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Medical Radiation Exposure of the European Population

Part 1/2

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FOREWORD

Luxembourg, December 2014

Ionising radiation has been used in medicine since the discovery of radioactivity and x-rays more than a hundred years ago and is now firmly established as an essential tool for medical diagnosis and therapy. Medical x-ray and nuclear imaging has experienced marked increase in the past decade or so when new technologies, such as computed tomography and positron emission tomography, have become widespread. These procedures – when medically indicated and properly conducted – provide great benefits to patients; however the associated radiation exposures have to be monitored and controlled in the view of their potential to cause harmful health effects.

In 2008 the European Commission published "Radiation Protection 154: European Guidance on Estimating Population Doses from Medical X-Ray Procedures" (RP 154). The 2008 publication also contained the results of the national medical exposure studies in ten European countries. However, full evaluation of the radiation exposure from medical diagnostic procedures in Europe has not been previously carried out. The present report is therefore intended to fill this gap.

This report provides comprehensive information on 36 European countries regarding frequencies and radiation dose of x-ray and nuclear medicine radiodiagnostic procedures. The information presented in the report is based on national surveys carried out between 2007 and 2010. The final results are presented as annual effective dose per caput in the participating European countries, which has been calculated to be about 1.1 mSv for all medical imaging. To put this value in perspective, it could be noted that it is about half the recent value of per caput medical radiation dose estimated in Australia and about one-third of the corresponding value in the USA. The report also shows that the radiation dose from medical imaging varies hugely among the different European countries and that there is a trend upwards in many countries; further analyses on national level are needed to better quantify and understand these differences and trends.

In terms of the significance of the different groups of medical imaging procedures, the report demonstrates that computed tomography alone is responsible for more than half of the medical radiation exposure of the European population in 2007-2010. Other x-ray procedures are responsible for most of the remaining population exposure, and nuclear medicine contributes with only about five percent.

The work undertaken to produce this report has provided several important additional benefits. Most importantly, the project activities have galvanised national efforts to develop and carry out population dose studies in the European countries, including in countries with limited previous experience. The report identified a “Top 7” approach to nuclear medicine procedures, which is complementary to the RP 154's "Top 20" for x-ray examinations and should be used by European countries in future dose surveys. Finally, a summary of the national diagnostic reference levels (DRLs) is published as Part 2 of this report (only available online).

I believe that the data and the results included in this report will serve as an important reference for authorities, scientists and professionals dealing with radiation protection of patients. High-quality and up-to-date information provides the basis of sound policies, and maintaining and updating our knowledge of the medical radiation exposure of the population should be of utmost importance. This is emphasized in the recently updated European Basic Safety Standards (Council Directive 2013/59/Euratom) requiring, among others, taking into account the age and gender distribution of the exposed patient population.

The publication of this report in the Commission's Radiation Protection series of publications has been recommended by the Group of Experts established under Article 31 of the Euratom Treaty.

Ivo Alehno

Head of Radiation Protection Unit

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LIST OF ABBREVIATIONS

ACHI	Australian Classfication of Health Insurance
AF	Adult Female
AM	Adult Male
AP	Anterior Posterior
APIC	Portuguese Association of Cardiovascular Intervention
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency
β-CIT	β-carboxymethyoxy-3-β-(4-iodophenyl) tropane
CA	Coronary Angiography
CBCT	Cone Beam Computed Tomography
CC	Conversion Coefficient
CIHI	Croatian Institute for Health Insurance
CRP	Centre of Radiation Protection (Moldova)
CT	Computed Tomography
CT-EXPO	Name of an organ dose calculation software package (Hannover, Germany)
DAP	Dose Area Product
DDM1	Dose Datamed 1, Acronym for the earlier EC project on European population doses
DDM2	Dose Datamed2, Acronym of the present EC project “Study on European Population Doses from Medical Exposure”
DDMedDB	Dose Datamed Database
DLP	Dose Length Product
DMSA	Dimercaptosuccinic acid
DRL	Diagnostic Reference Level
DTPA	Diethylene triamine pentaacetic acid
EC	European Commission
ECD	Ethyl Cysteinate Dimer
EFTA	European Free Trade Area
ESAK	Entrance Surface Air Kerma
ESD	Entrance Surface Dose
EUROSTAT	Directorate General of the European Commission with the mission to provide statistical information
EU	European Union
FAQ	Frequently Asked Questions
FDG	Fluorodeoxyglucose
GAEC	Greek Atomic Energy Commission

