100+]	N.S.	[95]
JBQH002	Retrograde pyelography	2.4	N.S.	[100+]	N.S.	[100+]
JBQH003	Antegrade pyelography, through a nephrostomy already in place	2.4	N.S.	[100+]	N.S.	[100+]
JDQH001	Retrograde urethrocystography	2.4	0.52	[73]	1.25	[29]
JDQH003	Urethrocystography, by percutaneous puncture of the bladder	2.4	N.S.	[100+]	N.S.	[81]
JZQH003	Intravenous urography with voiding urethrocystography	2.5	N.S.	[100+]	N.S.	[100+]
LDQK005	X-ray of the cervical segment and lumbar segment of the spinal column	0.95	N.S.	[100+]	N.S.	[94]
LEQK002	X-ray of the thoracic segment and lumbar segment of the spinal column	1.1	2.45	[40]	2.70	[13]
LFQK001	X-ray of the lumbar segment of the spinal column, 4 or more views	1.1	1.11	[56]	1.22	[30]
LFQK002	X-ray of the lumbar segment of the spinal column, 1 to 3 views	0.85	1.99	[42]	1.69	[21]
LGQK001	X-ray of the sacrum and/or coccyx	0.5	0.72	[65]	0.36	[50]
ZCQK002	Abdominal X-ray without preparation	1.2	10.33	[10]	12.42	[2]
Pelvis						
NAQK007	Pelvic girdle X-ray, 2 views	1.1	3.62	[30]	3.99	[9]
NAQK015	Pelvic girdle X-ray, 1 view	0.55	17.14	[9]	9.43	[3]
NAQK023	Pelvic girdle X-ray, 3 or more views	1.7	0.97	[59]	1.65	[23]
NAQK049	Pelvic girdle X-ray, 1 view, and bilateral X-ray of the coxofemoral articulation, 1 or 2 views per side	1.2	0.32	[80]	0.39	[48]
NAQK071	Pelvic girdle X-ray, 1 view, and unilateral X-ray of the coxofemoral articulation, 1 or 2 views	0.85	1.05	[57]	0.90	[33]
NEQH002	Hip arthrography	0.25	N.S.	[100+]	N.S.	[100+]
NEQK010	X-ray of the coxofemoral articulation, 1 or 2 views	0.3	1.45	[50]	0.43	[44]
NEQK012	X-ray of the coxofemoral articulation, 4 or more views	0.75	0.21	[87]	0.15	[66]
NEQK035	X-ray of the coxofemoral articulation, 3 views	0.45	0.30	[82]	0.13	[75]
ZCQK001	Pelvimetry by radiography	0.55	N.S.	[100+]	N.S.	[100+]

