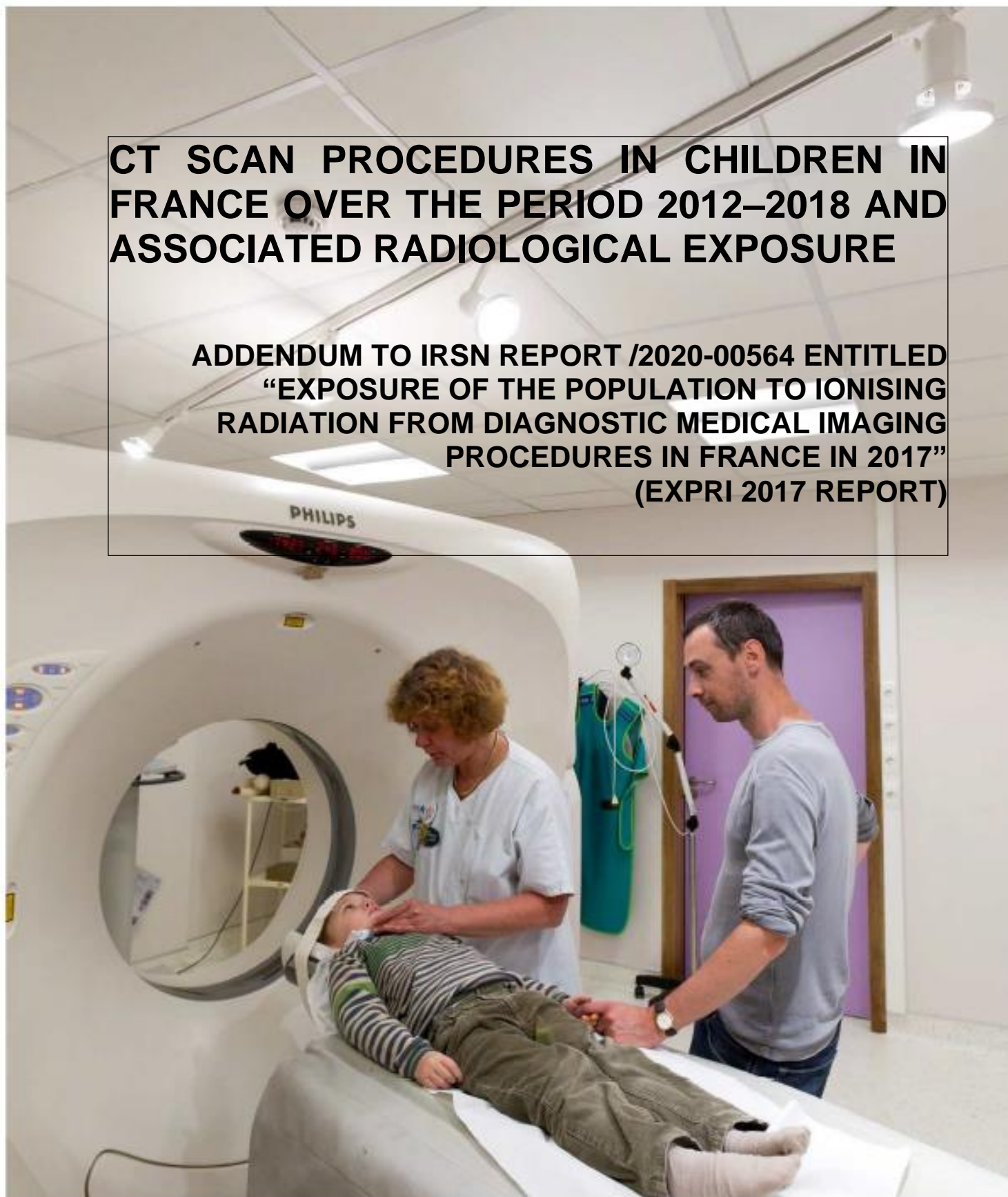


CT SCAN PROCEDURES IN CHILDREN IN FRANCE OVER THE PERIOD 2012–2018 AND ASSOCIATED RADIOLOGICAL EXPOSURE

ADDENDUM TO IRSN REPORT /2020-00564 ENTITLED
“EXPOSURE OF THE POPULATION TO IONISING
RADIATION FROM DIAGNOSTIC MEDICAL IMAGING
PROCEDURES IN FRANCE IN 2017”
(EXPRI 2017 REPORT)



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ABSTRACT

This report, produced by the French Institute for radiation protection and nuclear safety (IRSN), completes the "ExPRI 2017" study on the exposure to ionising radiation of the general population during diagnostic procedures in France in 2017. It describes the exposure of children under 16 during CT (computed tomography) procedures in France in 2012-2018. The study was based on procedures extracted from the "échantillon généraliste des bénéficiaires" (sample of persons who are protected by a health insurance in France), representative of 1/97 of the French population.

Over the period studied, the annual frequency of CT procedures is relatively constant (all ages and sexes combined) and fluctuates around an average of 13.7 ‰.

On average over this period, the frequency of CT procedures per year is highly variable according to the age of the child: around 15 ‰ for children under 1, less than 10 ‰ for those between 1 and 9, then it increases rapidly to reach more than 35 ‰ at 15 years old. Furthermore, the frequency of CT procedures is significantly higher in boys than in girls but with the same trend according to age.

In terms of anatomical area explored in CT, head and neck procedures are the most frequent (about 60 %). Overall, the proportion by anatomical area explored in CT is stable over the period studied. As CT and MRI (magnetic resonance imaging) have a large number of common indications and as the recommendations of professionals (in particular those of the French society of pediatric and prenatal imaging (SFIPP)) are moving towards a transfer to MRI of certain procedures (cerebral exploration for example), a study of the evolution

of MRI procedures was also carried out.

This study shows that, contrary to the CT, the annual frequency of MRI procedures increases significantly (+59 %) over the period studied and the frequency is higher for girls.

As in CT, head and neck procedures are the most frequent in pediatric MRI, with a proportion between 40 % and 45 % of procedures, relatively stable over the period studied. Limb procedures come in second place, with a proportion between 35 % and 40 %.

Over the period studied, the proportion of children having had at least one CT scan (exposed children) per year considered is relatively stable, at 1.1 % for all ages combined, with an average of 1.23 scan per exposed child. Among this population of children, between 11 % and 16 % had 2 or more CT scans depending on the year considered.

According to the pediatric data analyzed in the Diagnostic Reference Levels (DRL) system managed by IRSN, the doses received by children for a CT scan (for the brain, abdomen-pelvis and chest) show a decreasing trend between 2011-12 and 2016-18. However, due to the small amount of data collected during these periods, this decrease should be considered with caution. The new order of 23 May 2019 on DRL has included the obligation for establishments to send pediatric dosimetric data when more than 5 % of procedures on a given medical device concern pediatrics. This regulatory change has made it possible to obtain more data in pediatrics over the period 2019-2021. Their analysis, in the next DRL report to be published, will provide more precise information on the ionising radiation doses received by children.

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1. CONTEXT

The risk of long-term effects such as cancer from exposure of children to medical ionising radiation has been an active research topic for many years. As CT scan procedures are among the most irradiating diagnostic procedures, they have been the subject of particular interest and a large number of publications. Since the late 1990s, several of these publications, such as that of Brenner in 2001 [1], have reported excess numbers of cancers in the paediatric population based on excess risk calculations. At low doses, the dose-response relationship considered in several reports, such as BEIR VII (Biologic Effects of Ionizing Radiation, 7th report) [2] and ICRP publication 103¹ [3], is the linear no-threshold model. As the use of this model is regularly questioned in the light of advances in epidemiology and radiobiology (see report from the Nuclear Regulatory Commission [4], for example), these figures have been hotly contested. However, during the last decade, several epidemiological cohort studies dedicated to childhood exposure to CT scan procedures have been published ([5]–[10]). Most of these studies only look at the risk of brain tumours and leukaemia. For these two types of cancer, the results show a statistically significant excess risk overall, although the number of cancer cases remains low. As for other cancer locations, only the study by Mathews et al [6] considers these, the other studies having too few cancer cases for an analysis.

In addition, there are potential confounding factors in the above studies that may bias the results by attributing the occurrence of cancers to exposure to CT scans, whereas the cancers may be related to genetic or other conditions predisposing individuals to the occurrence of cancers, these underlying conditions being the very reason the scans were performed. In addition, uncertainties in dosimetric reconstruction may also impact the dose-response estimate.

It was in particular to try to take into account these potential methodological limitations that the European EPI-CT study² was launched in 2011. By combining 9 national cohorts (Belgium, Denmark, France, Germany, Great Britain, the Netherlands, Norway, Spain and Sweden), more than one million patients were included in this meta-cohort. The follow-up covered the period 1990–2013 (this period varies from country to country, generally starting between 1990 and 2000 and ending in 2013). Numerous precautions were taken to minimise potential bias due to these confounding factors. The results of this study are expected to be published in the coming months.

The majority of children included in the EPI-CT study had CT scans in the decade 2000–2010 and inclusion ended in 2012. However, the technology of these medical imaging devices has improved significantly since then, leading to a reduction in the dose delivered.

This report, prepared by the Institute for Radiation Protection and Nuclear Safety (IRSN), looks at evolution in the number of CT scan procedures performed on the French paediatric population between 2012 and 2018, the most recent data available in the national health data system (SNDS) at the time the report was written. It is an addendum to the previous ExPRI report (ExPRI 2017 [11]), which presented the exposure of the general population to ionising radiation due to diagnostic procedures for the year 2017 only, focusing on evolution over several years in CT scan procedures for children.

