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# Exposure of the Swiss population to ionizing radiation in medical radiology in 2013

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## Final Report

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## ABSTRACT

Countries have a legal obligation to follow their population's exposure due to medical imaging with x-rays (EURATOM 2013/59). The Swiss Federal Office of Public Health (FOPH) organizes an extensive survey every ten years to quantify the effective dose per inhabitant, with the goal of comparing Swiss practices to other countries as well as prioritize its policies in the field of radiation protection. The last large survey was conducted in 2008, in which the average annual effective dose was found to be 1.2 mSv. Between these large surveys, the data is updated upon the basis of studies that use a smaller sample size. The aim of this report is to present the results obtained for the survey conducted in 2013. The analysis presented in this report concerns:

- The contributions of different modalities (radiography, diagnostic and screening mammography, dental radiology, CT, conventional and interventional fluoroscopy (separating the diagnostic part to the therapeutic part));
- The analysis of the distribution of the most irradiating exams according to patient sex and age.

To conduct these surveys it is necessary, on the one hand, to determine the frequency of exams, and, on the other, the average effective dose delivered per exam. Frequency of exams was estimated using two sources:

- Responses from a sampling of general practitioners, chiropractors, private radiology practices, private clinics and dentists to questionnaires available online at [www.raddose.ch](http://www.raddose.ch).
- **"TARMED" invoicing codes** from public hospitals and from the University Hospital of Lausanne (CHUV); the pilot canton for this survey.

The average dose per exam was estimated on the basis of periodic surveys organized in Switzerland by the FOPH, as well as according to data from the literature. A validation of the CT-related doses was conducted using data collected over nine months at CHUV using the software DoseWatch™.

In 2013, the number of exams conducted in Switzerland was estimated to be around 10 million, or **some 1,219 radiological exams per 1000 inhabitants**. This generates **an annual effective dose per inhabitant of 1.42 mSv**.

Dental radiology, radiography, and CT scans are the most commonly used modalities with respective frequencies of: 47.4%, 38.8% and 9.6%. The three modalities contributing the most to the population's exposure are, respectively, CT scans, radiography, and interventional fluoroscopy for diagnostic purposes, with respective percentages of: 70.5%, 10.7% and 6.8%. CT scans delivered, on average, 1.0 mSv per inhabitant in 2013, in comparison to 0.8 mSv in 2008.

Accessing the "TARMED" invoicing codes, sometimes considered "sensitive" data because of their economic nature, made it possible to carry out more detailed research on how exposure is distributed:

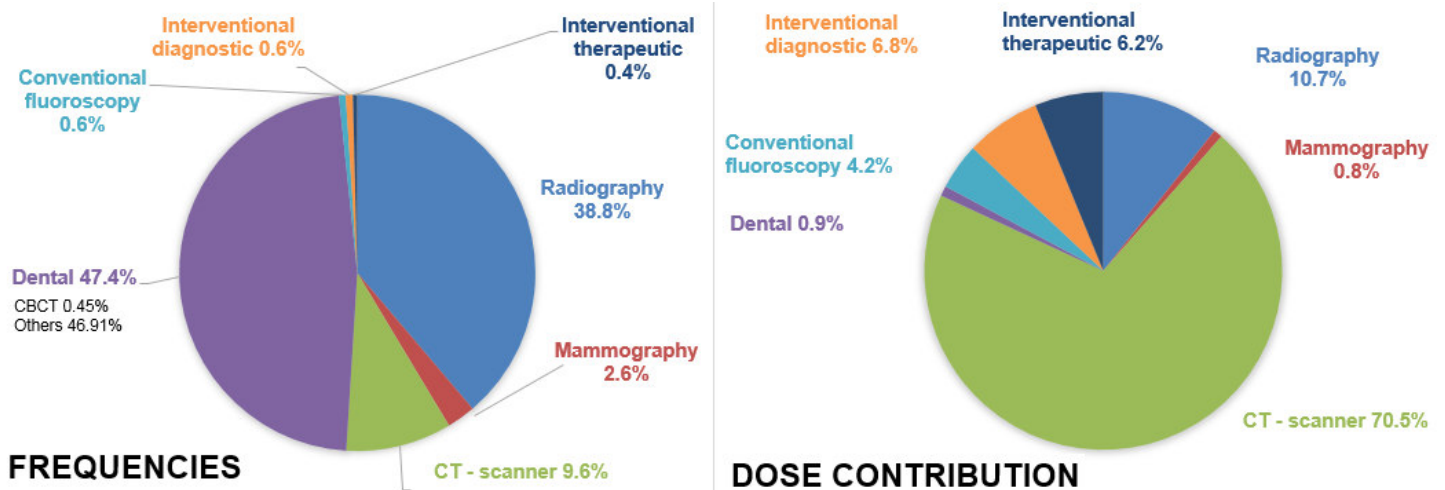
- **For radiography**, the male/female distribution shows a slight positive differential of 4% for men. In absolute numbers, fewer men are given x-rays in radiology departments, but those who are receive x-rays of a larger number of anatomical regions, which in the end generates a greater number of exams. The percentage of the female population receiving

radiography is about 18.7%, with an average of 1.38 exams for each patient. For the men, these figures are: 16.5%, with 1.63 exams per patient.

- **For CT scans**, the male/female distribution shows a positive differential of 21% for men. The percentage of Swiss women benefiting from CT is about 4.6%, with an average of 1.27 CT exams for each patient. For the men, these figures are: 5.4% with 1.33 CT exams per patient.

In conclusion, the updated evaluation of the population's exposure through medical imaging shows that we have moved from 1.2 mSv in 2008 to about 1.4 mSv in 2013. This increase is linked to CT use (117 exams per 1000 inhabitants in 2013 compared to 100 exams per 1000 inhabitants in 2008) and, to a lesser degree, to a slight increase in interventional fluoroscopy. This increase is, however, compatible with the practices of the countries that surround Switzerland.

Summary of the distribution of frequencies and doses:



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# 1 INTRODUCTION

Worldwide, between 1997 and 2007, the average effective annual dose per inhabitant, all exposure sources combined, was 3.1 mSv. The two main exposure sources were natural radiation (giving 2.4 mSv) and medical radiology (giving 0.68 mSv) [UNSCEAR, 2010]. In Switzerland, the average annual effective dose per inhabitant in 2008 was 5.6 mSv. The main source of natural exposure was radon (contributing 3.2 mSv). Medical imaging with x-rays contributed about 1.2 mSv [OFSP, 2009], a value which is compatible with data from other countries with similar health status. In light of technological developments, it is important to regularly monitor medical radiology practices.

According to the European Directive 97/43/EURATOM, and more recently, 2013/59/EURATOM [European Union Council, 2014], national studies on a population's exposure through medical imaging is required in order to monitor the exposure evolution over time and to strengthen, in a targeted manner, radiation protection policies. The 2013/59/EURATOM directive cites, among other things, that these national studies must, if possible, show the distribution of radiation by gender and by age.

A large national study was conducted in Switzerland in 1998. This study reported an annual effective dose of 1.0 mSv per inhabitant [Aroua, Vader, Burnand & Valley, 2000]. In 2003, this survey was updated using a representative, but much smaller (intermediate survey) sample and reported that the situation had remained relatively stable [Aroua, Vader, Valley & Verdun, 2007]. A study of the same size as 1998 was re-conducted in 2008, in which 225 radiological exams covering 8 radiological modalities were studied. The data of some 3500 users were collected (response rate of 42%) and showed, for that year, an annual effective dose of 1.2 mSv per inhabitant, with an average of 1.7 exams per inhabitant [Aroua, Samara, Bochud & Verdun, 2011]

The goal of this study was to investigate, using a limited but representative sample in Switzerland, the population's exposure for 2013, in a context in which medical radiology is rapidly evolving. Large-scale dosimetric surveys are conducted in Switzerland every 10 years; the next survey should investigate practices for 2018.

## 2 DETERMINATION OF THE FREQUENCY OF RADIOLOGICAL ACTS

### 2.1 DENOMINATION OF RADIOLOGICAL ACTS AND MODALITIES

#### 2.1.1 FREQUENCY: PROCEDURE USED

In this report, the frequency of exams was determined according to the notion of "radiological session" to guarantee a homogenous reporting structure that could also be easily compared to publications from other countries. This point is particularly important for CT scanning, in which different rules can be applied; a thoracic-abdominal acquisition may be counted as one exam (a passage) or two exams (acquisition of two anatomical regions). **In this way, a session corresponds here to a series of images, exposures, acquisitions, passages, even phases conducted upon the same patient during a single visit, for one anatomical region and a given modality [Dose Datamed 2, 2010].**

Several examples:

If a patient has come in for a mammography, during which four images are taken, a single session will be counted.