CCAM code	Procedure description	E/proc.	Proc. freq.		E_{mean}/child	
		mSv	/1000 child.	[rank]	µSv	[rank]
Whole spine						
LHQK002	Teleoroentgenography of the whole spinal column, 2 views	0.85	9.76	[13]	8.29	[4]
LHQK003	Teleoroentgenography of the whole spinal column, 2 views with supplementary segment view	1.1	3.71	[29]	4.09	[8]
LHQK004	Teleoroentgenography of the whole spinal column, 1 view	0.4	4.18	[27]	1.67	[22]
LHQK007	X-ray of the whole spinal column	0.85	4.36	[26]	3.71	[10]
Limbs						
MBQK001	Upper arm X-ray	0.001	1.80	[45]	<0.01	[100+]
MCQK001	Forearm X-ray	0.001	8.58	[15]	<0.01	[100+]
MDQK001	Hand or finger X-ray	0.0002	30.82	[4]	<0.01	[100+]
MDQK002	Bilateral hand and/or wrist X-ray, 1 view on a single plate, frontal	0.0002	0.49	[75]	<0.01	[100+]
MFQK001	Elbow X-ray, 3 or more views	0.002	2.67	[37]	<0.01	[100+]
MFQK002	Elbow X-ray, 1 or 2 views	0.001	9.63	[14]	<0.01	[100+]
MGQK001	Wrist X-ray, 3 or more views	0.0004	9.88	[12]	<0.01	[100+]
MGQK002	Dynamic radiographic examination of the wrist for non-dissociative sprain, 7 specific views	0.0008	N.S.	[100+]	N.S.	[100+]
MGQK003	Wrist X-ray, 1 or 2 views	0.0002	20.08	[6]	<0.01	[100+]
MZQK001	Unilateral or bilateral teleoroentgenography of the whole arm, frontal	0.002	N.S.	[100+]	N.S.	[100+]
MZQK003	X-ray of 2 segments of the arm	0.002	3.38	[31]	<0.01	[100+]
MZQK004	X-ray of 3 segments or more of the arm	0.003	0.79	[63]	<0.01	[100+]
NBQK001	Thigh X-ray	0.001	1.91	[44]	<0.01	[100+]
NCQK001	Leg X-ray	0.002	5.69	[20]	0.01	[100+]
NDQK001	Unilateral foot X-ray, 1 to 3 views	0.0002	20.75	[5]	<0.01	[100+]
NDQK002	Bilateral foot X-ray, 1 to 3 views per side	0.0004	2.94	[33]	<0.01	[100+]
NDQK003	Foot X-ray, 4 or more views	0.0004	1.46	[49]	<0.01	[100+]
NDQK004	Foot X-ray, 4 or more views, for podometric examination	0.0005	1.26	[55]	<0.01	[100+]
NFQH001	Knee arthrography	0.005	N.S.	[100+]	N.S.	[100+]
NFQK001	Unilateral knee X-ray, 1 or 2 views	0.002	8.47	[16]	0.02	[100+]
NFQK002	Bilateral knee X-ray, 1 or 2 views per side	0.004	1.65	[46]	<0.01	[100+]
NFQK003	Knee X-ray, 3 or 4 views	0.003	10.05	[11]	0.03	[100+]
NFQK004	Knee X-ray, 5 or more views	0.006	4.80	[25]	0.03	[100+]
NGQH001	Ankle arthrography	0.0005	N.S.	[100+]	N.S.	[100+]
NGQK001	Ankle X-ray, 1 to 3 views	0.0002	17.28	[8]	<0.01	[100+]

CCAM code	Procedure description	E/proc.	Proc. freq.		E_{mean}/child	
		mSv	/1000 child.	[rank]	µSv	[rank]
NGQK002	Ankle X-ray, 4 or more views	0.0004	8.00	[18]	<0.01	[100+]
NZQK001	Unilateral or bilateral teleoroentgenography of the whole leg, frontal, bipodal support	0.005	2.64	[38]	0.01	[100+]
NZQK003	Bilateral teleoroentgenography of the whole leg, frontal, bipodal support, one after the other	0.01	0.19	[89]	<0.01	[100+]
NZQK005	X-ray of 2 segments of the leg	0.003	5.30	[22]	0.02	[100+]
NZQK006	X-ray of 3 or more segments of the leg	0.005	1.42	[51]	<0.01	[100+]
PAQK001	Comparative radiography of the cartilages joining the long bones in the limbs	0.01	0.13	[94]	<0.01	[100+]
Other						
PAQK002	Bone age radiography, after the age of 2 years	0.01	3.86	[28]	0.04	[100+]
PAQK003	Skeletal survey (radiography of the whole body), segment by segment, in children	1.8	0.54	[72]	0.96	[32]
PAQK005	Hemiskeleton bone age radiography, before the age of 2 years	0.01	0.31	[81]	<0.01	[100+]
PAQK007	Bone mineral densitometry on 2 sites, by dual-photon absorptiometry	0.001	0.21	[86]	<0.01	[100+]
PAQK008	Whole body bone mineral densitometry by dual-photon absorptiometry, for constitutional bone diseases in children	0.001	N.S.	[100+]	N.S.	[100+]
PAQK900	Whole body bone mineral densitometry by dual-photon absorptiometry, for non-constitutional bone diseases	0.001	N.S.	[100+]	N.S.	[100+]
QEQK001	Bilateral mammography	0.36	N.S.	[100+]	N.S.	[100+]
QEQK005	Unilateral mammography	0.18	N.S.	[100+]	N.S.	[100+]
YYYY163	Hemiskeletal or skeletal survey in adults	1.8	0.25	[85]	0.44	[43]
ZZQK001	Bedside X-ray, 3 or more views	1.4	N.S.	[100+]	N.S.	[97]
ZZQK002	Bedside X-ray, 1 or 2 views	0.7	1.97	[43]	1.76	[20]

Table X. List of CCAM codes for dental radiology.