¹ International Commission on Radiological Protection

² “Epidemiological study to quantify risks for paediatric computerized tomography and to optimise doses” <https://epi-ct.iarc.fr/>

2. MATERIALS AND METHODS

To carry out this study, IRSN relied on data available in the generalist sample panel of health insurance beneficiaries accessible via the secure portal of the SNDS of the French Health Insurance Body (CNAM). As each medical procedure is associated with a specific code, it is possible to carry out the necessary queries to study the evolution in the number of paediatric CT scan procedures over a defined period.

2.1 THE GENERALIST SAMPLE PANEL OF HEALTH INSURANCE BENEFICIARIES (EGB)

The SNIIRAM decree³ of 20 June 2005 made it possible to create a national sample representative of 1/97 of the beneficiaries of the health insurance scheme (general scheme excluding local healthcare mutual sections), in terms of age and sex, called the generalist sample panel of health insurance beneficiaries (EGB). This is a permanent sample of beneficiaries, linking their administrative and socio-demographic characteristics to their “consumption” of care over time (this consumption may be equal to zero).

EGB data is accessed via a secure CNAM internet portal. Since the end of 2016, IRSN has had permanent access by decree [12] as part of its public service missions, and in particular for writing of the periodic report on the exposure of the population to ionising radiation due to diagnostic medical imaging procedures (EXPRI report) and its addenda.

2.2 IDENTIFICATION OF PROCEDURES: THE COMMON CLASSIFICATION OF MEDICAL PROCEDURES (CCAM)

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

The CCAM ensures that diagnostic procedures are unambiguously identified from one another. Each type of procedure is identified by a complete description and a code composed of four letters and three digits: for example, the CCAM code ACQK001 corresponds to the description “CT scan of the skull and its contents, without injection of contrast”.

2.3 COUNTING PROCEDURES

The consumption of care by each beneficiary is periodically entered in the EGB using billing data from the SNIIRAM. Since June 2011, the SNIIRAM has included reimbursement data for healthcare services (outpatient care) as well as public and private hospital data, thanks to the integration of additional data from the PMSI (Programme de médicalisation des systèmes d'information [Programme for the Medicalisation of Information Systems]) of the ATIH (Agence technique de l'information sur l'hospitalisation [Technical Agency for Information on Hospitalisation]). The CCAM is used to code the procedures performed. As each beneficiary included in the EGB is identified by his or her encrypted NIR⁴, it is therefore possible, while respecting the anonymity of the patients, to reconstruct the care pathway, whether it was carried out by a professional practising in the private or public sector and whether it took place in a practice or in hospital.

2.4 STUDY METHOD AND CHARACTERISTICS

2.4.1 Data analysed

The data analysed in this study are taken from the extraction of all CT scan procedures performed on children under 16 years of age (at the time the procedure was performed, to the nearest month) and recorded in the EGB from 2012 to 2018.

The data are processed independently year by year in order to estimate the variation of the different indicators over the whole period studied.

³ *Système national d'information interrégimes de l'Assurance maladie* (French inter-regime health insurance information system)

⁴ *Numéro d'inscription au répertoire national des personnes physiques* (Registration number in the national register of natural persons, the social security number)

Only beneficiaries of the general regime (RG), the social regime for the self-employed (RSI) and the agricultural social insurance mutual benefit fund (MSA) are included. Beneficiaries of local healthcare mutual fund sections (SLM), which were only gradually integrated into the EGB from 2015 onwards, are not taken into account. This choice avoids introducing an artificial bias in the annual comparisons by keeping the representativeness of the EGB in relation to the general population constant over the period 2012–2018.

The population considered was studied in 5-year age groups (or by year when the information was relevant), in accordance with the recommendations of European report No. 154 [13], with a specific group for children under one year old, given the particular morbidity of this age group.

2.4.2 Technical characteristics for the extraction of data of interest

Queries were carried out using the SAS Enterprise Guide 7.1 software on the databases of the national health data system (SNDS) to extract the EGB CT scan procedures performed over the years 2012–2018, as well as data relating to the beneficiaries (sex and age at the time of the procedure).

In practice, as the day of birth of the beneficiaries is not available in the EGB to avoid any re-identification, the age of the beneficiaries at the time of the diagnostic procedure is calculated to the nearest month, then rounded up. For example, a child born in February 2016 and having a radiological procedure in February 2017 is considered to be 12 months old at the time of the procedure, whereas their real age may be 11 or 12 months depending on whether the day of the procedure is before or after their birthday.

Paediatric procedures extracted include:

- procedures performed in the private sector, i.e. by practitioners in private practices, full-time hospital private practitioners, as well as practitioners working as a salaried employee in a privately-funded institution, which therefore includes procedures performed in local practices and in private healthcare institutions (during hospital stays or outpatient care);
- procedures performed during hospital stays in public healthcare institutions;
- procedures performed during outpatient care in public healthcare institutions.

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:
 - the care sector (private, public inpatient and outpatient);
 - the CCAM code and the description of the procedure;
 - the month and year it was performed.

2.4.3 Quantity used: procedure frequency (per 1,000 individuals)

Procedure frequency is defined as the number of CT procedures performed annually in a given population. For example, if in a population of n children aged 6 to 10 years old, m scans are performed during one year, the procedure frequency F , expressed per 1,000 individuals, will be $F = \frac{m}{n} \times 1000$ and is expressed in ‰. It should be noted that it is not taken into account whether the procedures concern the same individual or not. All results presented in this report, unless otherwise stated, are expressed in procedure frequency. This method makes it possible to avoid the influence of the age pyramid and differences by sex on the number of procedures. If the objective is to compare a number of CT scan procedures between boys and girls, this comparison must be carried out with constant numbers of boys and girls (for example 1,000 boys versus 1,000 girls). The same reasoning applies if the objective is to compare a number of procedures between two populations of different ages.

3. QUANTITATIVE EVOLUTION IN PAEDIATRIC CT SCAN PROCEDURES IN FRANCE OVER THE PERIOD 2012–2018

3.1 CT SCAN PROCEDURE FREQUENCY IN THE PAEDIATRIC POPULATION

3.1.1 Average frequencies over the period 2012–2018

Overall, the frequency of CT procedures varied greatly according to the age of the child. Sex is also an important factor, although less of a determining factor than age. For more details on this point, the reader may refer to the paediatric ExPRI study published by IRSN in 2018 on data from 2015⁵. Figure 1 below shows the average annual procedure frequencies observed between 2012 and 2018, according to the age of the child at the time of the procedure. To clarify the meaning of Figure 1 below with an example: over the period 2012–2018, on average per year, about 9 CT scan procedures were performed on a population of 1,000 children 5 years old at the time of the procedure.

The frequency is slightly above 15 procedures per 1,000 children under 1 year of age, then below 10% and relatively constant until the age of 9. The procedure frequency then gradually increases to more than 35 procedures per 1,000 children aged 15 years old.

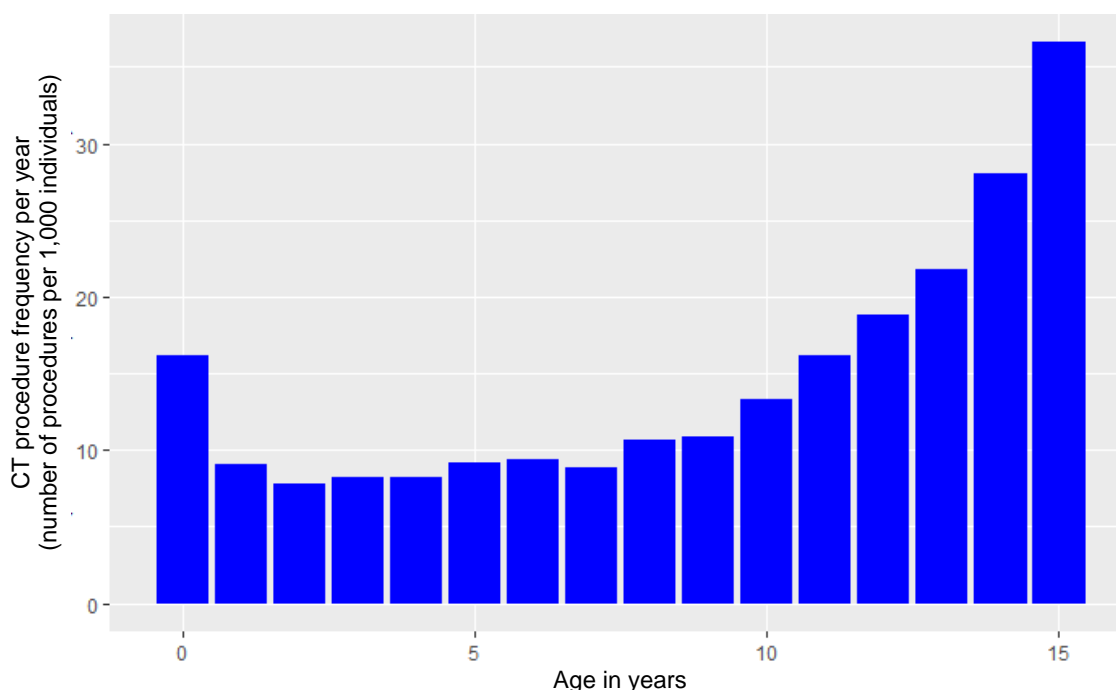


Figure 1: CT procedure frequency over one year (number of procedures per 1,000 individuals) according to age of the child (at the time of the procedure), on average over the period 2012–2018.