HCL1	Health Care Level 1
HPA	Health Protection Agency (UK)
IAEA	International Atomic Energy Agency
ICD	International Classification of Diseases
ICRP	International Commission on Radiological Protection
ICRU	International Commission on Radiation Units and Measurements
IHIS	Institute of Health Information and Statistics (Czech Republic)
InVS	National Institute for Public Health Surveillance (France)
IRSA	Icelandic Radiation Safety Authority
IVU	Intravenous Urography
IR	Interventional Radiology
IRSN	Institute for Radiation Protection and Nuclear Safety (France)
KAP	Kerma Area Product
LAT	Lateral
LSJ	Lumbo-Sacral Joint
MDCT	Multidetector Computed Tomography
MED	Medical Exposure Directive
MGD	Mean Glandular Dose
MIBI	Methoxyisobutylisonitrile
MIRD	Medical Internal Radiation Dosimetry
MRI	Magnetic Resonance Imaging
MUGA	Multi Gated Acquisition Scan
NCPH	National Centre of Public Health (Moldova)
NCRP	National Council on Radiation Protection
NCRPHC	National Centre for Radiation Protection in Health Care (Poland)
NCRRP	National Centre of Radiobiology and Radiation Protection (Bulgaria)
NHF	National Health Fund (Poland)
NM	Nuclear Medicine
NRPA	Norwegian Radiation Protection Authority
NRPB	National Radiological Protection Board (UK)
PA	Posterior Anterior
PACS	Picture Achieving and Communication System
PCI	Percutaneous Coronary Intervention
PCXMC	Name of an organ dose calculation software package (Ref.)
PEDDOSE	European project "Dosimetry and Health Effects of Diagnostic Applications of Radiopharmaceuticals with particular emphasis on the use in children and adolescents" under FP7
PET-CT	Positron Emission Tomography –CT

PTCA	Percutaneous Transluminal Coronary Angioplasty
QC	Quality Control
RIS	Radiological Information Systems
RP154	EC Publication "Radiation Protection 154: European Guidance on Estimating Population Doses from Medical X-Ray Procedure
RPD	Radiation Protection Dosimetry
SPECT-CT	Single Positron Emission –CT
STUK	Radiation and Nuclear Safety Authority (Finland)
TLD	Thermoluminescent Dosimetry
UK	United Kingdom
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
US	Ultrasound
USA	United States of America
WHO	World Health Organization
WP	Work Package

EXECUTIVE SUMMARY

Recent increases in medical imaging, particularly with respect to computed tomography (CT) and other high dose procedures, have led to significant increase of individual patient doses and of the collective dose to the population as a whole. Regular assessments of the magnitude and distribution of this large and increasing source of population exposure is therefore of high importance. The objective of the present Dose Datamed 2 (DDM2) project has been to collect available data on the doses from radiodiagnostic procedures (x-ray procedures and nuclear medicine) in the European Union and to facilitate the further implementation of Radiation Protection 154 (European Guidance on Estimating Population Doses from Medical X-Ray Procedures, published by the European Commission in 2008 (EC 2008)). An estimate of the collective effective doses to patients from radiodiagnostic procedures for the European Union as a whole has not been previously carried out. In the previous Dose Datamed1 (DDM1) project, collective effective doses was also surveyed but only for 10 European countries; therefore, the present survey for all European countries was much more comprehensive, while it has also been of interest to identify any trends in the collective effective doses in the 10 countries included in both projects.

The study was conducted by web-based questionnaires, with specific Excel-forms for detailed data collection, down- and uploadable at the project website. The questionnaires were distributed to all EU member states, EFTA countries and some other European countries. Frequency and effective dose data were collected for the “Top 20 procedures” (Top 20 approach) defined in RP 154 in all countries, while comprehensive data for all x-ray procedures and nuclear medicine (NM) procedures were collected in a few countries. Both sets of data were used to estimate the overall frequencies and collective effective doses to the European population. The data were stored in an established database which will enable future follow-up of the trends in European population dose. Data collection was backed by providing training and advice to the countries through the project organization, as well as providing expert verification and analysis of the received data. Conducting the questionnaires, organizing the training course and all other actions within this project have had a tremendous impact on the development of population dose estimations, including in those European countries that had little or no previous experience of this topic.