If a patient has come in for a thoracic-abdominal CT scan, with multiple passages, two sessions will be counted: one CT session for the thorax, and one CT session for the abdomen.

#### 2.1.2 MODALITIES RETAINED

The limited 2013 study involves the following modalities:

- Conventional radiography (x-ray)
- Mammography divided into two parts:
  - Mammography considered "diagnostic" or standard:
  - Mammography considered "screening", for exams conducted within the framework of breast cancer screening programs.
- Dental radiology with a specific sub-category for the use of 3D imagery ("Cone Beam CT (CBCT)").
- CT scanning, also called Computed Tomography
- Conventional radiology including follow-up exams for digestive, gall bladder, urinary, and gynecological systems as well as myelography and arthrography.
- Interventional radiology for diagnostic purposes, subdivided into two groups:
  - Cardiac radiology, which exclusively concerns coronary angiography (CA).
  - "Other" for all other angiographies.
- Interventional radiology for therapeutic purposes, subdivided into two groups:
  - "Cardiac radiology" for percutaneous transluminal coronary angioplasty (PTCA).
  - "Other" for all other cardiac interventions (myocardial biopsy, shunt closure...) as well as all other interventional radiology exams guided by radioscope.

Nuclear medicine was not integrated into this study.

## 2.2 DATA SOURCES - SAMPLE

For this intermediate survey, our data came from four distinct sources: the data provided by the questionnaires available on the [www.raddose.ch](http://www.raddose.ch) website, the "TARMED" invoicing codes connected with billing for medical radiology acts, the 2013 Swiss cardiologists annual report (for the CA and PTCA) and the figures provided by the Foundation for Breast Cancer Screening.

### 2.2.1 THE RADDOSE SITE AND ITS QUESTIONNAIRES

On the RADdose site ([www.raddose.ch](http://www.raddose.ch)), four questionnaires were specially prepared by radiology technicians. These questionnaires were made to be interactive, in order to improve the appropriateness and precision of the questions asked, while maintaining a strict limit on the time needed to fill out the questionnaire. Each questionnaire could be filled out individually in the time provided, included help categories and was available in the three national languages as well as English.

The four questionnaires were as follows:

- Radiographies (x-rays) and mammographies;
- CT scans or Computed Tomography (CT) and Magnetic Resonance Imagery (MRI);
- Fluoroscopy and interventional radiology guided by fluoroscopy;
- Dental radiology, including CBCT or not.

These questionnaires offered the possibility of indicating the number of images, passages, series, but also the number of sessions and/or the number of patients - and this with the goal of better specifying the information provided. In the event that the number of radiological sessions was not directly specified, conversion factors were created, following the analysis of the practices of the centers which gave us more information. For example, in the case of a chest X-ray, we used the factor 1.5 to move from the number of images to the number of sessions. And finally, only the figures of the sessions were used to determine frequencies.

Note that the data gathered via RADdose does not provide any information about patient sex and age.

Using a list of addresses of institutions with authorizations for radiological installations, provided by the FOPH a sample from each practice and from each Swiss canton was contacted via email at the beginning of the summer of 2014. The goal was to have approximately four suppliers of data per category and per canton. There was a low response to the first email, and so a second email was sent at the beginning of Autumn 2014. The selected sample as well as the limited rate of response received is presented in Table 1.

Table 1: Sample and rate of response obtained from the RADdose site

Practices	Swiss total	Contacted	Respondents	Response rate (%)	National Sampling (%)
Chiropractors	116	110	31	28.2	<b>26.7</b>
Generalists (low dose) *	2786	100	28	28.0	<b>1.0</b>
Generalists (high dose)*	929	100	28	28.0	<b>3.0</b>
Dentists without CBCT	3129	100	26	26.0	<b>0.8</b>
Dentists with CBCT	323	83	22	26.5	<b>6.8</b>
Radiology Institutes	118	110	31	28.2	<b>26.3</b>

\* The generalists (general practitioners) were separated into two categories as a function of their level of post-graduate training in radiology: a category called "low-dose" for physicians with only a FMH in medicine

and only able to take images of the chest or distal extremities, and a second category called "high-dose". For this second category the physicians could take more irradiating images, like x-rays of the abdomen or of the spinal column.

Swiss chiropractors, general practitioners, dentists, and radiological institutes were also contacted. Note that the generalists include the following FMH (Federation of Swiss Doctors) specialists [Radioprotection, 2015]:

- Internal medicine – general practioners
- Internal medicine
- Pediatrics
- Neurology
- Oncology
- Otolaryngology

Figures 1 to 3 show the geographic distribution of the respondents to the survey lead with the RADdose site, for Switzerland's seven large regions, commonly used by the Swiss Federal Office of Statistics (OFS).

Figure 1 :  
Geographic distribution of the generalists' responses "low-dose" (in black) and "high-dose" (in red).

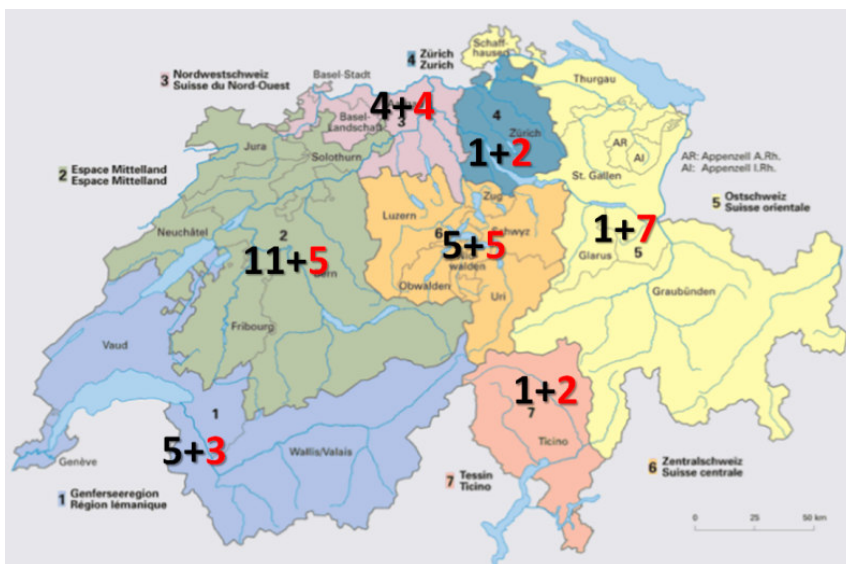


Figure 2 :  
Geographic distribution of the Dentists' responses with CBCT (in black) and without CBCT (in red).

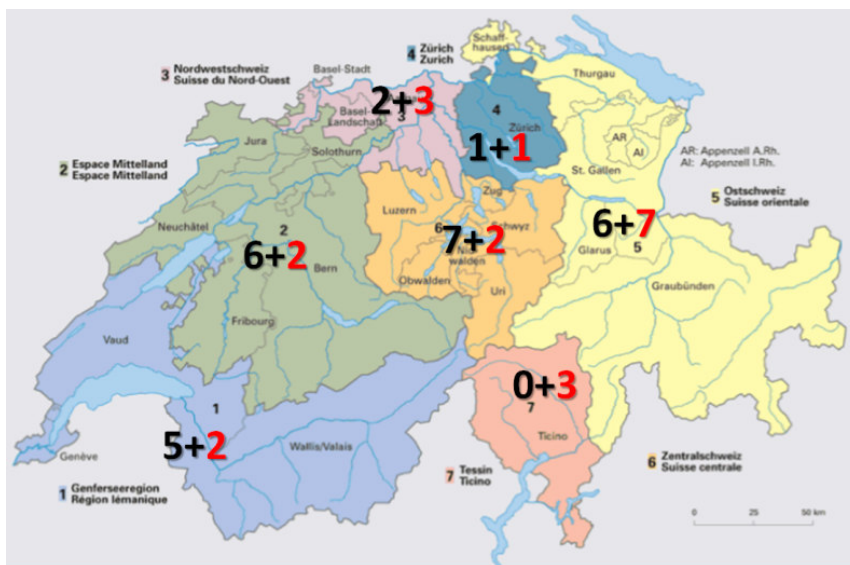
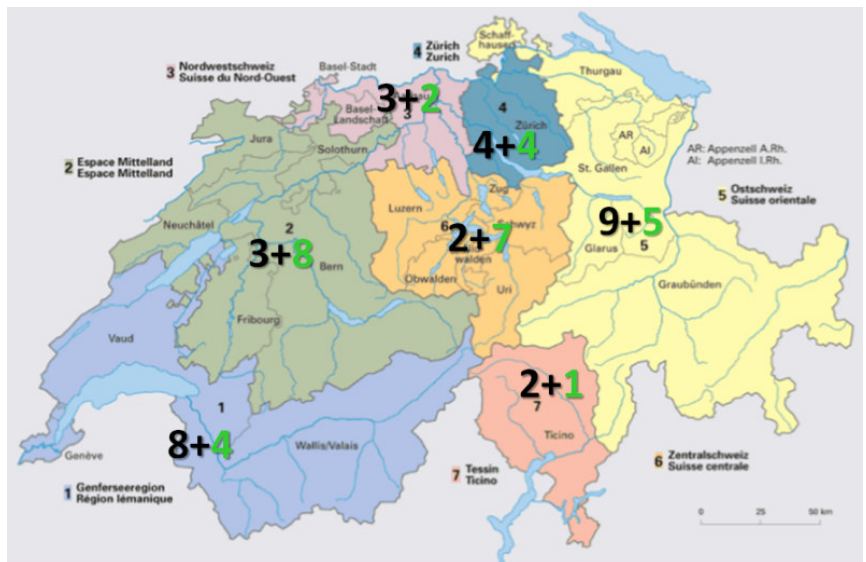