CCAM code	Procedure description	E/proc.	Proc. freq.		E_{mean}/child	
		mSv	/1000 child.	[rank]	µSv	[rank]
Extraoral						
HBQK002	Dentomaxillary panoramic radiography	0.02	63.14	[1]	1.26	[26]
LAQK001	Cephalometric projection of the skull and facial bones, 2 views	0.026	2.91	[35]	0.08	[89]
LAQK008	Cephalometric projection of the skull and facial bones, 3 views	0.039	0.11	[97]	<0.01	[100+]
LAQK012	Cephalometric projection of the skull and facial bones, 1 view	0.013	19.43	[7]	0.25	[54]
LAQK027	Cone-beam computed tomography [CBCT] of the maxilla, mandible and/or dental arch	0.1	1.58	[47]	0.16	[62]
Intraoral						
HBQK001	Occlusal X-ray	0.025	0.58	[68]	0.01	[100+]
HBQK040	Preinterventional or periinterventional intraoral periapical X-rays on a sector of 1 to 3 adjacent teeth with a final X-ray for root canal treatment	0.008	5.04	[23]	0.04	[100+]
HBQK041	Intraoral periapical and/or bitewing X-rays of 14 distinct sectors of 1 to 3 adjacent teeth	0.056	N.S.	[100+]	N.S.	[100+]
HBQK046	Intraoral periapical and/or bitewing x-rays of 9 distinct sectors of 1 to 3 adjacent teeth	0.036	N.S.	[100+]	N.S.	[100+]
HBQK061	Final intraoral periapical and/or bitewing X-ray of a sector of 1 to 3 adjacent teeth for root canal treatment or periinterventional and/or final intraoral periapical and/or bitewing X-ray for a procedure other than root canal treatment	0.004	2.51	[39]	0.01	[100+]
HBQK065	Intraoral periapical and/or bitewing X-rays of 10 distinct sectors of 1 to 3 adjacent teeth	0.04	N.S.	[100+]	N.S.	[100+]
HBQK142	Intraoral periapical and/or bitewing X-rays of 8 distinct sectors of 1 to 3 adjacent teeth	0.032	N.S.	[100+]	N.S.	[100+]
HBQK191	Intraoral periapical and/or bitewing X-rays of 2 distinct sectors of 1 to 3 adjacent teeth	0.008	8.14	[17]	0.07	[92]
HBQK303	Preinterventional, periinterventional and final intraoral periapical X-rays on a sector of 1 to 3 adjacent teeth for root canal treatment	0.012	2.96	[32]	0.04	[100+]
HBQK331	Intraoral periapical and/or bitewing x-rays of 3 distinct sectors of 1 to 3 adjacent teeth	0.012	1.42	[52]	0.02	[100+]
HBQK389	Intraoral periapical and/or bitewing X-rays of a sector of 1 to 3 adjacent teeth	0.004	37.64	[3]	0.15	[67]
HBQK424	Intraoral periapical and/or bitewing X-rays of 11 distinct sectors of 1 to 3 adjacent teeth	0.044	N.S.	[100+]	N.S.	[100+]
HBQK428	Intraoral periapical and/or bitewing X-rays of 5 distinct sectors of 1 to 3 adjacent teeth	0.02	0.40	[78]	<0.01	[100+]
HBQK430	Intraoral periapical and/or bitewing X-rays of 7 distinct sectors of 1 to 3 adjacent teeth	0.028	N.S.	[100+]	N.S.	[100+]
HBQK443	Intraoral periapical and/or bitewing X-rays of 4 distinct sectors of 1 to 3 adjacent teeth	0.016	2.79	[36]	0.04	[98]

CCAM code	Procedure description	E/proc.	Proc. freq.		E_{mean}/child	
		mSv	/1000 child.	[rank]	µSv	[rank]
HBQK476	Intraoral periapical and/or bitewing X-rays of 12 distinct sectors of 1 to 3 adjacent teeth	0.048	N.S.	[100+]	N.S.	[100+]
HBQK480	Intraoral periapical and/or bitewing X-rays of 6 distinct sectors of 1 to 3 adjacent teeth	0.024	N.S.	[100+]	N.S.	[100+]

Table XI. List of CCAM codes for computed tomography, categorised by anatomical area.