As a supplementary effort, a review of the European Diagnostic Reference Levels (DRLs) of patient doses was carried out and published as Part 2 of this report. In addition, through the general questionnaires, the implementation of the population dose estimation requirements of the MED directive and some supporting statistical data on the radiation practices and national healthcare systems were reviewed.

The general questionnaire revealed that except for a few countries, regulations and/or recommendations for population dose evaluation existed. The questionnaire also provided information on the organizations responsible for frequency and dose collections and for carrying out population dose estimations, as well as several details of their practical implementation (e.g. periodicity and national coding systems available for classification of x-ray and NM procedures).

In this study, for the determination of the collective effective dose, the general population has been used instead of the patient population, and no distinction has been made between adult and paediatric populations. This pragmatic approach is justified for several reasons related to the availability and comparability of the data and the deficiency of effective dose as a risk quantity for patient population.

The results of the data collection and analysis lead to the following conclusions on the overall total collective effective doses in European countries:

For x-ray procedures :

Group 1: EU-countries and EFTA countries (except Liechtenstein) (31 countries, see Table 3.1): 547500 manSv, resulting in a mean effective dose of 1,06 mSv per caput.

Group 2: All European countries included in this survey (36 countries, see Table 3.1) 605000 manSv, resulting in a mean effective dose of 1,05 mSv per caput.

For NM procedures :

Group 1: 30700 manSv, resulting in a mean effective dose of 0,06 mSv per caput.

Group 2: 31100 manSv, resulting in a mean effective dose of 0,05 mSv per caput.

The overall per caput effective dose for all medical imaging (X-rays + NM procedures) is therefore 1,12 mSv (Group 1) and 1,10 mSv (Group 2). The contribution to the total population dose of CT, plain radiography, fluoroscopy, interventional radiology and NM procedures is respectively about 57 %, 17%, 12 %, 9 %, 5 % (Group 1) and 52 %, 22 %, 13 %, 8 %, 5 % (Group 2).

The overall per caput effective doses are about half the recent value of per caput effective doses estimated in Australia (Wallace 2012) and about one-third of the corresponding value in the USA (NCRP 2009). Comparing the results with an earlier estimation of population dose in Europe, in the DDM1 countries, there seems to be a trend upwards; however, because for some of the DDM1 countries the new data are based on Top 20 estimations only, no strict conclusion about the percentage increase can be made. While the average dose in Europe turned out to be relatively low, there are high variations in the results between countries. The variation originates from many different sources and can not be explained without further studies on national level. It is important to investigate and ensure a proper balance between local imaging resources and optimal radiation protection. The distribution of the doses between various groups of examinations and other detailed results of this study can be exploited by comparing the practices and identifying the cases requiring highest attention.

While there are relatively large uncertainties involved in the estimation of population dose for different procedures and in different countries, it was estimated that the overall uncertainty of the European population dose can still be reasonable, less than 10 %.

The Top 20 approach is still considered to yield a good approximation of the population dose, in particular if this set of examinations is supplemented by a few extra types of examinations known or anticipated to also yield a significant contribution to the population dose. An approach similar to Top 20, called “Top7”, is proposed for NM procedures in order to cover a good percentage of the overall population dose from all NM procedures. A slight revision of the European guidance (RP 154) could be recommended in order to take into account the experiences of this project and to supplement the existing guidance with similar advice for NM procedures.

The database developed in the DDM2 project contains all the data collected in the project. The database is designed to support several data sets from future studies. This will allow a future project to compare the collected data and calculate trends in Europe. Even though there were not enough resources to establish a system with a sophisticated user interface, the system can handle data from several years/studies. Some suggestions for the future development and use of the database are discussed in Annex 11 to the report.

The project also included considerations of the importance of the new ICRP tissue weighting factors for the population dose estimations. It is concluded that the most recent revision in tissue weighting factors from ICRP 60 (E60) to ICRP 103 (E103) will have a significant impact (by more than a few tens of percent) for only a few types of x-ray examination and only a minor impact on the mean effective dose estimation in total.