The CT scan procedure frequency also depends on the child's sex, but to a lesser extent than on the child's age. Figure 2 below shows that the CT scan frequency was higher for boys than for girls for all ages (except 15 years old, where it is almost equivalent). However, these differences remain moderate and the distributions are fairly similar between the two sexes. To clarify the meaning of Figure 2 below with an example: on average over the period 2012–2018, 10 CT scan procedures were performed per year in 8-year-old girls for a population of 1,000 girls of the same age.

⁵ https://www.irsn.fr/EN/publications/technical-publications/Documents/IRSN_PSE-SAN-SER-2018-00004_2015-Expri-paediatric-study_072019.pdf

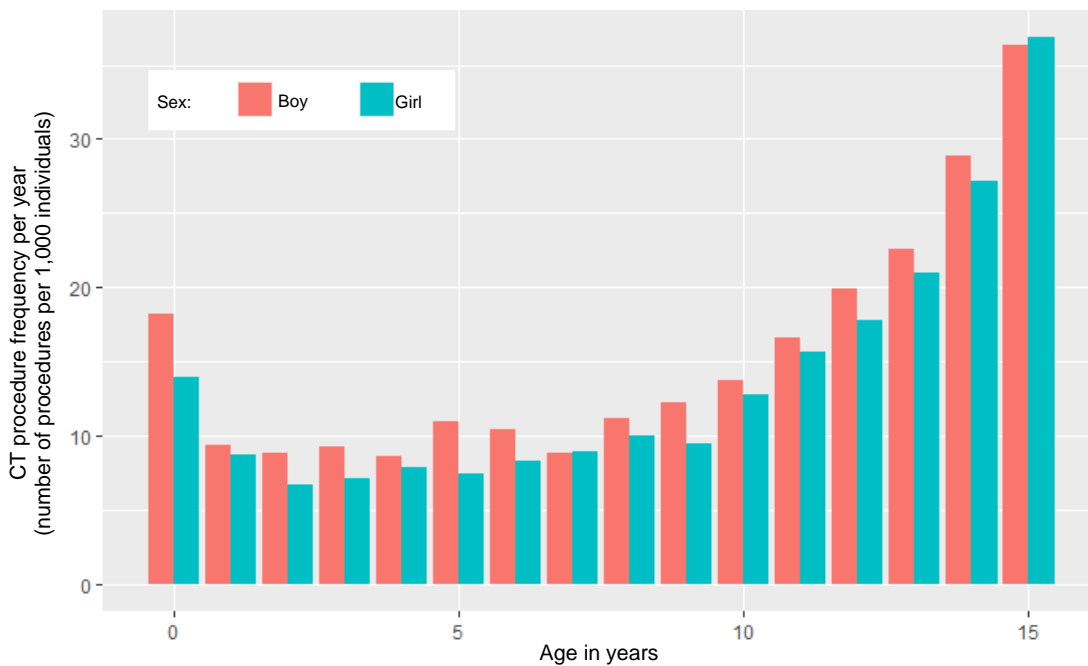


Figure 2: CT scan frequency over a year (number of procedures per 1,000 individuals) according to the child's age (at the time of the procedure) and sex, on average over the period 2012–2018.

The CT scan frequency varies greatly with the age of the child: from less than 10‰ between 1 and 9 years old, then more than 35‰ at 15 years old. It is worth noting the relatively high frequency in children under 1 year of age (about 15‰) and the significantly higher frequency in boys than in girls.

3.1.2 Evolution in CT scan procedure frequency over the period 2012–2018

Figure 3 below compares the annual procedure frequencies observed between 2012 and 2018 for the paediatric population of all ages. To clarify the meaning of Figure 3 below with an example: in 2012, 12.5 CT scan procedures were performed on girls out of a population of 1,000 girls under 16 years of age at the time the scan was performed.

There is no clear trend in the overall procedure frequency (i.e. boys and girls combined): it is relatively constant and fluctuates around an average value of 13.7 ‰. The frequency for girls was slightly lower (12.9‰) and also does not seem to have any clear trend over the 7 years studied. The procedure frequency among boys was slightly higher and seems to have a slightly upward trend (+3.8% between 2012 and 2018).

A study of the evolution in procedure frequency by child age group (see Figure 4 below) showed significantly different trends:

- the differences between boys and girls were smaller and the trend is similar for the age groups 1–5 and 6–10. In both groups, the trend is towards a slight decrease in procedure frequency;
- in the 11–15 age group, the differences between boys and girls tend to increase; a clear increase in CT scan frequency for boys and a near stability for girls was observed;
- for children under one year of age, the frequency varied greatly from one year to the next, with no clear trend emerging. It should be remembered that these variations were probably due to statistical uncertainty, since, on the one hand, the number of children under one year of age in the EGB is relatively small (a few thousand), and on the other hand, the number of CT scans per year for this population is very small (around 110 CT scans per year on average).

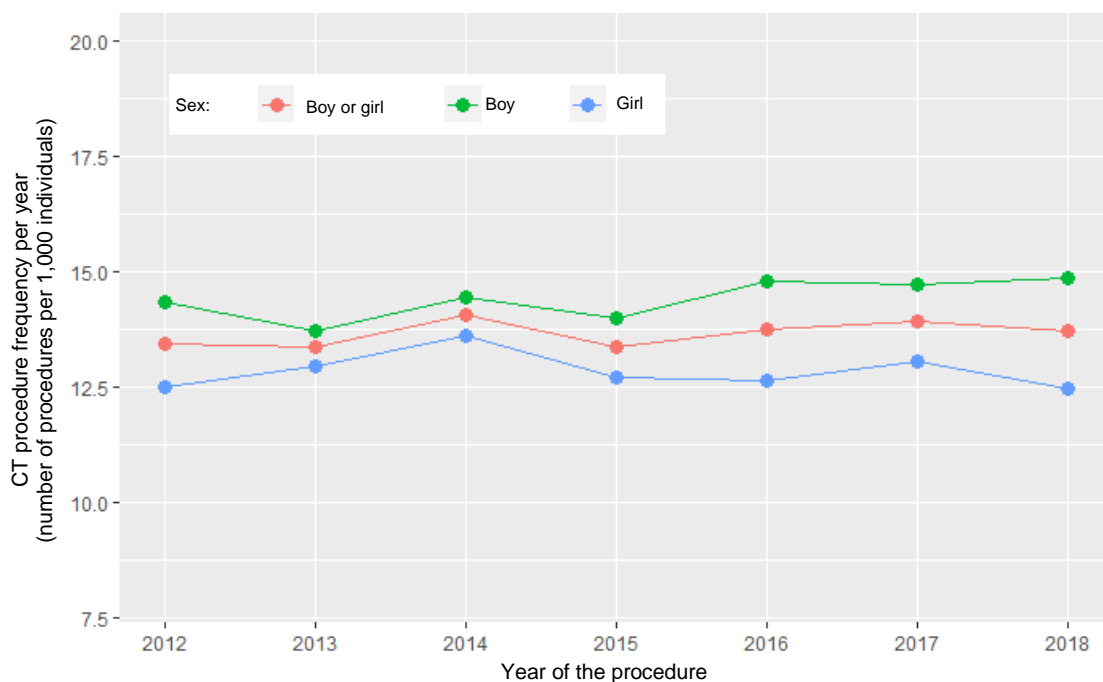


Figure 3: Evolution over the period 2012–2018 in CT procedure frequency per year (number of procedures per 1,000 individuals) for girls, boys and both.

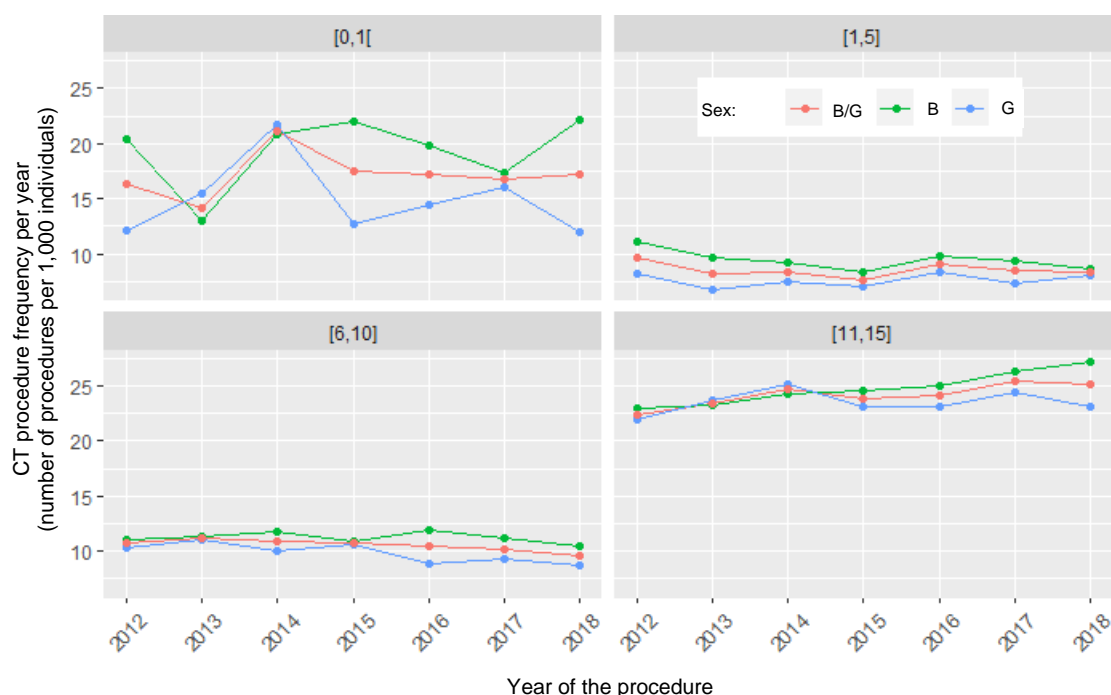


Figure 4: Evolution over the period 2012–2018 in CT procedure frequency per year (number of procedures per 1,000 individuals) for 4 age groups (under 1 year, 1 to 5 years old, 6 to 10 years old, 11 to 15 years old), for girls, boys and both.