CCAM code	Procedure description	E/proc.	Proc. freq.		E_{mean}/child	
		mSv	/1000 child.	[rank]	μSv	[rank]
Head and neck						
ACQH002	Computed tomography of the cranium, its contents and the chest, with intravenous contrast medium injection	5.7	N.S.	[100+]	N.S.	[60]
ACQH003	Computed tomography of the cranium and its contents, with intravenous contrast medium injection	1.4	0.90	[62]	1.26	[28]
ACQH004	Computed tomography of the cranium, its contents, and the trunk, with intravenous contrast medium injection	12	N.S.	[100+]	N.S.	[36]
ACQK001	Computed tomography of the cranium and its contents, without contrast medium injection	1.4	4.97	[24]	6.97	[6]
EAQH002	Computed tomography of blood vessels in the brain [Brain angiogram]	2.5	N.S.	[100+]	N.S.	[86]
EBQH004	Computed tomography of blood vessels in the head and neck [Head and neck angiogram]	3.6	N.S.	[100+]	N.S.	[59]
EBQH006	Computed tomography of blood vessels in the neck [Neck angiogram]	3.1	N.S.	[100+]	N.S.	[88]
LAQK002	Unilateral or bilateral computed tomography of the petrous part of the temporal bone and the middle ear	1.3	0.56	[70]	0.73	[35]
LAQK009	Computed tomography of the face with computed tomography of the neck soft tissues	1.8	0.20	[88]	0.36	[51]
LAQK011	Unilateral or bilateral computed tomography of the cerebellopontine angle and/or the internal acoustic meatus [internal auditory canal]	1.2	N.S.	[100+]	N.S.	[100+]
LAQK013	Computed tomography of the face = cone-beam	0.5	1.30	[53]	0.65	[38]
LCQH001	Computed tomography of the neck soft tissues, with intravenous contrast medium injection	4.2	0.16	[91]	0.66	[37]
LCQK001	Computed tomography of the neck soft tissues, without contrast medium injection	3.3	N.S.	[100+]	N.S.	[100+]
Chest and heart						
ECQH010	Computed tomography of blood vessels in the chest and/or heart [Chest angiogram]	10	0.15	[92]	1.48	[24]
ECQH011	Computed tomography of blood vessels in the chest and/or heart, with computed tomography of blood vessels in the abdomen and/or pelvis [Chest angiogram with angiogram of the abdomen/pelvis]	18	N.S.	[100+]	N.S.	[34]
ZBQH001	Computed tomography of the chest, with intravenous contrast medium injection	6.8	0.54	[71]	3.70	[11]
ZBQK001	Computed tomography of the chest, without intravenous contrast medium injection	4.3	0.58	[68]	2.51	[15]
Abdomen and pelvis						
ELQH002	Computed tomography of blood vessels in the abdomen and/or pelvis [Abdominal/pelvic angiogram]	19	N.S.	[100+]	N.S.	[52]

