

ARTICLE

# Exposure of the French population to ionizing radiations from medical diagnostic procedures in 2012

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**Abstract** – Monitoring the exposure of the population to ionizing radiation is a European Union requirement. This article presents the exposure of the French population originating from medical diagnostic procedures performed in 2012. The number of procedures was established from a joint health insurances database. The effective dose associated with each procedure was estimated from various sources (national DRL, recent surveys, guides of procedures). The number of procedures was approximately 81.8 million, representing an average of 1247 examinations per 1000 inhabitants. The mean effective dose per inhabitant originating from medical diagnosis exposure was 1.6 mSv. When restricted to the population actually exposed, the average number of examinations was 2760 per 1000 individuals and the mean effective dose per exposed individual was 3.4 mSv. 70% of exposed individuals received less than 1 mSv. Mean individual exposure strongly increased with age: below 1 mSv before the age of 20, around 7 mSv at 75 years. 44% of the French population (49% of the women, 39% of the men) has benefited from at least one diagnosis procedure. Conventional radiology, dental radiology and computed tomography represented respectively 54%, 34% and 10.5% of the number of procedures and contributed to 18%, 0.2% and 71% of the collective effective dose, respectively. A 20% increase of the average effective dose per inhabitant was observed, when compared to the year 2007. While efforts are still needed in the optimization of delivered dose and in the harmonization of practices, whatever the imaging field, specific interest should be paid to the justification of certain examinations which have particularly increased in numbers.

**Keywords:** radiation exposure / diagnostic imaging / population exposure

## 1 Introduction

In accordance with the requirements of the European Union Council directives 97/43/EURATOM and 2013/59/EURATOM (EU Council, 1997, 2013), the Institute for Radiological Protection and Nuclear Safety (IRSN) is periodically monitoring the exposure of the French population to ionizing radiation. The exposure related to medical diagnosis examinations performed during the year 2012 has been assessed in a study published in 2014 (IRSN, 2014a). Two previous studies had focused on the years 2002 and 2007 (IRSN, 2006, 2010). In particular, the characteristics of the medical exposure by imaging modality (conventional radiology, computed tomography, diagnostic interventional radiology and diagnostic nuclear medicine), by explored anatomic region, by patients' age and sex was investigated, as well as the part of the French population (numbers, age and sex) who actually undergone medical diagnostic examination in 2012.

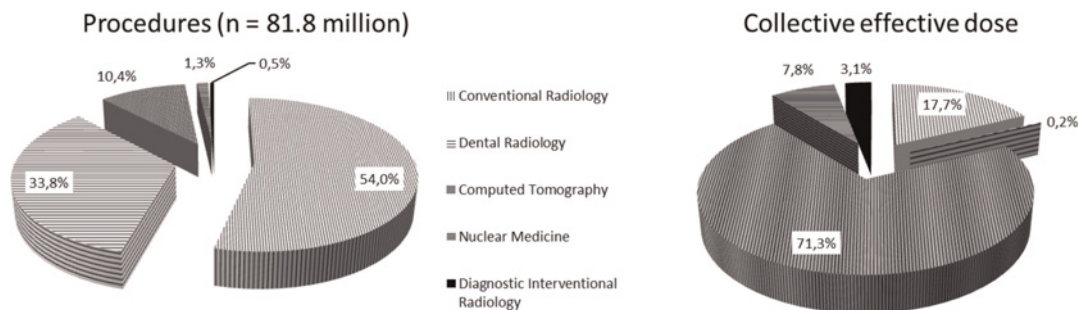
The complete analysis of the study is available online<sup>1</sup>, in French only. The purpose of this article is to present the main results of the study to non-francophone readers.