3.1.3 Comparison with the evolution in MRI (magnetic resonance imaging) procedure frequencies

It is interesting to compare the evolution in CT procedure frequency with that of MRI procedures. These two procedures have many common indications and professionals (in particular the French Society of Paediatric and Prenatal Imaging (SFIPP)⁶) recommend a transfer to MRI of certain procedures (cerebral exploration for example). Figure 5 below shows the annual MRI procedure frequency in children between 2012 and 2018, overall (red curve) and for each sex (green and blue curves). **Unlike with CT scans, the use of MRI showed very clear growth: +59% growth over the period 2012–2018.** The overall MRI procedure frequency, which

⁶ <https://sfip-radiopediatrie.org/irm-encephale/>

was significantly lower than that of CT scans in 2012 (10.6‰ vs. 13.3‰, respectively), exceeds the latter starting in 2016 (13.8‰ vs. 15‰, respectively). However, the MRI procedure frequency for boys still remained lower than that of CT scans in 2018 (14.4‰ vs. 14.9‰, respectively).

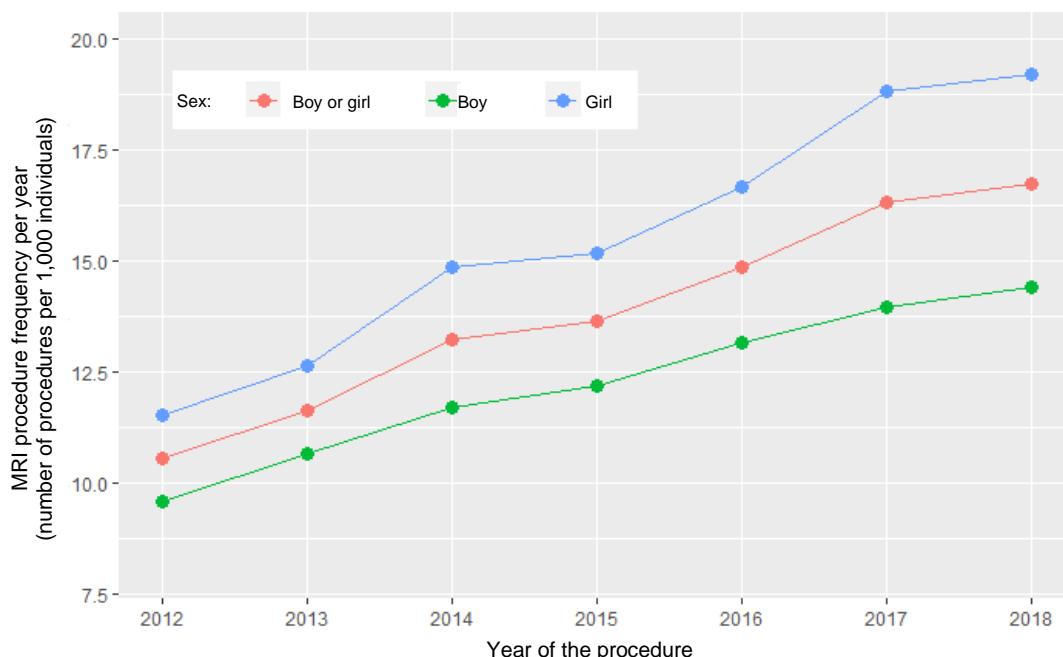


Figure 5: Evolution over the period 2012–2018 in MRI procedure frequency per year (number of procedures per 1,000 individuals) for girls, boys and both.

The evolution by age group, presented in Figure 6 below, showed some notable differences and similarities with the evolution in CT procedure frequency:

- the MRI procedure frequency was approximately equivalent to that of CT procedures in the 1–5 and 6–10 age groups. It has been significantly higher since 2015 for children under 1 year old and significantly higher since 2014 in the 11–15 age group;
- the increasing trend in MRI procedures is observed for all age groups, but is much more marked for the 11–15 age group;
- the difference in frequency is in favour of girls for the 6–10 and 11–15 age groups, with a very marked difference for the latter.

The CT scan procedure frequency has been stable overall since 2012. CT scans do not have the same change trends as MRI scans for the paediatric population, particularly for older children. Overall, boys have more frequent CT scans than girls, contrary to what is observed for MRI. This study of MRI procedures was carried out because of the common indications with CT scans and the fact that professional societies (in particular the SFIPP) are recommending a transfer from CT scans to MRI for certain procedures (e.g. cerebral exploration).

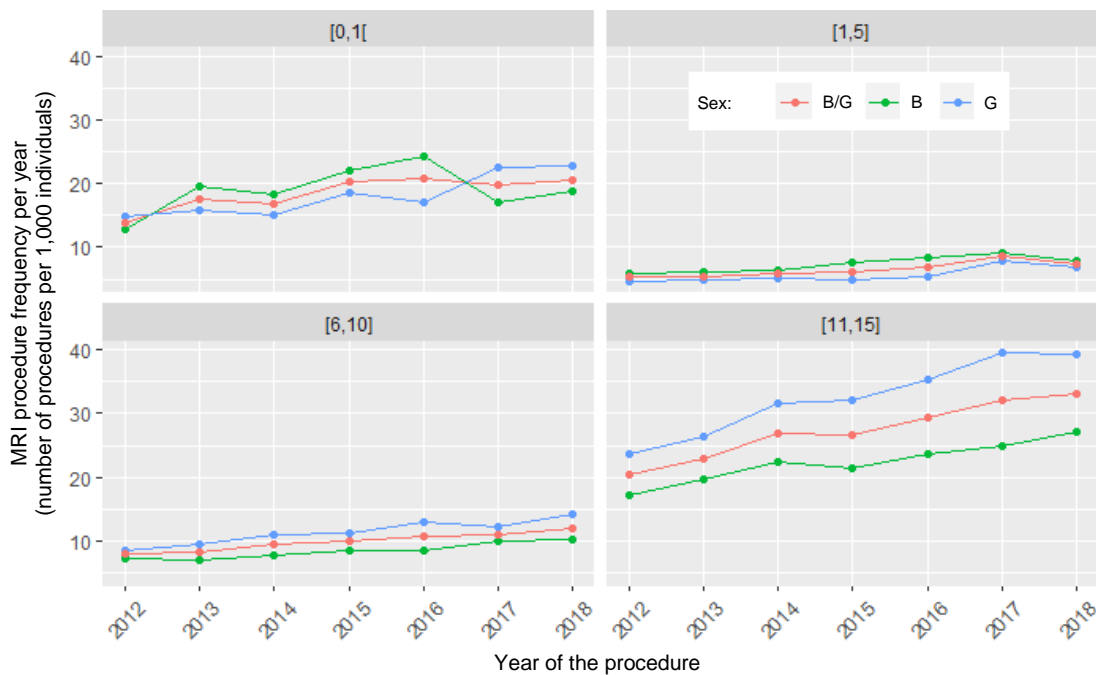


Figure 6: Evolution over the period 2012–2018 in MRI procedure frequency per year (number of procedures per 1,000 individuals) for 4 age groups (under 1 year, 1 to 5 years old, 6 to 10 years old, 11 to 15 years old), for girls, boys and both.

3.2 DISTRIBUTION OF CT SCAN PROCEDURES BY ANATOMICAL AREA

3.2.1 Evolution in the distribution of CT scan procedures over the period studied

Figure 7 below shows the evolution over the period 2012–2018 of the anatomical distribution of CT scan procedures overall (all ages and sexes). **Head and neck scans are by far the most common procedure, though their proportion showed a downward trend (60% in 2012, 56% in 2018).** Procedures on the abdomen and/or pelvis, on the limbs and on the chest and heart had roughly equal proportions, around 10% each. No clear trend for these procedures was observed over the period 2012–2018. Procedures on the spine were stable overall, with a proportion of around 5%. Finally, procedures involving multiple areas (mainly chest-abdomen-pelvis) were the least common, but their proportion seems to be growing steadily.