Figure 3 :  
Geographic distribution of the responses from the Radiology Institutes (*in black*) and from chiropractors (*in green*).



## 2.2.2 TARMED INVOICING CODES

Since September 2002, a medical invoicing scale called "TARMED" has been used in a uniform way across the entire country, within the framework of Switzerland's mandatory accident insurance (AA), the mandatory health insurance (LAMal), the military insurance (AM) and invalidity insurance (AI). In the health insurance, TARMED serves to invoice outpatient care, in both medical offices and hospitals [Office Fédéral de la Santé Publique, 2014].

It became quickly clear that using this data to establish surveys would be an interesting option in terms of determining the frequency of exams. All of this became more detailed with the complete redesign of the 2008 catalogue. In essence, this redesign was clearly dedicated to medical imaging, even if all specialities of radiology were not included. The development of the methodology allowing for the extraction of data useful to dosimetric surveys was the object of a research study that included the validation of the suggested method. [Le Coultré, Aroua, Samara, Rochat, Coendoz & Verdun, 2012].

Note that the catalogue of TARMED "codes" is regularly updated and adapted. It is thus necessary to identify the different versions, in order to follow the one used during the year studied, in this case 2013.

Finally, the collection of this kind of data necessitates a high level of trust from the participants, since other analyses may be conducted (this mostly concerns economic comparisons). We promised to only use data that was rendered anonymous, and not to proceed with any other analysis other than the one enabling us to obtain the frequency of radiological sessions as a function of patient age and sex.

In this way it was necessary to establish a trust-filled relationship with the administrators, IT services, as well as the management of the different "source hospitals", in order to obtain access to all of their TARMED codes for 2013 in an analysable and anonymized form. It was also imperative that this data was collected before any of it went through administrative processing by the billing departments. Essentially, initial invoicing is sometimes modified, for example, in favor of fixed-rate hospital charges (APDRG), etc...

The vast scale of the TARMED files we received necessitated a semi-automated procedure of pre-processing, of processing, and data analysis. It was impossible to manage these millions of lines using standard office software. The computing solution, developed within the framework of the previously mentioned research project, was thus much improved. This, also, with the goal of managing the multiplicity of data sources.

About fifty hospital institutions, including the five Swiss university hospitals, provided their codes to us. Table 2 presents the distribution of TARMED code providers, for the seven large Swiss regions.

Table 2: Distribution of providers of TARMED codes for 2013

Regions	Cantons	University Hospitals	Public Sites	Private Sites
Lake Geneva Region	GE, VD, VS	2	20	4
Swiss Midlands	BE, FR, JU, NE, SO	1	11	
Northwest Switzerland	AG, BL, BS	1	2	
Zurich	ZH	1	1	
Eastern Switzerland	AI, AR, GL, GR, SG, SH, TG		1	
Central Switzerland	LU, NW, OW, SZ, UR, ZG			
Tessin	TI		4	3

The Federation of Vaud Hospitals (FHV) provided us with their 2013 TARMED codes from all working sites; this involves 12 establishments covering 20 different sites. In all, 833,387 TARMED codes associated with imaging (Ch. 39 of TARMED) were used. For the five national university hospitals, nearly 3.8 million 2013 TARMED "lines" were analyzed, including 651,793 from the CHUV.

The great advantage of TARMED data is that it provides a specific distribution for both the gender and the age of patients treated in radiology. They also make it possible to know the percentage of these patients who are truly exposed, knowing that certain patients underwent several sessions throughout 2013. These two facts encouraged us to attempt to obtain the greatest number of TARMED code providers. Even if these data are not directly usable to conduct a projection of frequency on the national level, nevertheless they provide details about the specifics of different patients exposed to medical radiology.

### 2.2.3 SWISS CARDIOLOGY ANNUAL REPORTS

The Swiss centers for interventional radiology publish an annual statistical report, which is available on the site of the working group: [www.ptca.ch](http://www.ptca.ch). The data linked to the most frequent interventions are presented in this report; like diagnostic coronagraphy (CA) or percutaneous coronary interventions (PTCA) [*Groupe de travail en cardiologie interventionnelle et syndrome coronarien aigu, 2015*]. In this survey, the data for CA and PTCA were extracted from their 2013 statistical report. The PTCA values do not represent all interventional cardiology for therapeutic purposes, other data were extracted from the Swiss University Hospitals TARMED codes and then added to the therapeutic interventional radiology sessions ("other" category).

### 2.2.4 THE FOUNDATION FOR BREAST CANCER SCREENING

In Switzerland, all cantons do not have a systematic mammography program for breast cancer screening. Furthermore, these radiological sessions are taken care of under the mandatory health insurance and so there are arrangements between the insurance companies and the screening programs in terms of medical costs. The TARMED codes for this were hardly used. The figures for the ten Swiss cantons conducting screening mammographies were provided to us by the Foundation for Breast Cancer Screening. For 2013,

these cantons were: Vaud, Fribourg, Valais, Geneva, Thurgovie, Saint-Gall, Grisons and "BEJUNE" - the association of the cantons of Bern, Jura and Neuchatel.

## 2.3 METHODOLOGY FOR DATA PROCESSING - NATIONAL PROJECTION

### 2.3.1 THE CANTON OF VAUD AS "PILOT" CANTON FOR SWISS PROJECTION

A national projection must be done using a sample that is as complete as possible. But because of the low RADdose response rate and the disparate geographic distribution of our sources - in particular that of our TARMED code suppliers (Table 2) - we established the following hypothesis:

The imaging practices of the canton of Vaud could be used to establish a national projection. The practices of this canton, which represents approximately a tenth (factor 10.86) of the Swiss population, are sufficiently varied and broad to serve as pilot canton.

The different groups of service providers identified for the canton of Vaud are:

- a. the university hospitals - the CHUV
- b. The regional hospitals and public institutions for the canton of Vaud: the FHV.
- c. The private clinics.
- d. The imaging institutes.
- e. The doctors (generalists, dentists, and chiropractors).

Note that projecting data to the national level requires a certain number of precautions and hypotheses:

For the first two groups (Groups A and B), the CHUV and all of the FHV, all data collection was done using the provided TARMED codes. It is important, however, to be aware of the existence of two categories of patients within these establishments: outpatients and inpatient or hospitalized patients. It is vital that TARMED codes are collected before any processing by the billing departments, because the information necessary for establishing the frequency of exams may be eliminated for inpatients (fixed-rate billing) [*SwissDRG AG, 2015*].

The three other groups (Groups C, D and E), the private clinics, institutes, and the doctors, fall under the private practice of radiology. Billing for acts can be done through various methods (autonomous management, using the Society of Medicine in Vaud (SMV), and/or through the clinics themselves). Note that these different billing methods may be combined for any given physicians.

For the private clinics (Group C), we had planned to collect data via TARMED codes. However, despite the good will of several administrators, these codes were not able to be collected. Neither in such a way as to have a good cantonal coverage, nor in such a way that we could precisely identify the percentage of our sample. Furthermore, most of the data provided were incomplete or in an ambiguous format. For numerous clinics, this information was therefore not transferred to us. In the end we decided to use the TARMED codes obtained uniquely for their information on the age and sex of exposed patients.

Because it was impossible to easily collect TARMED information for the institutes and doctors (Groups D and E), we used RADdose data.