## 2 Material and methods

The examination frequency was estimated from the *Échantillon Généraliste de Bénéficiaires* (EGB). The EGB is a permanent representative sample of the population protected by French health insurance (De Roquefeuil *et al.*, 2009). EGB is based on a survey on about 1% of the beneficiaries from the three main French health insurance schemes (*Régime général*, RSA and RSI), whether these beneficiaries have received healthcare reimbursements or not. The three health insurance schemes cited above currently cover around 85% of beneficiaries of all French social security schemes. Characterization of the population actually exposed in 2012, in numbers, sex and age, was also established from the EGB database.

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<sup>1</sup> [http://www.irsn.fr/FR/expertise/rapports\\_expertise/radioprotection-homme/Pages/Rapport-IRSN-HOM-2014-006\\_Exposition-rayonnements-ionisants-diagnostic-medical.aspx](http://www.irsn.fr/FR/expertise/rapports_expertise/radioprotection-homme/Pages/Rapport-IRSN-HOM-2014-006_Exposition-rayonnements-ionisants-diagnostic-medical.aspx).



**Fig. 1.** Proportion of the number of radiodiagnosis procedures and of the associated collective effective dose in 2012, according to the imaging modality.

The average effective dose was calculated for each type of medical diagnosis procedure, using mainly the data transmitted to the IRSN as part of the update of national diagnostic reference levels (IRSN, 2013), the results of recent national surveys (IRSN, 2011, 2014b; Etard and Aubert, 2012; Etard *et al.*, 2012a) and the guides of procedures established by professionals (SFR, 2004, 2013; HAS, 2006; SFMN, 2012; Georges *et al.*, 2014). Uncertainty on the procedures' average effective dose was estimated to more than 50%, on a general basis and following recommended methods (European Commission, 2008; Etard *et al.*, 2012b). Sources of uncertainties were essentially: (a) dispersion of the delivered effective doses for a given type of procedure at a national level, due to variations in protocols or equipment; (b) inconsistencies between the national codification and the actual clinical practices; and (c) rarity of certain types of procedures.

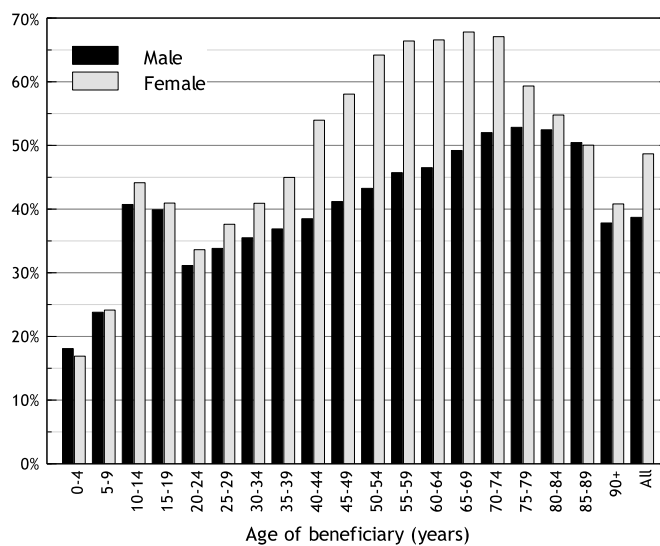
### 3 Results

The number of medical diagnosis procedures using ionizing radiation is estimated at approximately 81.8 million in 2012. It represents an average of 1247 examinations for 1000 inhabitants. The mean effective dose per inhabitant originating from medical exposure is estimated to 1.6 mSv for the year 2012.