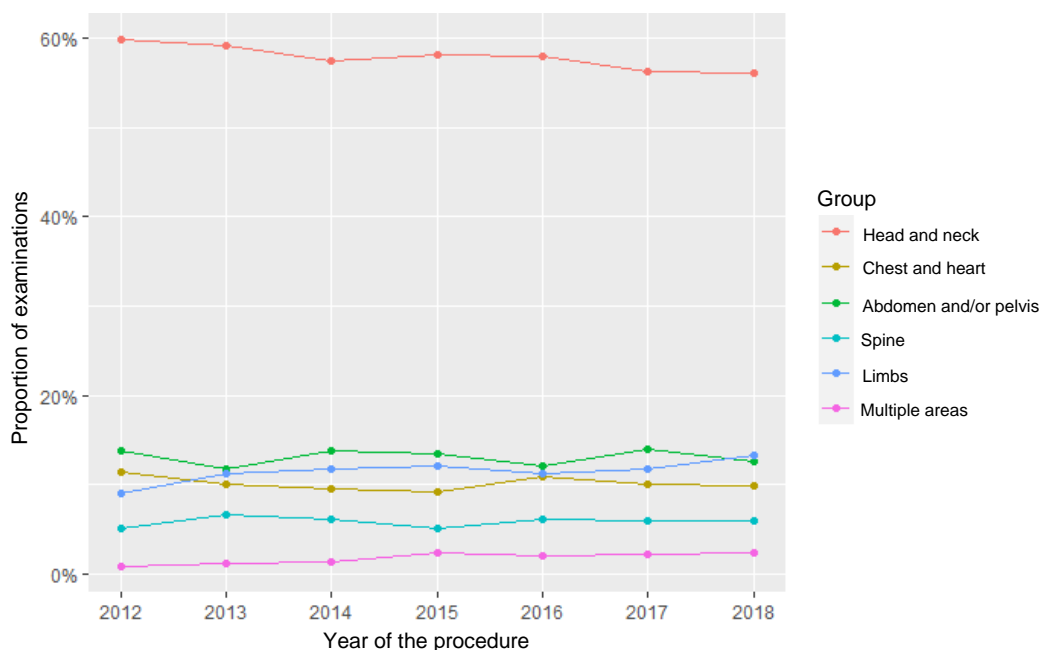


Figure 7: Evolution over the period 2012–2018 in distribution of CT scan procedures according to procedure group (anatomical area)

The distribution of procedures by age group, as shown in Figure 8 below, shows that:

- among the youngest children (under 6 years), the proportion of head and neck procedures was higher than for older children, and the overall trend of a decrease in the share of these procedures over the period 2012–2018 was not observed. Chest or heart procedures were the second most common in this population, with a share of 15–20%, which remained fairly stable from 2012 to 2018. All other areas represented less than 10% of the procedures and show no clear trend;
- among older children (aged 6 years and older), a decrease in the proportion of head and neck procedures was observed over the period 2012–2018, as for the overall paediatric population (see Figure 7 above). The other groups of procedures were either stable or slightly grew, representing, each, less than 20% of procedures.

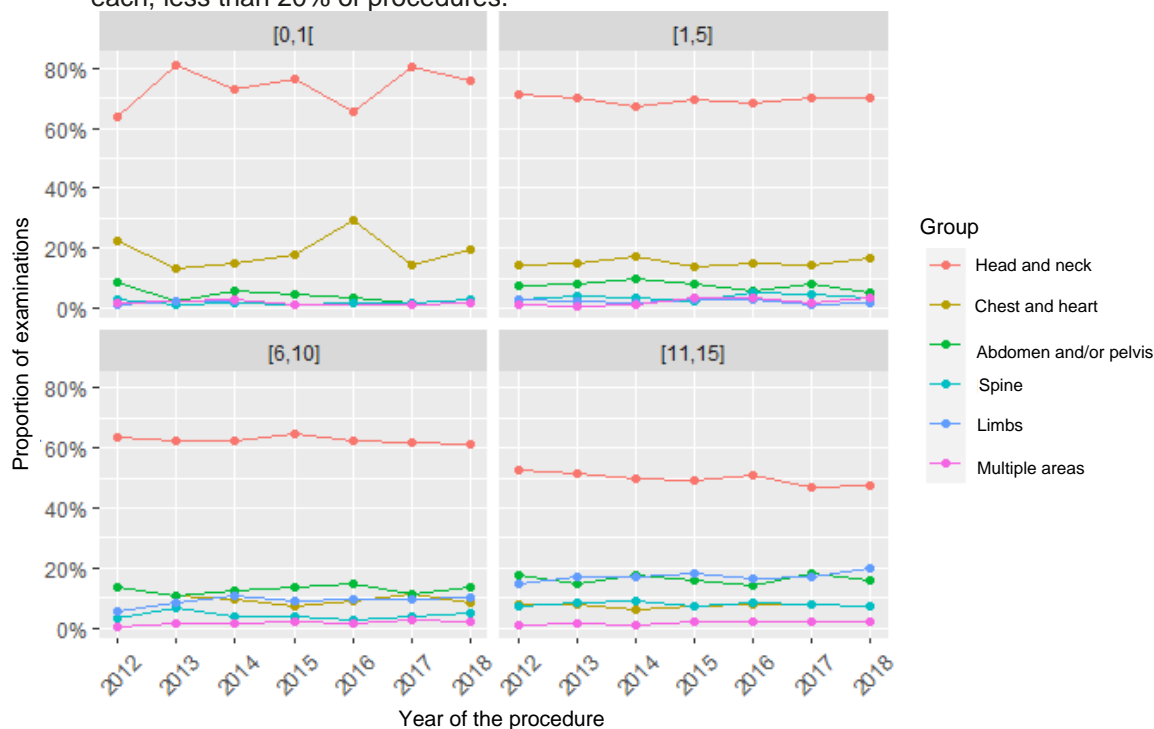


Figure 8: Evolution over the period 2012–2018 in the distribution of CT scan procedures according to procedure group (anatomical area), for 4 age groups (under 1 year, 1 to 5 years old, 6 to 10 years old, 11 to 15 years old)

3.2.2 Comparison with evolution in the distribution of MRI procedures

To put the evolution observed for CT scans into perspective, Figure 9 below represents the proportions of each anatomical group in relation to the total number of annual MRI procedures. As with CT scans, but in a smaller proportion, procedures involving the head and neck were in the majority in paediatric MRIs with a proportion varying between 40 and 45%, and a decreasing trend over the period studied (compared to 56–60% for CT scan procedures).

Procedures involving the limbs were the second most represented anatomical group, with a proportion of total procedures varying between 35 and 40%. This proportion also remained roughly stable annually. The other groups represented, respectively, about 10% for the spine, 4–8% for the “Other” group⁷, and less than 5% for the other groups. The proportion of all these groups of procedures was roughly constant over the period 2012–2018.

The distribution of MRI procedures according to the child age groups, visible in Figure 10 below, does not show any obvious evolution over the period studied. Head and neck procedures represented the overwhelmingly majority among children under 6 years of age, and the majority among 6–10 year olds. Among 11–15 year olds, procedures involving limbs predominated.

⁷ This group consists almost entirely of the CCAM code ZZQN001 - Magnetic Resonance Imaging [MRI] with 6 or more sequences, which is generally used for procedures involving multiple anatomical areas

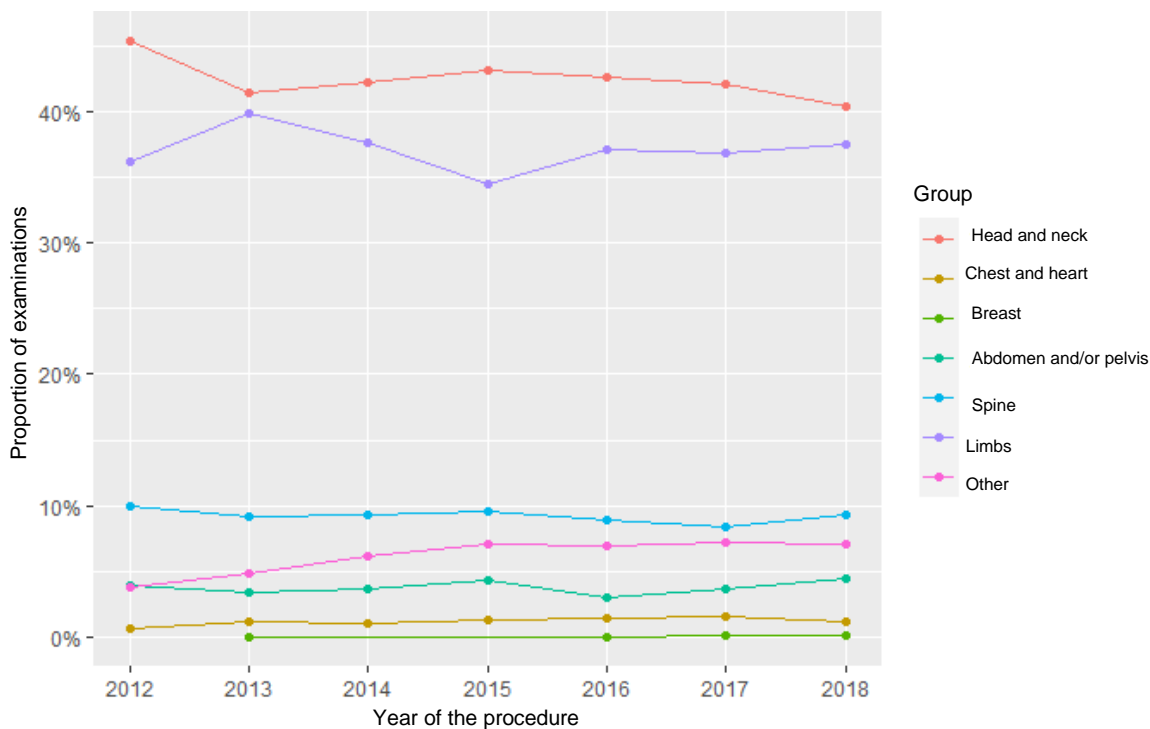


Figure 9: Evolution over the period 2012–2018 in the distribution of MRI procedures by procedure group (anatomical area)