### 2.3.2 NATIONAL ESTIMATION

To determine the factor with which the Vaud data would be projected to the Swiss level, the figures concerning **outpatient consultations** from 2013 were used [SASIS SA, 2015].

Our starting hypothesis was:

Radiological activity is not or is no longer proportional to the size of an establishment (number of beds), neither to the number of visits, nor the number of days in-hospital, but is instead proportional to the number of exams ordered during **medical consultations** within offices or on hospital grounds. Radiological activity is more and more an **outpatient** reality.

Several options exist for projecting data onto the national level:

- Divide the number of national outpatient consultations conducted by physicians by the same type of consultations recorded in the canton of Vaud. Doing this gives a factor 12.53 (see Table 3).
- Divide the number of national outpatient consultations conducted in hospitals by those conducted in Vaud hospitals. Doing this gives 9.01 (see Table 3).
- Or, divide the total number of outpatient consultations in Switzerland by those conducted in the Canton of Vaud. Doing this gives a factor 11.41 (see Table 3).

The average of the first two options (average of 12.53 and 9.01: equals 10.77) is slightly lower than the option of simply basing the figure upon the total number of outpatient consultations, but comparable to the relationship between the Swiss population and the Canton de Vaud population in 2013 (10.86). Nevertheless, to compensate for the lack of robustness of our sample related to non-hospital practices, we decided to retain **11.41** as the multiplicative factor for 2013 (with the exception of screening mammography and cardiology, for which the national data was available).

Table 3: Factors linked to outpatient consultations

Outpatient consultations	Factors: # Swiss women / # Vaud women
Doctors	12.53
Hospitals	9.01
<b>Total</b>	<b>11.41</b>

As for interventional fluoroscopy for therapeutic purposes, excluding PTCA procedures, a factor of two was selected by estimating that the practices of the university hospitals and the St. Gallen hospital covered half of the actual acts conducted in Switzerland. In essence, these exams are conducted on a more occasional basis and take place in general in more specifically equipped centers. (See § 2.2.3)

To these national frequencies, we added the RADdose frequencies. For the latter, the results of the national sample visible in Table 1 were used to then make the national projection.

The **Swiss frequencies** for this 2013 survey were calculated in the following manner:

$$\text{Swiss frequency} = (\text{TARMED frequency from the Canton of Vaud} \times 11.41) + (\text{RADdose Frequency} / \text{national sample})$$

### 3 DETERMINATION OF THE DOSES ASSOCIATED WITH THE RADIOLOGICAL MODALITIES

#### 3.1 EFFECTIVE DOSE [mSv]

**Effective dose E**, expressed in millisievert [mSv], is the selected dosimetric indicator for this survey to evaluate the Swiss population's exposure to the ionizing radiation linked to medical radiology acts.

As a standardized indicator, E makes it possible to compare radiological risk linked to the various radiological modalities, but it also makes it possible to conduct comparisons between different countries as well as study the evolution of exposure over time [*Institut de Radioprotection et de Sureté Nucléaire, 2014*].

In this study, an effective dose E was calculated for each radiological modality, by multiplying the frequency of radiological sessions for one modality by a dose vector for that very modality.

**The collective effective dose S** corresponds, here, to the sum of the different effective doses, calculated for each modality. **The annual effective dose per inhabitant** is obtained by dividing the collective effective dose S by the Swiss population for the year studied, whether exposed or not to ionizing radiation. The 2013 Swiss population was 8,138,631 inhabitants, comprised of 4,117,540 women and 4,022,091 men [*Office Fédéral de la Statistique, 2015a*].

#### 3.2 DETERMINATION OF THE EFFECTIVE DOSES LINKED TO EACH RADIOLOGICAL MODALITY.

The dose vectors associated with each modality, for this study, come from the last study conducted in 2008 [*Aroua, Samara, Bochud & Verdun, 2011*], with the exception of the following modalities:

For dental CBCT and interventional cardiac radiology, our dose vectors come from recent national surveys and recent publications, [*Pauwels et al, 2014*] in particular.

For CT scans, a first dose vector was calculated using data from the literature. These data were then validated using the CT data, from an entire year, supplied by the automatic dose collection program installed at the Lausanne University Hospital (CHUV).

## 4 EXPOSURE OF THE SWISS POPULATION IN 2013

### 4.1 GENERAL REPORT

In 2013, the number of radiological "sessions" conducted in Switzerland was estimated to be more than 9.9 million, or **some 1,219 radiological exams per 1000 Swiss inhabitants**. This generates **an annual effective dose per inhabitant on the order of 1.42 mSv**.

### 4.2 CONTRIBUTION OF EACH MODALITY IN TERMS OF FREQUENCY AND COLLECTIVE EFFECTIVE DOSE.

The detail for each modality is presented in Table 4. Figures 4 and 5 present the contribution in frequency and in dose of the different modalities.

Dental radiology, x-rays, and CT scans are the modalities that contribute the greatest percentages of sessions; with respectively 47.36%, 38.83% and 9.61%. The three modalities contributing to the majority of the collective effective dose are CT scans, x-rays, and interventional radiology for diagnostic purposes - either cardiac or otherwise - with the following respective percentages: 70.49%, 10.67% and 6.81%. CT scans delivered 1.0 mSv per inhabitant in 2013.

Table 4: Frequency and dose of each modality for 1000 inhabitants and dose vectors

Modalities	Sessions / 1000 inhabitants	Frequencies [%]	Dose vectors [mSv]	Dose [mSv] / 1000 inhabitants	Contribution to the collective dose [%]
Radiography	473	38.83%	0.32	151.44	10.67%
Diagnostic mammography	20	1.66%	0.36	7.30	0.51%
Screening mammography	11	0.93%	0.36	4.06	0.29%
CT scanning	117	9.61%	8.54	1'000.21	70.44%
Dental radiology (except CBCT)	572	46.91%	0.02	11.44	0.81%
Dental CBCT	6	0.45%	0.20	1.10	0.08%
Conventional fluoroscopy	7	0.61%	8.00	59.09	4.16%
<i>Interventional fluoroscopy for diagnostic purposes:</i>					
- Coronary angiographies ♥ (CA)	6	0.47%	14.00	79.59	5.61%
- Other angiographies	2	0.17%	8.00	16.98	1.20%
<i>Interventional fluoroscopy for therapeutic purposes:</i>					
- Percutaneous coronary angioplasties ♥ (PTCA)	3	0.22%	20.00	54.12	3.81%
- Other therapeutic interventional	2	0.14%	20.00	34.52	2.43%
<b>TOTAL</b>	<b>1'219</b>	<b>100%</b>		<b>1'419.87</b>	<b>100.00%</b>

### 4.3 EVOLUTION OF THE MEDICAL EXPOSURE OF THE SWISS POPULATION FROM 2008 TO 2013 & COMPARISON TO OTHER COUNTRIES

Since the report of frequencies from the 2008 survey involved several uncertainties, the longitudinal follow-up of radiological practices will be brief, with the exception of CT, the modality for which our figures are more robust.

X-ray practices and dental radiology remained stable between 2008 and 2013, however we report a 17% increase in the number of CT scan sessions. Swiss CT practices are, nevertheless, roughly 10% lower compared to French and German CT practices in recent years.

Table 5: Annual dose [mSv ] per inhabitant and per modality for 4 different studies

	Switzerland 2008	Switzerland 2013	France 2012	Germany 2012
Radiography and Radioscopy	0.36	<b>0.41</b>	0.34	0.67
Dental radiology	0.01	<b>0.01</b>	0.003	0.005
<b>CT scanning</b>	<b>0.80</b>	<b>1.00</b>	<b>1.14</b>	<b>1.15</b>
TOTAL*	1.20	<b>1.42</b>	1.47	1.80

\* Total including more modalities, but without nuclear medicine.