CCAM code	Procedure description	E/proc.	Proc. freq.		E_{mean}/child	
		mSv	/1000 child.	[rank]	µSv	[rank]
ZCQH001	Computed tomography of the abdomen and pelvis, with intravenous contrast medium injection	12	1.29	[54]	15.71	[1]
ZCQH002	Computed tomography of the abdomen or pelvis, with intravenous contrast medium injection	12	0.21	[87]	2.47	[16]
ZCQK004	Computed tomography of the abdomen and pelvis, without intravenous contrast medium injection	7.7	0.27	[83]	2.09	[17]
ZCQK005	Computed tomography of the abdomen or pelvis, without intravenous contrast medium injection	7.7	N.S.	[100+]	N.S.	[39]
Spine						
LHQH002	Computed tomography of several segments of the spinal column, with intravenous contrast medium injection	13	N.S.	[100+]	N.S.	[45]
LHQH006	Computed tomography of one segment of the spinal column, with intravenous contrast medium injection	11	N.S.	[100+]	N.S.	[42]
LHQK001	Computed tomography of one segment of the spinal column, without intravenous contrast medium injection	9.3	0.51	[74]	4.75	[7]
LHQK005	Computed tomography of several segments of the spinal column, without intravenous contrast medium injection	11	0.12	[95]	1.36	[25]
Limbs						
EMQH001	Computed tomography of the blood vessels in the legs [Leg angiogram]	20	N.S.	[100+]	N.S.	[61]
MZQH001	Arthrography of the arm with computed tomography [Arm arthrogram]	5.8	N.S.	[100+]	N.S.	[71]
MZQH002	Unilateral or bilateral computed tomography of an arm segment, with contrast medium injection	4.8	N.S.	[100+]	N.S.	[63]
MZQK002	Unilateral or bilateral computed tomography of an arm segment, without contrast medium injection	3.8	0.71	[66]	2.69	[14]
NZQH001	Unilateral or bilateral computed tomography of a leg segment, with contrast medium injection	0.2	N.S.	[100+]	N.S.	[100+]
NZQH002	Arthrography of the leg with computed tomography [Leg arthrogram]	3.8	N.S.	[100+]	N.S.	[57]
NZQH005	Computed tomography of the hip and leg for computed-aided design of a bespoke osteoarticular prosthesis	10	N.S.	[100+]	N.S.	[87]
NZQK002	Unilateral or bilateral computed tomography of a leg segment, without contrast medium injection	0.2	0.77	[64]	0.15	[65]
NZQK004	Computed tomography scan to measure leg length	5.5	N.S.	[100+]	N.S.	[72]
Trunk						
ZZQH033	Computed tomography of 3 or more anatomical areas, with intravenous contrast medium injection	11	0.18	[90]	1.99	[19]
ZZQK024	Computed tomography of 3 or more anatomical areas, without contrast medium injection	9.6	N.S.	[100+]	N.S.	[64]

Table XII. List of CCAM codes for nuclear medicine, categorised by anatomical area.

CCAM code	Procedure description	E/proc.	Proc. freq.		E_{mean}/child	
		mSv	/1000 child.	[rank]	µSv	[rank]
Head and neck						
ACQL002	Brain SPECT scan, with dedicated PET camera	3.8	N.S.	[100+]	N.S.	[100+]
KCQL001	Thyroid gland scintigraphy with radioactive iodine uptake test	1.8	N.S.	[100+]	N.S.	[100+]
KCQL003	Thyroid gland scintigraphy	1.6	N.S.	[100+]	N.S.	[100+]
Chest and heart						
DAQL009	SPECT myocardial perfusion scan at rest, with SPECT myocardial perfusion scan after effort or pharmacological stress, ECG-synchronised	11	N.S.	[100+]	N.S.	[83]
GFQL002	Lung ventilation/perfusion SPECT	3.5	N.S.	[100+]	N.S.	[100+]
GFQL007	Lung perfusion scintigraphy	3.2	N.S.	[100+]	N.S.	[100+]
GLQL002	Alveolar-capillary permeability measurement with radioisotopes	3.8	N.S.	[100+]	N.S.	[100+]
Abdomen and pelvis						
FFQL001	Spleen scintigraphy by injection of a special radiotracer	1	N.S.	[100+]	N.S.	[100+]
HEQL001	Radionuclide detection of gastro-oesophageal reflux	0.6	N.S.	[100+]	N.S.	[100+]
HEQL002	Oesophageal transit scintigraphy with a solid or liquid	0.9	N.S.	[100+]	N.S.	[100+]
HFQL002	Gastric or duodenal transit scintigraphy with a solid or liquid without pharmacological stress	0.3	N.S.	[100+]	N.S.	[100+]
HFQL004	Gastric or duodenal transit scintigraphy with solids and liquids without pharmacological stress	0.6	N.S.	[100+]	N.S.	[100+]
JAQL001	Renal glomerular or tubular scintigraphy [Radioisotope renography] without pharmacological stress	1.3	N.S.	[100+]	N.S.	[100+]
JAQL002	Renal cortical scintigraphy	1	0.26	[84]	0.26	[53]
JAQL003	Renal glomerular or tubular scintigraphy [Radioisotope renography] with pharmacological stress	1.3	0.12	[96]	0.15	[68]
JAQL005	Renal glomerular or tubular scintigraphy [Radioisotope renography] without pharmacological stress, with anterograde pyelogram of the bladder	1.3	N.S.	[100+]	N.S.	[100+]
KEQL001	Adrenal gland scintigraphy	3.2	0.12	[95]	0.40	[47]