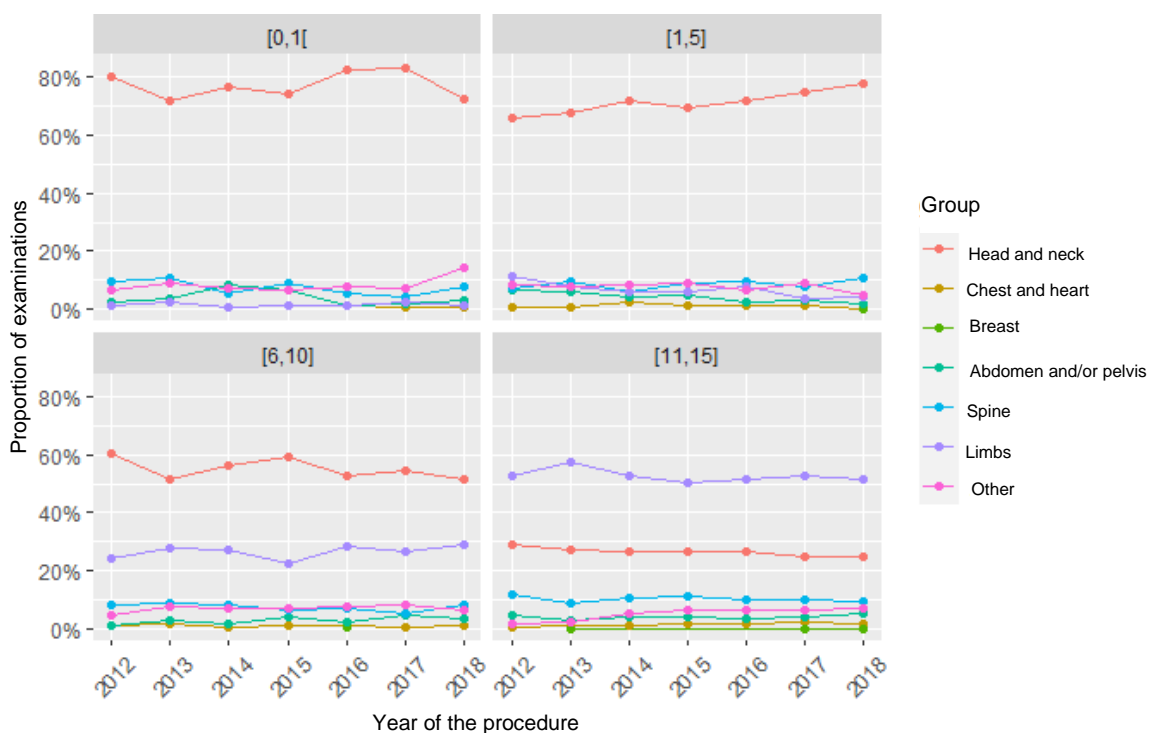


Figure 10: Evolution over the period 2012–2018 in the distribution of MRI procedures according to procedure group (anatomical area), for 4 age groups (under 1 year, 1 to 5 years old, 6 to 10 years old, 11 to 15 years old)

As the frequency of MRI procedures increased significantly over the period studied, as indicated in paragraph 3.1.3 above, it is interesting to compare the frequencies of the different types of CT and MRI procedures directly, as shown in Figure 11 below. It is clear that most of the growth in the number of MRI procedures is related to those involving the head and neck and limbs. It is likely that part of the increase observed for MRI procedures involving the head and neck is related to a move away from CT scan procedures, although it is not possible to confirm this based on this information alone.

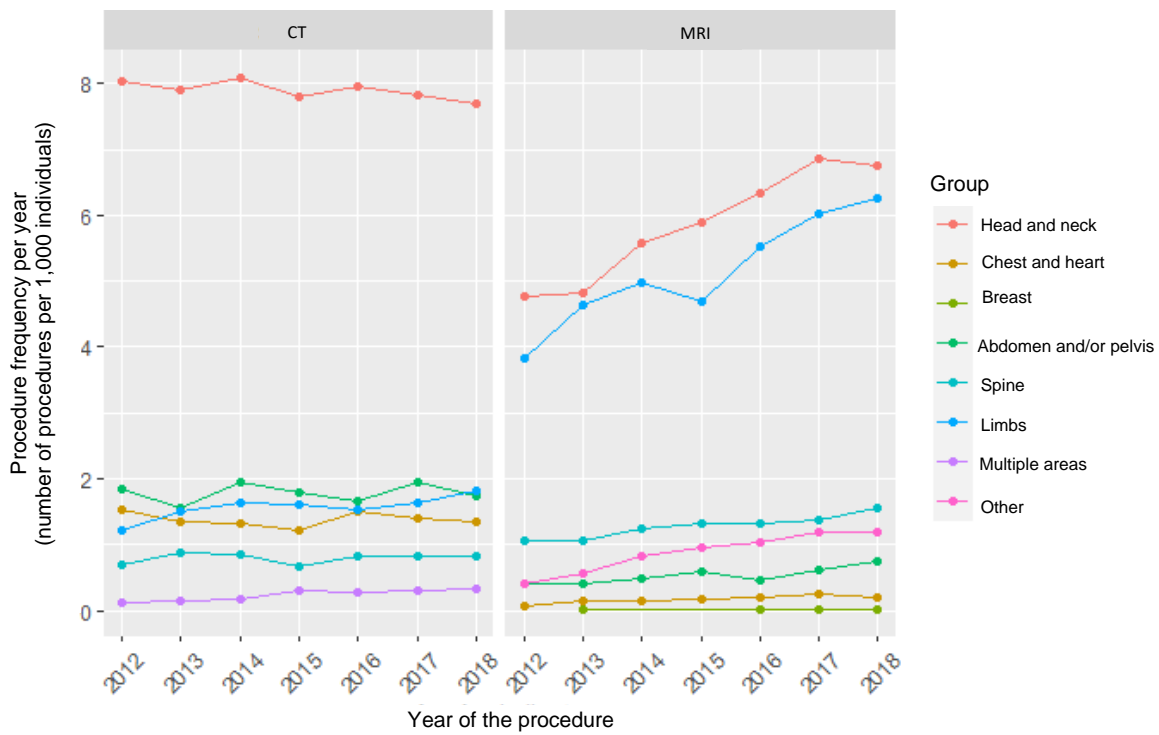


Figure 11: Evolution over the period 2012–2018 in procedure frequency (number of procedures per 1,000 individuals) according to the procedure group (anatomical area): CT/MRI comparison

4. EVOLUTION IN THE TOTAL NUMBER OF CT SCANS PER CHILD OVER THE PERIOD 2012–2018

The data presented in this section only concern children who were actually exposed to a CT scan, i.e. those who received at least one CT scan during the year in question. These children are referred to as “patients” below. The data are therefore annual totals per patient, for each of the years in the period studied.

4.1 PROPORTION OF CHILDREN EXPOSED TO A CT SCAN

The proportion of children exposed to CT scans annually, i.e. the percentage of children who had one or more CT scans in the year in question, is an indicator that is similar to but different from the procedure frequencies presented in Part 3 of this report. To illustrate, Figure 12 below shows that, in 2014, the proportion of children exposed to CT scan was 1.15% (red curve). This means that 1.15% of children, or 11.5 per one thousand children (11.5‰), had at least one CT scan in the year. This proportion can be compared with the corresponding procedure frequency in 2014 for the whole population of children under 16, whether exposed or not, which is about 14‰ (see Figure 3 above). The difference between these two figures indicates that some procedures were performed on the same children as part of their medical care.

4.1.1 Proportion, all ages

Figure 12 below shows the proportion of children in the EGB who had at least one CT scan procedure in the year. This proportion was relatively stable **between 2012 and 2018: about 1.1% of children had one or more CT scans in the year**. This proportion was slightly higher for boys (1.14% on average over the period 2012–2018) than for girls (1.04%).

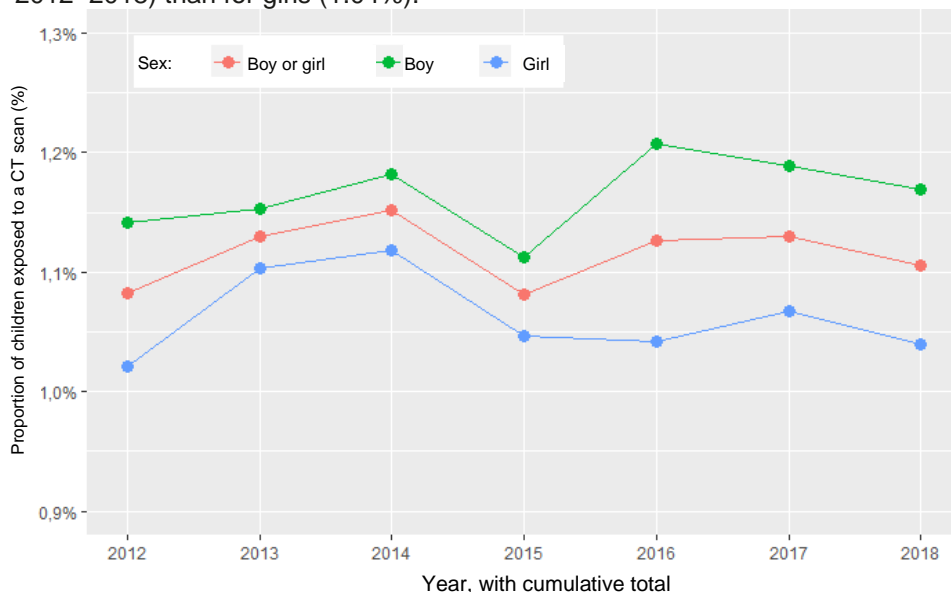


Figure 12: Evolution over the period 2012–2018 in the proportion of children exposed to a CT scan, for girls, boys and both

4.1.2 Proportion by age group

The proportion of children exposed to CT scan varies with age, as observed in Figure 13 below. Less than 1% of children aged 1–10 years had at least one CT scan in a year, while the figure was around 2% in the 11–15 age group.

The case of children under 1 year old is special: the proportion seems to have increased between 2012 and 2018, from about 1.1% to 1.5%. Moreover, the gap between boys and girls seems to be widening: 1.8% vs. 1.1% in 2018. However, these two observations about children under 1 year old must be considered in context with the statistical uncertainty due to the small number of children under 1 year old in the EGB and the very small number of procedures: less than one hundred children under 1 year old had a CT scan procedure, per year, over the period 2012–2018.