Table 6: Number of CT sessions per 1000 inhabitants per year

	Switzerland 2008	Switzerland 2013	France 2012	Germany 2012
CT scanning	100	<b>117</b>	130	132

Figure 4: Break-down of radiological sessions into frequency per modality

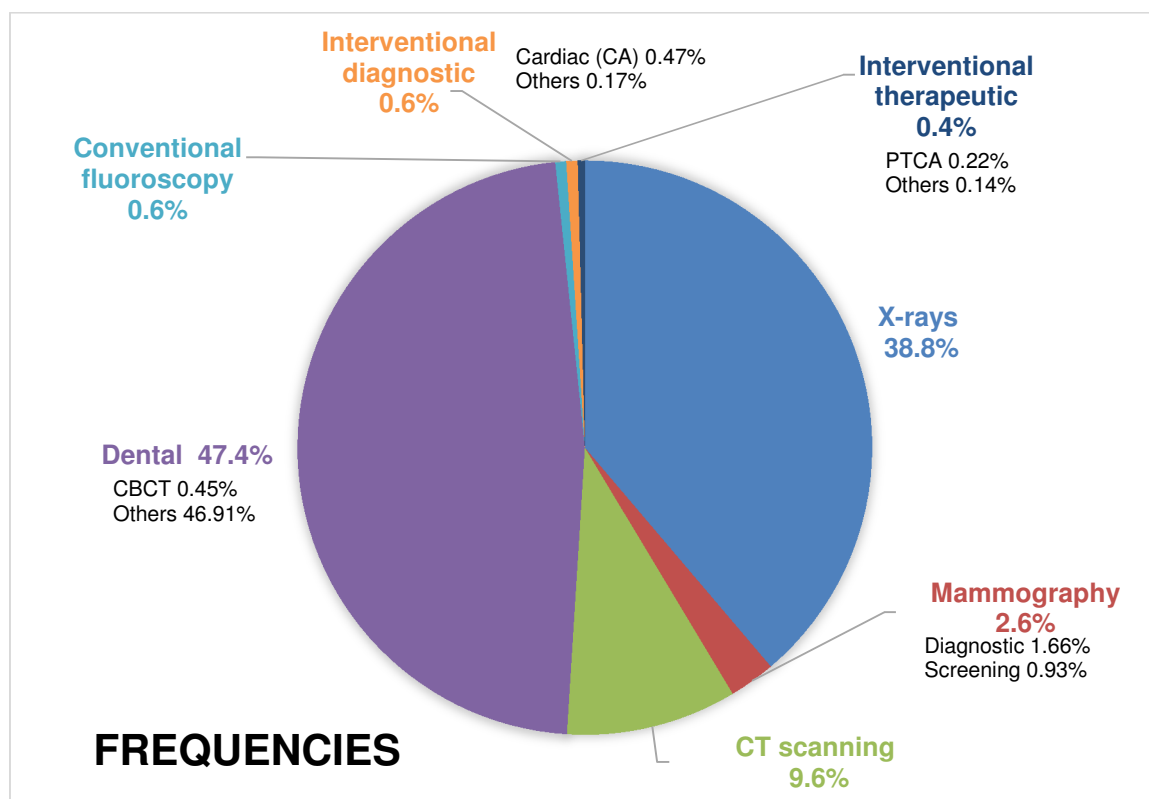
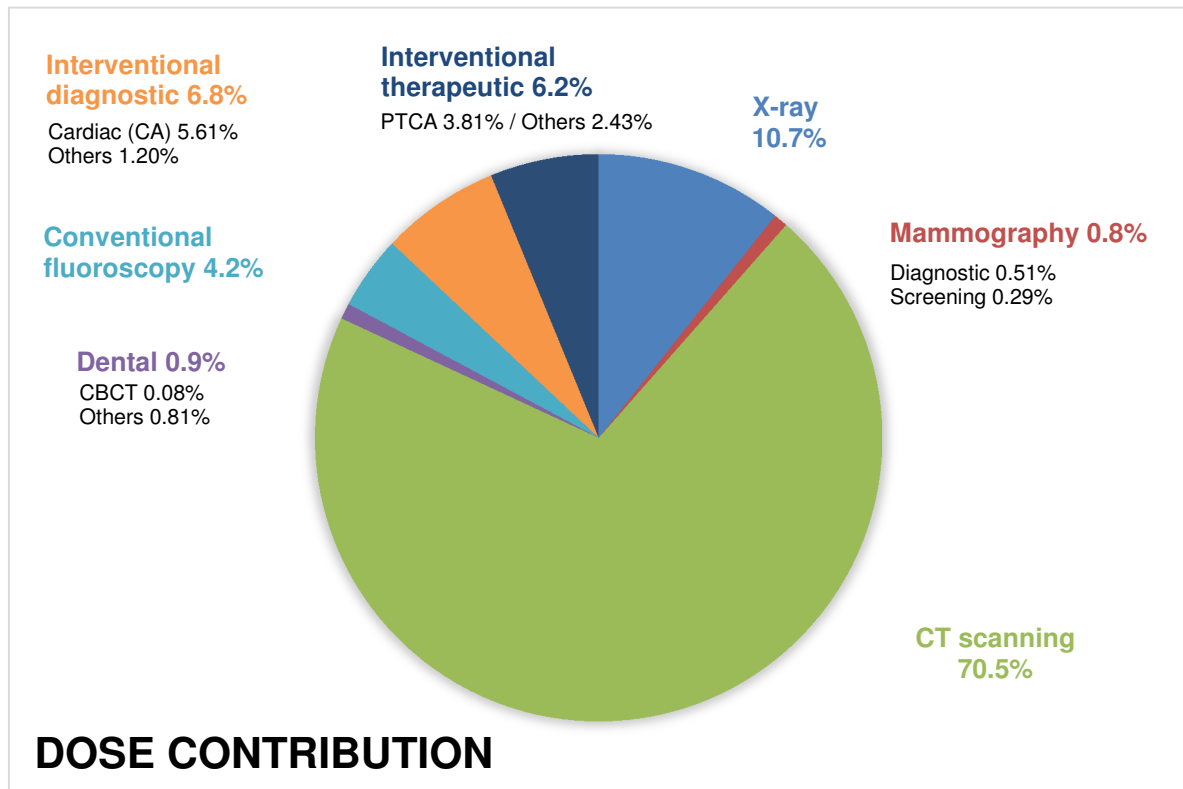


Figure 5: Contribution of each radiological modality to collective dose



#### 4.4 DETAILED ANALYSIS FOR X-RAYS (EXCLUDING DENTAL) FOR 2013

##### 4.4.1 POPULATION ACTUALLY EXPOSED THROUGH RADIOGRAPHY

The section of Switzerland's female population that is actually exposed is on the order of 18.7%, with an average of 1.38 sessions for each of these patients. For the men, these figures are: 16.5%, with 1.63 exams per patient. Overall, fewer men undergo radiology for radiography (excluding mammography's), however more images are taken on a variety of anatomical regions, which engenders a larger number of sessions for them.

##### 4.4.2 DISTRIBUTION ACCORDING TO PATIENT SEX AND AGE FOR RADIOGRAPHY

The analysis of the TARMED data enables us to make the following statements:

Approximately 4% more women than men, in 2013, were given standard x-rays.

Patients between the ages of 65 and 69 received this radiological modality the most. This age bracket received, on average, 20 sessions for 1000 Swiss women and 17 sessions for 1000 Swiss men.

The regions the most explored were the thorax and the limbs, with a rate of 65% for women and 78% for men (see Figures 6 - 8).



Figures 6 - 8: Distributions of x-ray sessions for 1000 women (pink) and 1000 men (blue).