CCAM code	Procedure description	E/proc.	Proc. freq.		E_{mean}/child	
		mSv	/1000 child.	[rank]	µSv	[rank]
Whole body						
PAQL002	Whole body bone scintigraphy in several stages	4.4	0.47	[76]	2.07	[18]
PAQL003	Whole body bone scintigraphy in one pass [late scan]	4.4	0.08	[99]	0.36	[49]
PAQL005	Whole body bone scintigraphy segment by segment in several stages, without additional image acquisition by a pinhole collimator	4.4	0.09	[98]	0.40	[46]
PAQL007	Bone scintigraphy of a segment in several stages, with additional image acquisition by a pinhole collimator	4.4	N.S.	[100+]	N.S.	[78]
PAQL008	Bone scintigraphy of a segment in several stages, without additional image acquisition by a pinhole collimator	4.4	N.S.	[100+]	N.S.	[70]
PAQL010	Whole body bone scintigraphy segment by segment in several stages, with additional image acquisition by a pinhole collimator	4.4	N.S.	[100+]	N.S.	[90]
ZZQL016	Whole body SPECT scan, with dedicated PET camera	13	0.08	[99]	1.07	[31]
Other						
FEQL002	Platelet life span measurement with radioisotopes	5.5	N.S.	[100+]	N.S.	[84]
KGQL001	Measurement of plasma and urine radioisotope clearance	0.04	N.S.	[100+]	N.S.	[100+]
KGQL004	Measurement of plasma radioisotope clearance	0.02	N.S.	[100+]	N.S.	[100+]

Table XIII. List of CCAM codes for diagnostic interventional radiology.

CCAM code	Procedure description	E/proc.	Proc. freq.		E_{mean}/child	
		mSv	/1000 child.	[rank]	µSv	[rank]
Cardiac						
DDQH012	Coronary arteriography with left ventriculography, by percutaneous arterial catheterisation	9	N.S.	[100+]	N.S.	[69]
Vascular radiology						
DFQH001	Selective arteriography of the trunk and/or pulmonary artery branches, by percutaneous venous catheterisation	5	N.S.	[100+]	N.S.	[55]
DFQH002	Hyperselective arteriography of the pulmonary arteries, by percutaneous venous catheterisation	5	N.S.	[100+]	N.S.	[85]
DGQH002	Full arteriography of the abdominal aorta, by percutaneous arterial catheterisation	12	N.S.	[100+]	N.S.	[79]
DGQH006	Full arteriography of the thoracic aorta, by percutaneous arterial catheterisation	5	N.S.	[100+]	N.S.	[100+]
DHQH006	Full venography of the superior vena cava [Superior vena cavography], by percutaneous venous catheterisation	5	N.S.	[100+]	N.S.	[100+]
EBQH002	Selective arteriography of 3 or more cervico-cephalic axes, by percutaneous arterial catheterisation	5	N.S.	[100+]	N.S.	[76]
EBQH008	Arteriography of several cervico-cephalic axes, by multiple percutaneous intra-arterial injections	5	N.S.	[100+]	N.S.	[100+]
EZMH001	Secondary radiological permeability and/or position check of a vascular access device or a vascular stent, by contrast medium injection	0.1	N.S.	[100+]	N.S.	[100+]