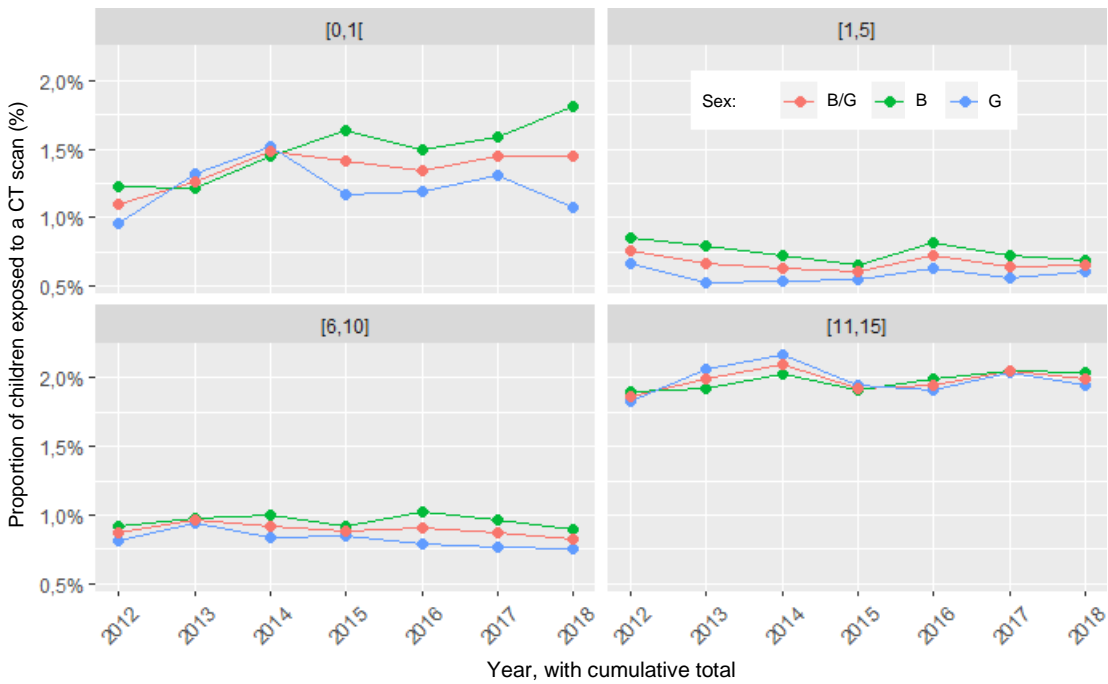


Figure 13: Evolution over the period 2012–2018 in the proportion of children exposed to a CT scan, for 4 age groups (under 1 year, 1 to 5 years old, 6 to 10 years old, 11 to 15 years old), for girls, boys and both

4.1.3 Number of CT scan procedures per patient

Figure 14 below shows the average annual number of CT scan procedures per patient, by sex. To clarify the meaning of Figure 14 below with an example: in 2018, out of the population of girls who had one or more CT scan procedures, the average number of CT scans was 1.2.

This number was relatively stable over the period studied and close to 1.23 CT scan procedures per year. It was always slightly higher for boys (1.24 on average over the period) than for girls (1.21 on average).

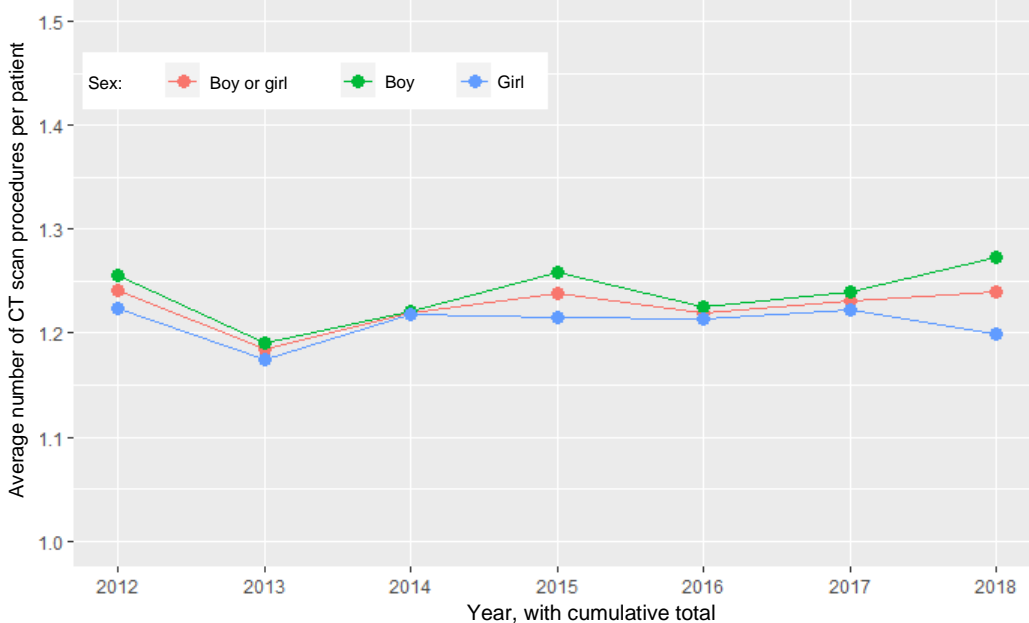


Figure 14: Evolution over the period 2012–2018 in the average annual number of CT scan procedures per patient, for girls, boys and both

4.2 PATIENTS WHO HAD AT LEAST TWO CT SCAN PROCEDURES IN ONE YEAR

Figure 15 below shows the proportion of patients who had more than one CT scan in a year. To clarify the meaning of Figure 15 below with an example: in 2016, out of the population of children under 16 who had at

least 1 scan, 15% had 2 or more.

The vast majority of patients had only one CT scan in the year. The percentage of patients who had multiple CT scans varied between 11 and 16% depending on the year, with no clear trend. The small visible differences between boys and girls do not seem to be interpretable. Statistical uncertainty should not be ruled out due to the small number of children and the very small number of procedures (about 100 patients of each sex had more than one annual CT scan procedure in the EGB).

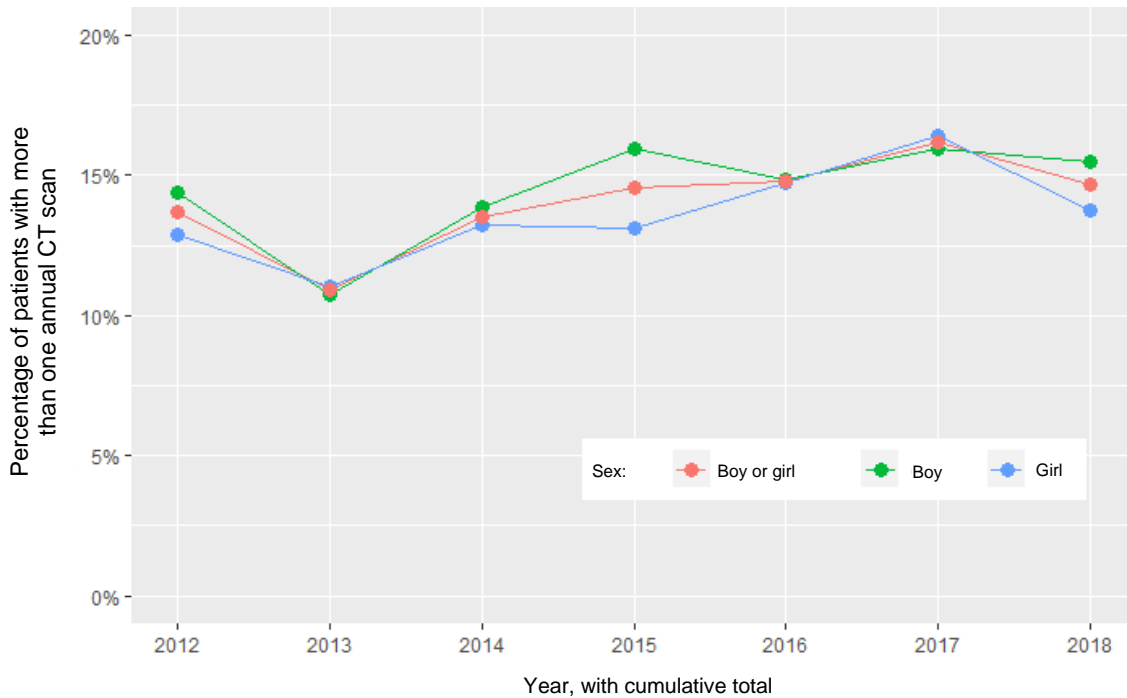


Figure 15: Evolution over the period 2012–2018 in the percentage of patients having more than one CT scan procedure per year, for girls, boys and both

5. EVOLUTION IN CT DOSE INDICES FOR CHILDREN OVER THE PERIOD 2012–2018

The Diagnostic Reference Level (DRL) system, managed by IRSN in France⁸, collects paediatric dose data for some CT scan procedures. Figure 16 below shows the average dose-length product (DLP) values for the procedures “Brain (10 kg)”, “Abdomen-pelvis (20 kg)” and “Chest (20 kg)” for three different periods: 2011–2012, 2013–2015 and 2016–2018. A clear decrease in dosimetric indices for these three procedures can be observed: the decreases between 2011–12 and 2016–18 are, respectively, 35% for the brain, 42% for the abdomen-pelvis and 45% for the chest.