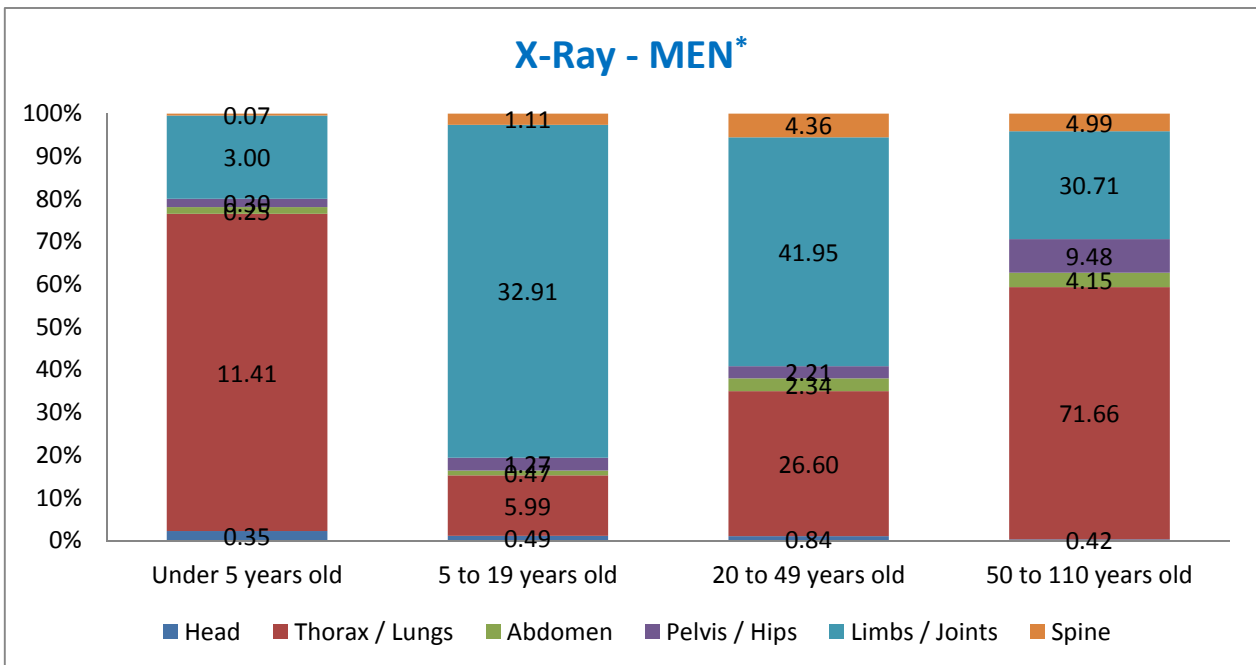
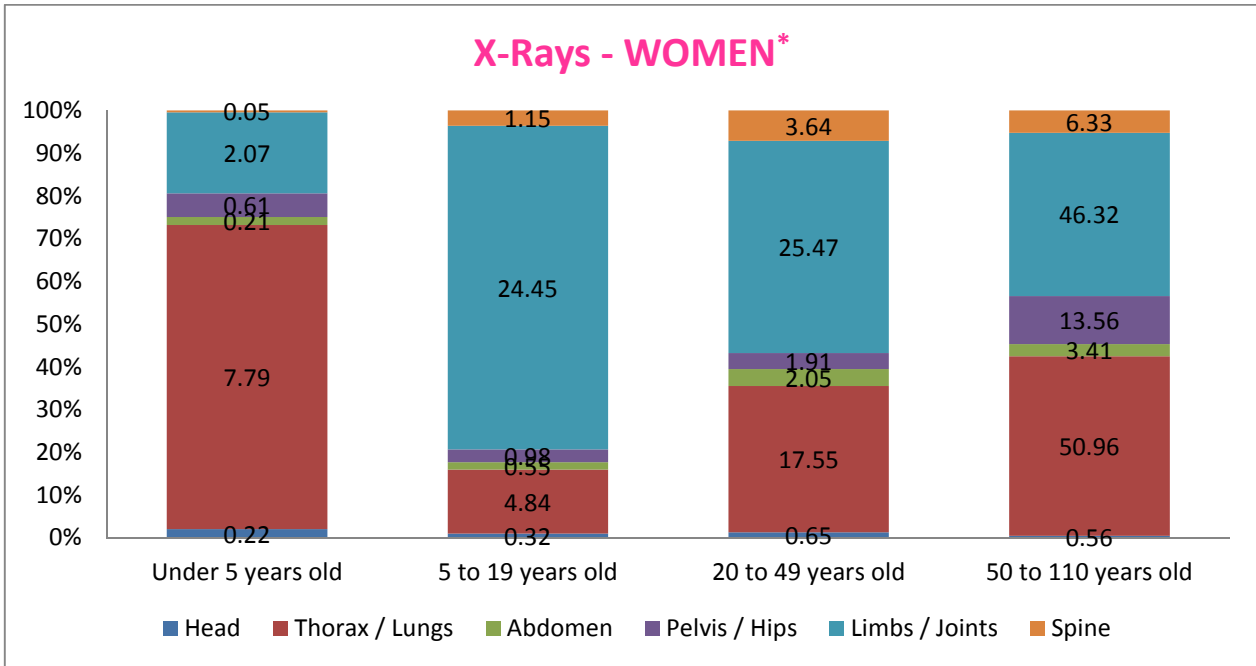
\* Our TARMED data only corresponded to about 80% of our total figures, and so these were normalized to agree with the 2013 values of sessions for 1000 inhabitants (Table 4).

The data presented in Figures 9 and 10 enable us to come to the following conclusions:

- The x-ray exposure of patients under five years of age principally concerns the thorax, at 71% for young girls and 74% for young boys.
- For children five years old and older, irradiation via x-rax concerns mostly the limbs and the joints, at 76% for girls and 78% for boys.
- For adults under 50, x-ray irradiation also mainly concerns the limbs followed by the thorax, with an average of 52% and 34% from, respectively, from all regions.
- After 50 it is again the thorax that predominates, with 42% for women compared to 59% for men.

- For cranial, thoracic, and abdominal x-rays men have more exposure, with nearly 43% more thoracic sessions (respectively 2.1 compared to 1.8; 116 compared to 81 and 7 compared to 6 sessions for 1000 individuals). In terms of x-rays of pelvic bones or hips, limbs and spinal column, more women were examined, with 29% more sessions for the pelvic region (respectively, 17 compared to 13; 109 compared to 98, and 11.2 compared to 10.5 sessions for 1000 individuals).

Figures 9 and 10: Distribution of x-ray sessions by anatomical region and age group. Number of x-ray sessions for 1000 inhabitants.



\* Our TARMED data only corresponded to about 80% of our total figures, and so these were normalized to agree with the 2013 values of sessions for 1000 inhabitants (Table 4).

## 4.5 DETAILED ANALYSIS FOR CT SCANS IN 2013

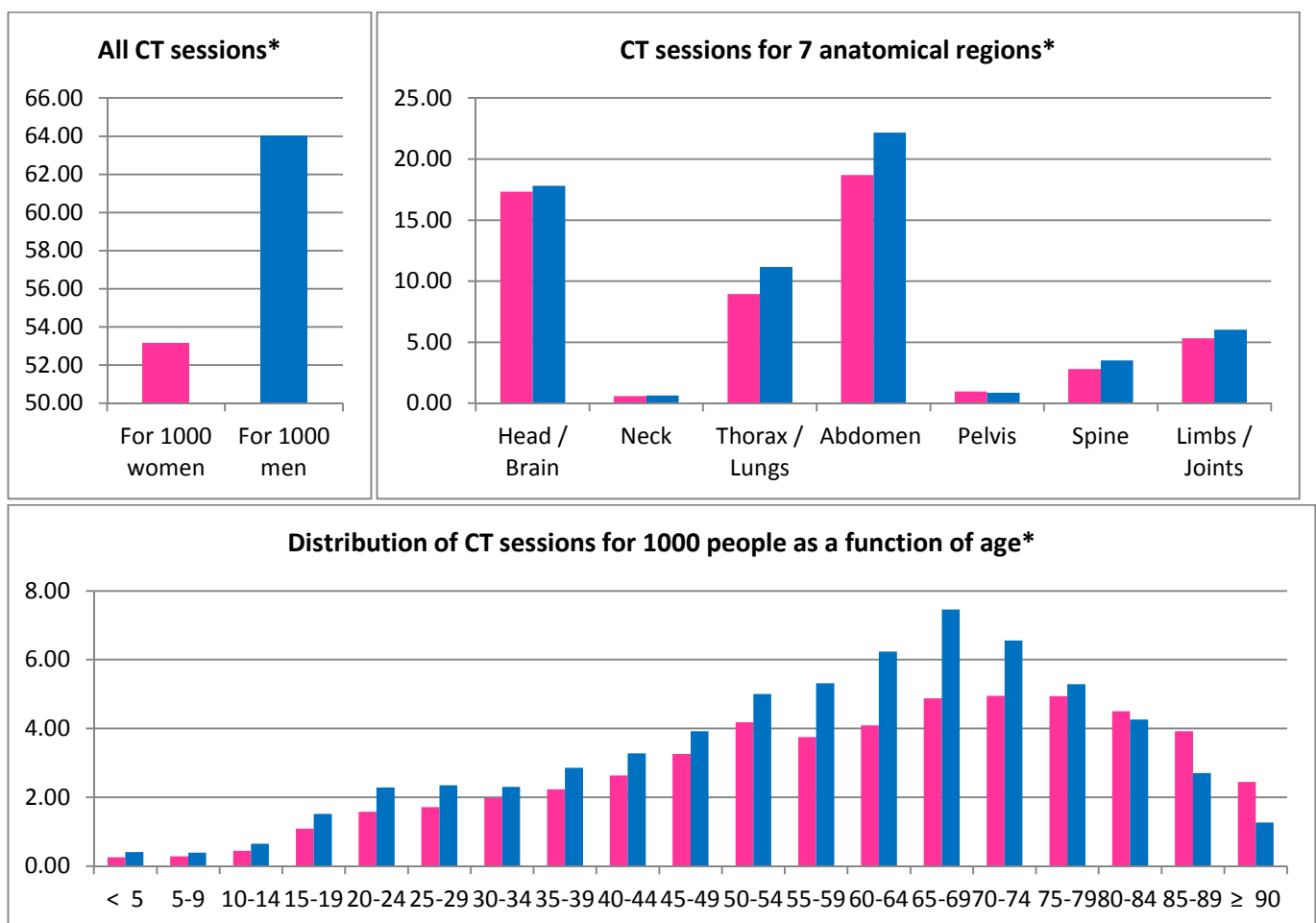
### 4.5.1 POPULATION ACTUALLY EXPOSED BY CT

The section of Switzerland's female population that is actually exposed is approximately 4.6%, with an average of 1.27 CT sessions for each of these patients. For the men, these figures go up to 5.4% with 1.33 CT exams per patient.