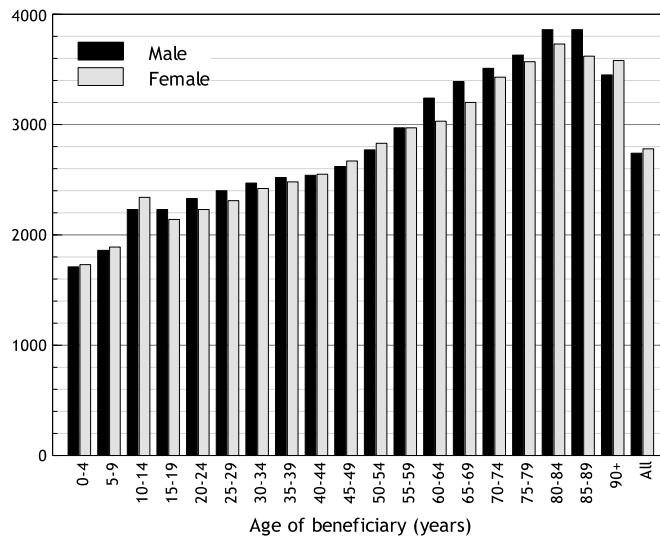
Conventional radiology, dental radiology and computed tomography represent respectively 54%, 34% and 10.5% of the number of procedures. These three imaging modalities contribute respectively for 18%, 0.2% and 71% of the collective effective dose (Fig. 1).

In 2012, about 44% of the French population has benefited from at least one diagnosis procedure. This percentage rises from 18% among children aged less than 5 years to approximately 60% among adults aged around 70 years (Fig. 2). Women are more likely to receive a radiodiagnosis: 49% of the female population underwent at least one diagnosis procedure, whereas this figure is 39% only for the male population. The differences between the two genders are particularly obvious for the adults aged 30–80 years, as it is depicted in Figure 2. A significant peak can also be observed for children and adolescents aged 10–19 years, who are roughly 10% more likely to undergo a radiodiagnosis than the young adults aged 20–29 years.

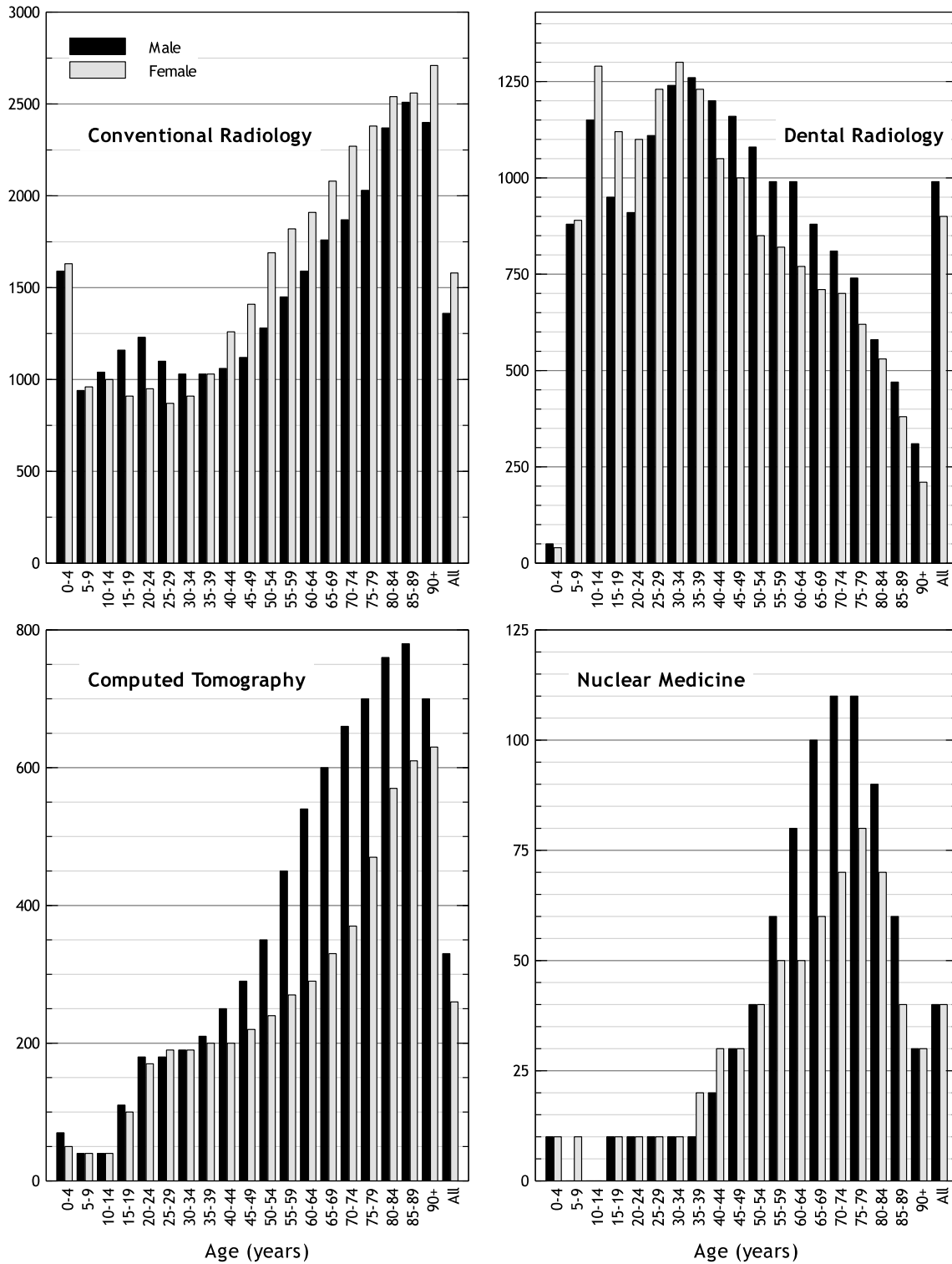
When restricted to the population actually exposed, the mean number of examinations is 2760 for 1000 individuals in 2012. Figure 3 illustrates the distribution of the mean number