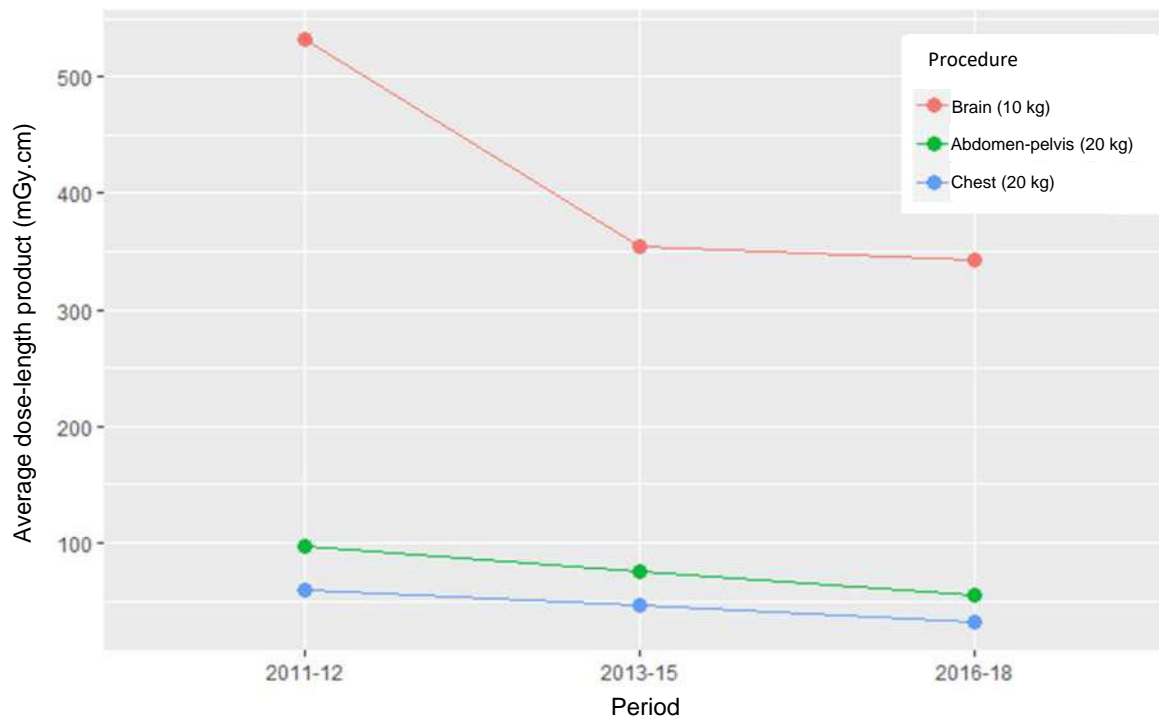


Figure 16: Dosimetric evolution from CT scans (Dose-Length Product) in children, for 3 anatomical areas (brain 10 kg, abdomen-pelvis 20 kg and chest 20 kg) monitored within the DRL system

It should be noted that the paediatric data recorded in the DRL system are very fragmentary, as the number of radiology departments that have sent these data to IRSN is very low: 3 in 2011–12 and 10 in 2016–18 for chest CT, 3 in 2011–12 and 11 in 2016–18 for brain and 2 in each of the 3 periods for abdomen-pelvis. The decreases noted should therefore be considered with caution, but they are nevertheless consistent with the downward trend in CT dose indices for the adult population (see 2016–2018 IRSN report on DRLs⁹). The new order of 23 May 2019 [14] relating to DRLs includes an obligation to send paediatric dose assessments when more than 5% of procedures on a given medical device are on children. This regulatory change made it possible for IRSN, over the period 2019–2021, to obtain a greater number of dose assessments for children for CT scans than it had in the period 2016–2018. The number of paediatric dose assessments is shown in Table 1 below: overall, the number of assessments and institutions sending these data slightly more than doubled between 2016–2018 and 2019–2021. The next IRSN report on DRLs will cover this last period and will consolidate knowledge of the ionising radiation doses received by children.

⁸ <https://nrd.irsn.fr/>

⁹ https://www.irsn.fr/FR/expertise/rapports_expertise/Documents/radioprotection/IRSN_NRD-Report-2016-2018_202009.pdf

Table 1: Number of paediatric dose assessments received by IRSN under the DRL system in 2016–2018 and 2019–2021 and number of institutions that sent these data.

Field	Item measured	2016–2018	2019–2021
CT scan	Number of institutions	23	49
CT scan	Number of dose assessments	90	202
All (conventional radiology, CT scan, nuclear medicine)	Number of dose assessments	305	747

CONCLUSION

The study conducted by IRSN on exposure of children under 16 years of age to ionising radiation due to CT scan procedures in France over the period 2012–2018 supplements the previous ExPRI study (ExPRI 2017), which presented the exposure of the general population to ionising radiation due to diagnostic procedures over the year 2017 only. As in the ExPRI 2017 study, the data were obtained from the generalist sample panel of health insurance beneficiaries representative of 1/97 of the French population.

Over the period studied, the CT scan procedure frequency was relatively constant (across all ages and sexes), fluctuating around an average of 13.7‰ per year. For girls, this frequency was slightly lower (12.9‰) and did not show a clear change over the period studied. The procedure frequency among boys was slightly higher and seemed to be increasing slightly (+3.8% between 2012 and 2018).

On average over the same period, the CT scan procedure frequency per year varied greatly according to the age of the child: about 15‰ under 1 year old, less than 10‰ between 1 and 9 years old, then increasing rapidly to reach about 35‰ at 15 years old. Moreover, the CT procedure frequency was significantly higher among boys than among girls, but with the same trend according to age.

In terms of the anatomical area explored in CT scan, the head and neck procedures were the most common (about 60%) over the period studied. Overall, the proportion of CT procedures by anatomical area was stable over the period studied. Because of this observation and the common indications between CT and MRI, a study of evolution in MRI procedures was carried out. Indeed, the recommendations of professionals (in particular the SFIPP) support transferring certain procedures (e.g. cerebral exploration) to MRI.

This study shows that, unlike in CT, the annual frequency of MRI procedures increased significantly (+59%) over the period studied, and the frequency was higher for girls. This growth was mainly due to the very rapid increase in the number of MRI procedures, specifically for the 11–15 age group. As in CT, procedures involving the head and neck were the most common among paediatric MRI procedures, representing a proportion between 40 and 45%, relatively stable over the period studied. The second largest category was procedures involving the limbs, with a proportion between 35 and 40%. However, these procedures represented the majority for children aged 11–15 years, unlike other age groups where procedures involving the head and neck predominated.

Concerning the possible transfer of certain CT scan procedures to MRI, it is likely that a part of the increase observed for MRI procedures involving the head and neck is related to a move away from CT, although it is not possible to confirm this based solely on the data analysed in the study conducted.

For CT, the proportion of children having had at least one CT scan procedure (exposed children) per year considered was relatively stable, at about 1.1% for all ages combined, with an average of 1.23 procedures per exposed child. Among this population of children, between 11% and 16% had two or more CT scans depending on the year.

Finally, according to paediatric data analysed in the diagnostic reference level (DRL) system managed by IRSN, the doses received by children for a CT scan (for the brain, abdomen-pelvis and chest) showed a decreasing trend (of -35% to -45%) between the periods 2011–2012 and 2016–2018. However, due to the small amount of paediatric data collected during these periods, this decrease should be interpreted with caution. The new order of 23 May 2019¹⁰ relating to DRLs includes an obligation for institutions to send paediatric dose assessments when more than 5% of procedures on a given medical device are on children. This regulatory change allowed IRSN to obtain a greater number of dose assessments in paediatrics for the period 2019–2021 than in the past, for all types of diagnostic tests. The next DRL review to be published will cover these three years and will consolidate knowledge of the ionising radiation doses received by children.

¹⁰ <https://www.legifrance.gouv.fr/loda/id/JORFTEXT000038529178/>

GLOSSARY

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

BEIR VII: Biologic Effects of Ionizing Radiation, 7th report

CCAM: *classification commune des actes médicaux* (common classification of medical procedures)

CNAM: *Caisse nationale de l'assurance maladie* (French Health Insurance Body) (CNAMTS before January 1st 2018)

CNAMTS: *Caisse nationale d'assurance maladie des travailleurs salariés* (French Health Insurance Body for salaried workers) (CNAM since January 1st 2018)

CT: computed tomography

DLP: dose-length product

DRL: diagnostic reference levels

EGB: *échantillon généraliste des bénéficiaires* (Generalist sample panel of health insurance beneficiaries)

EPI-CT: Epidemiological study to quantify risks for paediatric computerized tomography and to optimise doses

ExpRI: *Exposition de la population aux rayonnements ionisants* (Exposure of the population to ionising radiation)

ICRP: International Commission on Radiological Protection

IRSN: Institute for Radiation Protection and Nuclear Safety

MRI: magnetic resonance imaging

MSA: *Mutualité sociale agricole* (agricultural social insurance mutual benefit fund)

NIR: *numéro d'inscription au répertoire national des personnes physiques* (national individual registration number; social security number)

PMSI: *Programme de médicalisation des systèmes d'information* (Programme for the Medicalisation of Information Systems)

RG: *Régime général* (General scheme)

RSI: *Régime social des indépendants* (Social security scheme for the self-employed)

SFIPP: *Société française d'imagerie pédiatrique et prénatale* (French Society of Paediatric and Prenatal Imaging)

SLM: *Sections locales mutualistes* (local healthcare mutual fund sections)

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

SNIIRAM: *Système national d'information interrégimes de l'Assurance maladie* (French inter-regime health insurance information system)

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Keywords

Radiology, CT scan, paediatrics, medical exposure, ionising radiation, DRL

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