The importance of age/and sex distributions was also reviewed. Based on EUROSTAT data, the overall age distribution of the EU 27 countries shows no significant differences between

the data from 2005 and 2010. Comparisons of the average data on age/sex distribution for the five DDM 1 countries and four DDM 2 countries, for specific x-ray examinations, indicated that the distributions are sufficiently similar to conclude that the usage of the European average distributions (published in DDM1 project) is still reasonable when specific national data on age and sex distribution per examination are not available. New data on age and sex distributions for the Top 20 examinations are provided in this report that can be used by any European country, in the absence of more reliable national data. In nuclear medicine, typical paediatric procedures are different from adult procedures: about three quarters of micturating cystography are performed on children.

This report includes a large number of annexes providing further information in support of European population dose estimation: details of the results of the European questionnaires, a collection of experiences on the use of the European guidelines (RP 154, EC 2008), additional recommendations on population dose estimations to support the use of RP 154, information on the population dose database established in the project, and the effect of tissue weighting factors on the estimation of effective dose for x-ray procedures.

1 INTRODUCTION

At the end of 2004 the European Commission (EC) launched a project to provide information and develop guidance on the implementation of Article 12 of the Medical Exposure Directive in Member States with regard to medical radiodiagnostic procedures. This “DOSE DATAMED” study (referred to hereinafter as DDM1) covered ten European countries with national experiences in conducting surveys of dose distributions from medical radiodiagnostic procedures. The guidance developed under the DDM1 project, together with best available survey data from these ten countries around the year 2002, was published by the European Commission as Radiation Protection 154 - European Guidance on Estimating Population Dose from Medical X-ray Procedures (RP154) (EC 2008).

At the beginning of 2011 EC launched a new project, a follow-up called “Study on European Population Doses From Medical Exposure”, or Dose Datamed 2 (DDM2). Reference was made to the rapid technological development during the last decade and the need for updated comparable data about the doses from medical exposure procedures, in x-ray diagnostics, interventional radiology and nuclear medicine (NM), in the European Union Member States. The availability of such data will facilitate the implementation of radiation protection requirements in the EU Member States as well as future decision-making on these matters on national and EU level. An estimate of the doses to patients from radiodiagnostic procedures for the European Union as a whole had not been carried out previously, and it has also been of interest to identify any trends in the doses.

2 PURPOSE AND SCOPE

The objective of the DDM2 project has been to collect available data on the doses from radiodiagnostic procedures (x-ray procedures and nuclear medicine) in the European Union and to facilitate the further implementation of Radiation Protection 154. European Guidance on Estimating Population Doses from Medical X-Ray Procedure, published by the European Commission in 2008.

To achieve the objectives, the following actions have been undertaken:

- Providing advice and collecting feedback from the application of guidance RP 154;
- Providing estimates of population doses in EU Member States and the population dose in European Union as a whole;
- Providing a database for population dose information which will enable continuous collection and follow-up of European population doses.

As a supplementary aim, due to their close relationship with population dose evaluations, Diagnostic Reference Levels (DRL) for several x-ray and NM procedures were collected in the context of the project questionnaires. The comparison of the DRLs with the data from mean effective doses used in population dose calculations can provide helpful information for the studies of the appropriateness of the DRLs. The results of the DRL survey are presented in Project Report Part 2.

3 METHODOLOGY AND CONCEPTS

3.1 Project organization and methods of data collection

The project consortium has included partners from both the previous DDM1 project and from those countries that were not involved in the earlier project but had recent experiences in the implementation of report RP154. Furthermore, the project consortium has been supported by a panel of scientific experts, with participants from several other DDM1 countries and the relevant international bodies, and by an observer representing WHO and UNSCEAR. Finally, the collection of information and data has been ensured through national contact persons established by contacting the authorities and other relevant organizations in all European countries.

The project was divided into six separate work packages (WP):

- WP 1: Management and coordination
- WP 2: General questionnaire and database
- WP 3: Population dose for countries with national surveys
- WP 4: Population dose for countries without national surveys
- WP 5: Population dose in European Union as the whole
- WP 6: European Workshop

The first step was the circulation of a general questionnaire (Annex 1) to the EU member States and affiliated states, altogether 40 countries. The purpose of the general questionnaire was to survey the national regulatory frameworks and the status of implementation of the requirements for medical dose surveys and population dose estimations. The questionnaire was based on the experiences and information collected within the DDM1 project. The questionnaire was distributed to the national contact persons; the list of national contact persons was subsequently updated through the implementation of WP2, and the final list is available in Annex 1. The final list consists of contact data for 36 countries that supplied most of the requested data; this includes the 28 EU Member States, 3 EFTA and 5 other European countries. All 36 countries, their country symbols and population numbers as used in this report are shown in Table 3.1. Besides these countries, two countries, Belarus (BY) and Bosnia and Herzegovina (BA) supplied some of the general data, and these countries are therefore included in some tables and graphs.