**Fig. 2.** Proportion of beneficiaries from the three major French health insurance schemes who received at least one radiodiagnostic procedure in 2012, by sex and age category.



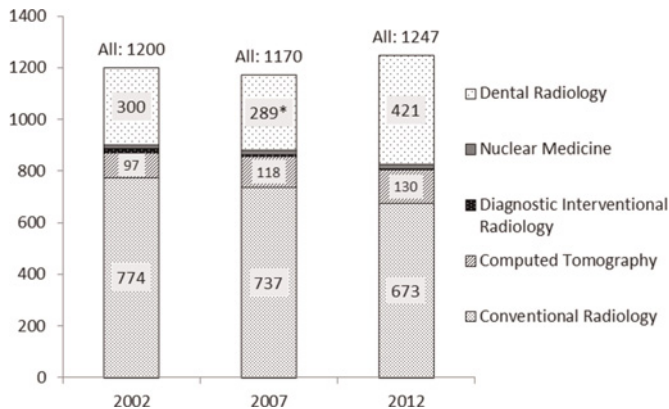
**Fig. 3.** Age and sex distribution of the mean number of radiodiagnosis examinations per 1000 exposed individuals.



**Fig. 4.** Age and sex distribution of the mean number of radiodiagnosis examinations per 1000 exposed individuals, for various imaging modalities: conventional radiology (top left), dental radiology (top right), computed tomography (bottom left) and nuclear medicine (bottom right).

of examinations with age of the exposed individual. The mean number of examinations for 1000 individuals varies considerably, rising from around 1720 for young children to around 3800 for elders aged 80 years and more. The peak observed in Figure 2 for the generation aged 10–19 is reduced in Figure 3,

but is nevertheless visible on the mean number of examinations for children aged 10–14 years. Within the exposed population, the exposure accumulated over the year is very heterogeneous: per individual exposed, the median effective dose is 0.08 mSv whereas the average effective dose is equal to 3.4 mSv. Indeed



**Fig. 5.** Evolution of the average number of radiodiagnosis examinations per 1000 inhabitants in France between 2002 and 2012, for the different imaging modalities. \*Based on 2002 data, presumably underestimated.