### 4.5.2 DISTRIBUTION ACCORDING TO PATIENT SEX AND AGE FOR CT

Figures 11 to 13 summarize the results obtained. The data analysis shows that 21% more men than women are exposed. Swiss women aged 70 to 74 and Swiss men aged 65 to 69 are the ones mainly concerned by this modality, with respectively 5.0 CT sessions for 1000 women and 7.5 CT exams for 1000 men in this age bracket.

Figures 11 - 13: Distributions of CT sessions for 1000 women (pink) and 1000 men (blue).



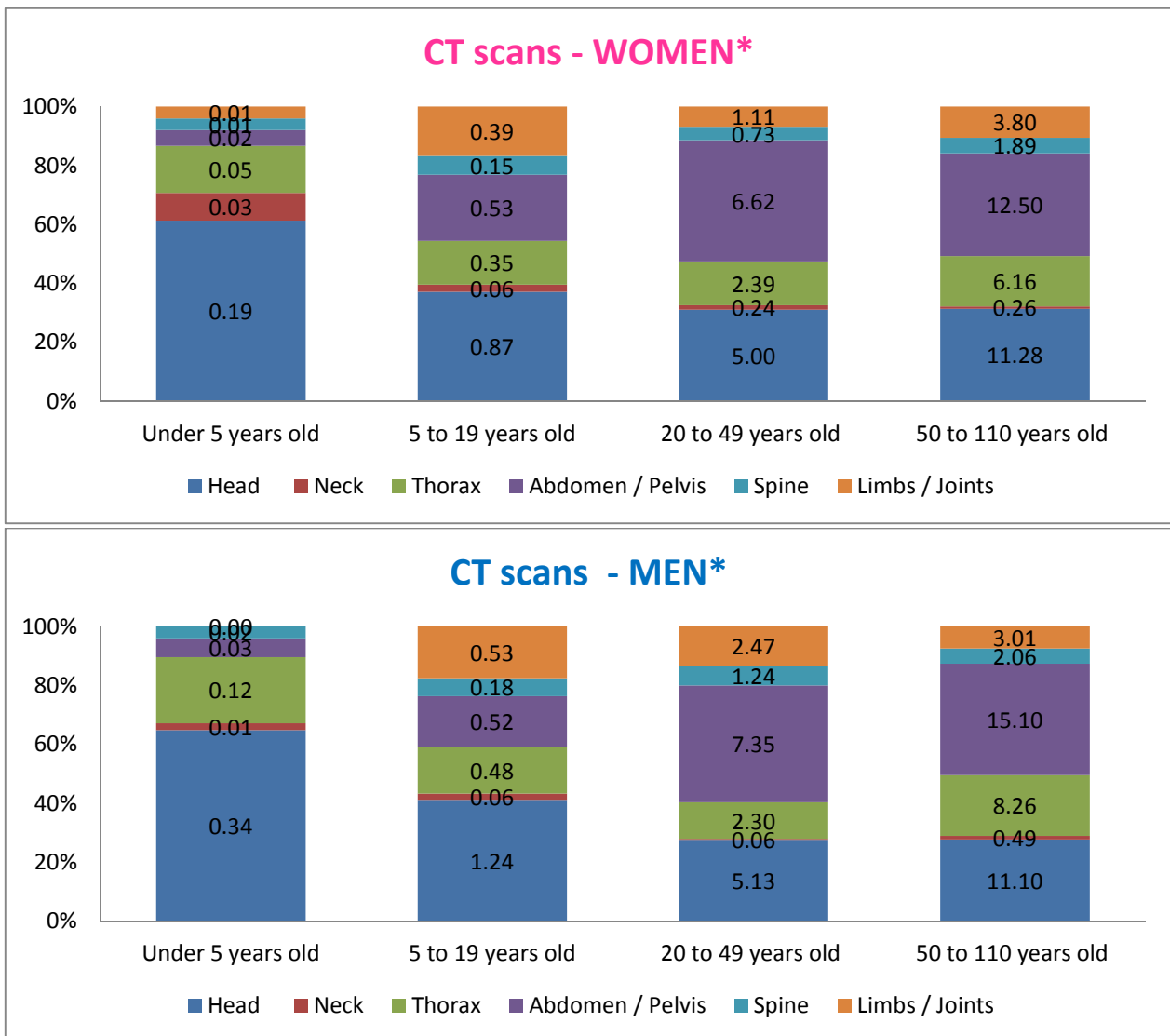
\* Our TARMED data only corresponded to about 80% of our total figures, and so these were normalized to agree with the 2013 values of sessions for 1000 inhabitants (Table 4).

- For CT of the neurocranium, the neck, the thorax, the upper abdomen, the abdomen, limbs and the spinal column, it is mostly Swiss men who are exposed; with men between the ages of 50 to 74 mostly concerned for the first four regions mentioned above (15.2 compared to 14.7; 0.8 compared to 0.6; 11.2 compared to 8.9; 1.3 compared to 0.6 and, respectively, 20.9 compared to 18.1 exams for 1000 inhabitants); and individuals between the ages of 15 and 64 mostly concerned for CT exams of the limbs (6.0 compared to 5.3) and the spinal column (3.5 exams for 1000 men compared to 2.8 for 1000 women).

- Swiss women over 50 years of age are more exposed, in terms of CT, for pelvic exams (1.0 compared to 0.8). This may be related to exams associated with gynecology. Swiss women over 65 are also more exposed to CT exams of the limbs.
- The CT exposure of patients under 5 mostly concerns the cranium and the neurocranium; this at 61% for little girls and at 65% for little boys. A particular effort must be made to optimize the CT acquisition protocols.
- For children 5 years of age and older, irradiation through x-ray also mainly concerns the cranium and the neurocranium, followed, in a decreasing manner, the abdomen, the limbs, and the thorax (with an average, respectively, of 36.5%, 19%, 16% and 14.5% of all anatomical regions).
- For adults starting at 20 years of age, the most explored region is the abdomen, then the cranium and the neurocranium, followed by the thorax. (with an average, respectively, 36%, 28%, and 15% of all anatomical regions).

As was done for x-ray, the distribution of exams by age group is presented in Figures 14 and 15.

Figures 14 and 15: Distribution of CT sessions by anatomical region and age group. Number of CT sessions for 1000 inhabitants.



\* Our TARMED data only corresponded to about 80% of our total figures, and so these were normalized to agree with the 2013 values of sessions for 1000 inhabitants (Table 4).

## 5 DISCUSSION

### 5.1 REPRESENTATIVITY OF DATA

#### 5.1.1 RESPONSE RATE

In terms of the RADdose survey, despite a concerted effort to improve the clarity of information to provide and two additional calls for participation, the response rate rarely surpassed 28%. Our survey is one of many similar calls which ultimately makes our project less attractive. A significant effort has been made in recent years to develop a method that would automatize data processing, and to do this by using invoicing codes. Unfortunately, many centers did not want to provide this kind of data, considering it too sensitive. This is truly regrettable, especially because we obtained an earlier agreement with the leading association of Swiss hospitals (H+). Our proximity to the Vaud centers did, however, enable us to make use of a highly complete sample, covering approximately 10% of the Swiss population.

### 5.2 DATA PROJECTION METHOD

To validate the factor 11.41, used to project our "pilot" data from the canton of Vaud to the national level, other statistical data was necessary. Here below we present various figures and reasonings verifying the robustness of our approach.

#### 5.2.1 VALIDITY OF THE PROPOSED FACTOR

Data linked to outpatient consultations in 2013, supplied by SASIS SA, were compared to the statistics from the hospitals published by the OFS [*Office Fédéral de la Statistique, 2015b*].