The results of the general questionnaire were used to plan the more detailed surveys in WP3 and WP4. Two separate questionnaires (countries “with and without national surveys”) were originally planned, but this approach turned out to be unfeasible and was replaced by a joint questionnaire to all countries. The joint questionnaire was planned in a way that all countries were able to submit their available data, but also consider and be aware of the different options according to the existing guidance of RP 154.

The practical implementation of the joint questionnaire and data collection was carried out using state-of-the-art internet-based techniques. This has provided a remote online access to the platform from all participating parties. A significant number of general questions included in the questionnaire, e.g. statistics on health providers and professionals and a review of Diagnostic Reference Levels (DRLs), were directly implemented in the web-based system allowing easy response, with a possibility to return to the questionnaire whenever needed before the final submission. For practical reasons, however, the actual dose survey for population dose estimations (i.e., the frequency and dose data) was implemented through specific EXCEL files. Templates of those EXCEL spreadsheets have been integrated into the

online system for download and the completed files have been collected there as well within an integrated upload feature.

Table 3.1. Country names, symbols and population numbers.

Country name	Country symbol (Eurostat)	Population, millions	Group 1 countries (31)	Group 2 countries (=all countries) (36)
EU Member States (28)				
Austria	AT	8,40	x	x
Belgium	BE	10,87	x	x
Bulgaria	BG	7,54	x	x
Cyprus	CY	0,84	x	x
Czech Republic	CZ	10,50	x	x
Germany	DE	81,80	x	x
Denmark	DK	5,56	x	x
Estonia	EE	1,32	x	x
Greece	EL	10,96	x	x
Spain	ES	47,02	x	x
Finland	FI	5,33	x	x
France	FR	63,70	x	x
Croatia	HR	4,29	x	x
Hungary	HU	10,01	x	x
Ireland	IE	3,45	x	x
Italy	IT	60,63	x	x
Lithuania	LT	3,25	x	x
Luxembourg	LU	0,47	x	x
Latvia	LV	2,07	x	x
Malta	MT	0,41	x	x
The Netherlands	NL	16,49	x	x
Poland	PL	38,14	x	x
Portugal	PT	10,56	x	x
Romania	RO	21,00	x	x
Sweden	SE	9,20	x	x
Slovenia	SI	2,05	x	x
Slovakia	SK	5,44	x	x
United Kingdom	UK	61,40	x	x
EFTA countries (3)				
Switzerland	CH	7,70	x	x
Iceland	IS	0,32	x	x
Norway	NO	4,74	x	x
Other European countries (5)				
Moldova	MD	3,57		x
Montenegro	ME	0,67		x
Former Yugoslavian Republic Of Macedonia	MK	2,03		x
Serbia	RS	7,50		x
Ukraine	UA	45,90		x

For the purpose of systematic evaluation of the results and to enable a continuous follow-up and update of population dose in Europe and the trends in their development, a database for population doses was established. This database is implemented using standard

technologies that enable versatile use of the database and the possibility of continued updates of the EU Member States and other European countries. Dedicated software components have been developed to import the data provided into the database (online questionnaire and Excel data) in a structured way. The data within the database are now accessible in different views, for the analysis needed. These views on the data can be exported to Excel files at any time to support the analysis. Selected views are available on the project website (see Annex 11).

To ensure a successful data collection and to reduce the uncertainties, five European countries were selected as “test countries”. The selection was based on the information received from the first general questionnaire and aimed at ensuring representative information for different health care and reimbursement systems/level of technical development in radiology and other factors. This arrangement was also used to contribute to the testing of the guidelines (RP 154) and identify any deficiencies and needs for amendment or further development.

A special two-day training course was held in Sofia, Bulgaria, to give practical information and advice to the test countries (contact persons or persons responsible for organizing the national surveys for population dose estimations) and also to the representatives of some other countries willing to participate. The training course included both lectures and practical demonstrations or exercises, and resulted in preparing a detailed plan for the implementation of the data collection in each test country. Further, individual advisors for each test country were nominated from the project staff (partners or panel of experts) to give additional advice and support in organizing the national survey for population dose estimation and on the analysis and reporting of the results.