70% of exposed individuals received less than 1 mSv, 18% received between 1 and 10 mSv, 11% received between 10 and 50 mSv and 1% received more than 50 mSv. Similarly, the exposure strongly depends on the age of the individual: below 1 mSv before 20 years, around 2.5 mSv at 45 years and around 7 mSv at 75 years.

The characteristics of exposure vary greatly with age and sex, as illustrated in Figure 4. Exposure of children aged less than 5 years is mainly due to the conventional radiology, with 1600 procedures for 1000 children exposed (70% of these procedures concern the thorax and the limbs). During adolescence, conventional radiology and dental radiology make up almost all of the exposure (respectively 1020 and 1220 procedures for 1000 individuals exposed). Girls tend to undergo slightly more dental radiology procedures than boys, who in turn benefit from more conventional radiology examinations than girls.

In the adult population, conventional radiology is more common for women, with an average of 20% more procedures by exposed individual than men. This difference is due mainly to mammograms, but also to additional limbs examinations. On the contrary, computed tomography and nuclear medicine procedures are much more frequent in men than in women (45% more CT and 40% more nuclear medicine examinations in average per exposed individual). These disparities are explained mainly by extra thorax and abdomen-pelvis scanners, as well as cardiac scintigraphies in men after 50 years old.

Figure 5 depicts the evolution of the average number of radiodiagnosis examinations per 1000 inhabitants and per year between 2002 and 2012. All modalities altogether, an increase of almost 4% is observed over the decade. This is mainly due to an important rise in dental radiology (40% over the same period) and to a lesser extent to computed tomography (34%). Conventional radiology remains the most frequent type of radiodiagnosis examination but nevertheless decreases by 13%. It has to be pointed out that as the EGB database could not be considered as representative for dental radiology procedures before 2012, the number of dental radiology procedures for 2002 was established after a survey conducted by health insurances. The number of dental radiology procedures for 2007 was taken almost equal to 2002, therefore

the calculated frequency for dental radiology in 2007 can be considered as strongly underestimated.

The average individual effective dose has increased by 20% between 2007 and 2012, from 1.3 mSv to 1.6 mSv. This increase – much less important than that of the previous period (+57% between 2002 and 2007) – can be mostly explained by an increase of 10% in the number of computed tomography examinations per inhabitant between 2007 and 2012; and by a better knowledge of clinical practices and delivered doses, particularly for computed tomography. The 2012 average exposition of the French population related to radiodiagnosis examinations sits in the higher third of the European countries (European Commission, 2015), but remains much lower than Belgium, the EU country where the population is most exposed (2.7 mSv per year and per inhabitant in 2013).

## 4 Conclusion

Numerous actions have been taken in recent years at the national level to harmonize and optimize the doses delivered to patients during radiodiagnosis examinations, such as the establishment of procedures guides by professionals, their regulatory training to radiation protection of patients as well as the update of diagnostic reference levels. To meet the goal of reduction of the delivered doses, clearly announced by the French ministry of health's *Plan Cancer 2014–2019*, these efforts must continue. In accordance with the basic principles of the radiation protection of patients, specific interest should be paid to the justification of certain examinations which have particularly increased in numbers, such as dental radiology (even if the actual increase is lower than the one reported here, due to limitations with EGB's representativeness in previous studies). Likewise, the increase in computed tomography examinations is to be analysed in the light of the decrease in conventional radiology procedures and of the expected medical benefits of cross-sectional imaging. The possible substitution of a part of computed tomography examinations by magnetic resonance imaging would contribute significantly to moderate the increase in the exposure of the population at the national level. The recent technical evolutions of CT scanner, such as iterative reconstruction or improved detector efficiency, which came into clinical use mainly after 2012, are also expected to play an important role for dose control. However, more efforts are still needed in the optimization of delivered dose and in the harmonization of practices, whatever the imaging field.

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