Table 7: Comparison of 2013 data from SASIS AG and the OFS

Sources	Factors: # Switzerland / # Vaud
SASIS AG - Outpatient consultations on hospital grounds	9.01
FOS - Number of intra-hospital CT sessions	8.95

Furthermore, being in possession of the TARMED data, not only for 2013 but also for 2008, we applied the same approach as the one described in the 2008 data report. We did this to verify whether we would get figures similar to those published for 2008. Here we concentrated on CT exams since these have a significant impact on the population's exposure. The data presented in Table 8 show the robustness of our approach.

Table 8: 2013 Extrapolation method applied to 2008 data

	2013	2008
Swiss population	8'139'600	7'701'900
Number of CT sessions via TARMED codes / 1000 inhabitants	104.89	89.43
Number of CT sessions collected via RADdose / 1000 inhabitants	12.23	10.43 ( <i>extrapolated</i> )
Factor: outpatient consultations # Swiss women / # Vaud women	11.41	11.17
Number of CT sessions calculated with our method	117 CT/ 1000 inhabitants	<b>99.86 CT</b> /1000 inhabitants
Figure published in the 2008 Swiss survey	→	<b>100 CT</b> / 1000 inhabitants

## 5.2.2 GOOD CHOICE OF "PILOT" CANTON?

The "pilot" canton, the canton of Vaud, has a particularly dense network of radiological installations and this may have added a bias to our result. To take this limitation into consideration, we used FOS figures regarding the medical-technical infrastructure. Our reasoning is set out below for CT sessions, in a hospital setting, of 24 Swiss cantons (Soleure and Appenzell Outer-Rhodes were excluded because of a lack of data). What we discovered was that, despite its strong provision in radiological devices, there are neither more nor less CT sessions conducted on Vaud equipment than there are on the installations of other cantons.

Table 9 : Validity of our choice of "pilot" canton

Hospital CT equipment (for 24 cantons)	189
Number of CT sessions, published by the FOS (for 24 cantons)	Some 730,000
Number of CT sessions per installation of hospital CT	3'862

Because CT installations in hospital settings work all week long, contrary to certain private installations, we wanted to correct the figure above by 0.71 (5/7). But it can happen that installations not used on evenings and weekends are used more. Because of this, the factor 0.83 was selected (5/6).

Table 10: Validity of our choice of "pilot" canton

Number of CT sessions per installation of hospital CT corrected by 0.83	3'217
Number of CT sessions for the 296 Swiss installations listed by the FOPH.	<b>116.99</b> CT sessions / 1000 inhabitants
Number of CT sessions obtained in the current study	<b>117</b> CT sessions / 1000 inhabitants

## **6 PERSPECTIVES AND CONCLUSIONS**

### **6.1 MAINTAIN CONTACT WITH TARMED CODE PROVIDERS**

The opportunity to easily conduct this kind of study greatly depends on maintaining close relationships with TARMED code providers. Only in this way will future data collection be less problematic. One could, in essence, imagine that the data would all arrive in a directly analysable format, rendered anonymous and collected before their administrative correction.

It is also important to remember that TARMED data enable a more detailed and concrete analysis of the distribution of medical irradiation over the population.

### **6.2 FUTURE STUDIES**

#### **6.2.1 CT SCANNING: FREQUENCY AND LONGITUDINAL ANALYSIS**

Future research could focus on Swiss CT practices, in light of the fact that this modality is a major contributor to the irradiation of the population and that its frequency of use continues to increase.

The analysis of CT sessions TARMED codes from 2013 revealed that we often irradiate several anatomical regions of a patient during a single visit. Reporting, as it is currently done, is therefore often biased. It would be interesting to explore this CT irradiation in a more concrete and detailed way.

Future studies could contain a longitudinal analysis of Swiss CT practices. Is there a tendency in recent years to cover more anatomical regions? Have certain CT sessions been replaced by MRI or ultrasound exams; non-irradiating modalities?

### **6.3 PERSPECTIVES**

#### **6.3.1 AUTOMATED DOSE COLLECTION**

A limitation of this type of survey is the collection of exam frequencies separated from actually delivered doses. This is particularly critical for CT exams, in which doses can vary in a significant way from one center to another. The use, in a centralized manner, of data coming from automated dose collection software (DoseWatch, Radimetrics...) would provide for a set of data that is more appropriate for initiating an optimization approach. These data also make it possible to obtain the distribution figures for exams into age and gender categories. One could also estimate the fraction of the population who is actually exposed through x-ray imaging.

#### **6.3.2 RADIOLOGY AND VOLUME OF CONTRAST MEDIUM**

The follow-up of data published for cardiology procedures is also an area to focus upon in the future. Note that, as much for CT as for radiology, it would be interesting to collect volumes of injected contrast medium. In essence, a strong decrease in dose may require a significant increase in contrast medium.

#### **6.3.3 NUCLEAR MEDICINE**

Separating follow up of activities between radiology and nuclear medicine is becoming more and more problematic, since CTs conducted within nuclear medicine departments are not reported. In the future, it would be interesting to synchronize these surveys.

#### **6.3.4 "CBCT" INSTALLATIONS**

Finally, the follow-up of "CBCT" installations, used in dental practices, must be better regulated because the effective doses delivered may vary from tens to hundreds of microsieverts.

## 6.4 CONCLUSION

The updated evaluation of the population's exposure through medical imaging shows that we have moved from 1.2 mSv en 2008 to about 1.4 mSv in 2013. This increase is linked to CT use (117 exams per 1000 inhabitants in 2013 compared to 100 exams per 1000 inhabitants in 2008) but also, to a lesser degree, to a slight increase in interventional radiology. This increase is, however, compatible with the practices of the countries that surround Switzerland.



## ABBREVIATIONS

AA.....	Assurance-accidents obligatoire (Mandatory Accident Insurance)
AG .....	Canton d'Argovie (Canton of Argovie)
AI .....	Canton d'Appenzell Rhodes-Intérieures ou l'Assurance Invalidité (Canton of Appenzell Inner-Rhodes or Invalidity Insurance)
AM .....	Assurance militaire (Military Insurance)
AR.....	Canton d'Appenzell Rhodes-Extérieures (Canton of Appenzell Outer-Rhodes)
BE.....	Canton de Berne (Canton of Bern)
BL .....	Canton de Bâle Campagne (Canton of Basel Country)
BS.....	Canton de Bâle Ville (Canton of Basel-City)
CA.....	Angiographie des coronaires ou coronographie (Coronary Angiography or Coronagraphy)
CBCT .....	Cone Beam CT
CHUV .....	Centre Hospitalier Universitaire Vaudois (Vaud University Hospital)
CT.....	Scanographie, Scanner ou Tomodensitométrie (CT Scanning or Computed Tomography)
FHV .....	Fédération des Hôpitaux Vaudois (Federation of Vaud Hospitals)
FR.....	Canton de Fribourg (Canton of Fribourg)
GE .....	Canton de Genève (Canton of Geneva)
GL.....	Canton de Glaris (Canton of Glarus)
GR .....	Canton des Grisons (Canton of Grisons)
H+ .....	Association faîtière des hôpitaux suisses (Swiss Hospitals Association)
IRM .....	Imagerie par Résonance Magnétique (Magnetic Resonance Imaging)
JU .....	Canton du Jura (Canton of Jura)
LAMal .....	Assurance obligatoire des soins (Mandatory Swiss Health Insurance)
LU .....	Canton de Lucerne (Canton of Luzern)
MN .....	Médecine nucléaire (Nuclear Medicine)
NE.....	Canton de Neuchâtel (Canton of Neuchatel)
NW.....	Canton de Nidwald (Canton of Nidwald)
OFS .....	Office Fédéral de la Statistique (Federal Offices of Statistics)
OFSP .....	Office Fédéral de la Santé Publique (Federal Office of Public Health)
OW .....	Canton d'Obwald (Canton of Obwald)
PTCA .....	Angioplastie coronarienne transluminale (Transluminal Coronary Angioplasty)
RX.....	Radiographie conventionnelle (Conventional x-ray)
SG .....	Canton de Saint-Gall (Canton of St. Gallen)
SH.....	Canton de Schaffhouse (Canton of Schaffhausen)
SMV .....	Société des Médecins Vaudois (Society of Vaud Doctors)
SO .....	Canton de Soleure (Canton of Solothurn)
SZ .....	Canton de Schwytz (Canton of Schwytz)
TI .....	Canton du Tessin (Canton of Ticino)
UR .....	Canton d'Uri (Canton of Uri)
VD.....	Canton de Vaud (Canton of Vaud)
VS.....	Canton du Valais (Canton of Valais)
ZG.....	Canton de Zug (Canton of Zug)
ZH.....	Canton de Zürich (Canton of Zurich)

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