The results of data collection, the population dose estimations, the test implementation of the European Guidance (RP 154) with the proposed modifications or amendments, and the proposed database and follow-up of population doses were presented to open discussion at a European Workshop. The purpose of this workshop was to provide information on the results and gain extensive feedback on the European Guidance and follow-up schemes, in order to finalize the report to the EC. The purpose was also to encourage all countries to establish and maintain continuous population dose estimations in accordance with EC directive requirements. The workshop attracted 135 participants from 33 countries including Australia (Australian Radiation Protection and Nuclear Safety Agency, ARPANSA) and the USA (National Council on Radiation Protection, NCRP). The participants represented radiological practitioners, competent authorities, national organizations responsible for collecting health care statistical information and other stakeholders. Keynote presentations were given by speakers from the project staff (consortium, the Panel of Scientific Experts and the UNSCEAR observer).

3.2 Main concepts

For the purpose of this report, the following definitions have been used:

- TOP20 (EC 2008): The 20 types of examinations or procedures that are amongst the highest contributors to the collective effective dose. Together these ‘Top 20 Exams’ contribute between 50-70% to the total frequency and between 70-90% of the total collective effective dose from all medical x-ray procedures (excluding dental).

- Radiodiagnostic (MED): pertaining to diagnostic nuclear medicine, medical diagnostic radiology, and dental radiology.

- Radiological examination: x-ray examination/procedure or NM procedure.

- x-ray examination: x-ray examinations or interventional procedure defined as one or a series of x-ray exposures of one anatomical region/organ/organ system, using a single imaging modality (i.e. radiography/fluoroscopy or CT), needed to answer a specific diagnostic problem or clinical question, during one visit to the radiology department, hospital or clinic (EC 2008).

- NM procedure**:** The use of very small amounts of radioactive materials (called radiopharmaceuticals or radiotracers) to evaluate molecular, metabolic, physiologic and pathologic conditions of the body for the purposes of diagnosis (Society of Nuclear Medicine and Molecular Imaging).

- Population dose: the collective effective dose to the total population caused by radiological imaging and procedures (x-ray procedures and nuclear medicine procedures). No distinction has been made between adult and paediatric populations. Dose delivered in radiotherapy, including therapeutic use of nuclear medicine, is not included in the estimation.

In principle, the collective effective dose can also be determined for given groups of population, e.g. for paediatric population, and also for the patient population. In this study, however, general population is used instead of patient population, and no distinction is made between adult and paediatric populations as shown by the above definition of population dose. This pragmatic approach is justified for several reasons: first, the data which most of the countries could provide did not distinguish between the frequency of procedures and the number of patients (i.e. there was no information on how many of the examinations had been carried out on the same patient), and mostly included the frequency of procedures without age or sex distributions. Some countries could provide only data concerning adults and some even had difficulties providing data that was needed in the TOP20 method. Therefore, the estimation of the population dose had to be based on the data reasonably available from the countries. Second, the approach chosen is the one generally used for population dose estimation, so the results of this study are comparable to the published estimations from some other countries outside Europe. Third, the estimation of population dose, based on effective dose, to the patient populations suffers from the fact that the effective dose is not recommended for assessing the radiation risk of patient populations, because the age distributions for workers and the general population (for which the effective dose is derived) can be quite different from the overall age distribution for the patients undergoing medical procedures using ionizing radiation (ICRP 2007).

4 RADIOLOGY IN EUROPE - GENERAL DATA

As background information, for the purpose of analyzing the differences between the population dose estimates in various countries, a number of selected statistical data on radiology was collected. This data could be used, for example, to study the correlation between the examination frequencies or population doses and the proportion of public versus private health care units providing radiological services.

In this chapter, the results of the general questions are summarized. The list of countries, country codes as used in this report and the numbers of populations are given in Table 3.1 (Section 3.1). The detailed results of the first general questionnaire on the availability of frequency and population dose data have been summarized in Annex 7.

4.1 Radiation practices and national healthcare systems

The structure of healthcare varies greatly from country to country as can be seen from the distribution of the number of different healthcare providers, Fig. 4.1 and Table 4.1 (Annex 4). In particular, there is a high variation in the relative proportion of state (governmental) hospitals and private hospitals: In some large countries, nearly half or more than a half, of the hospitals are private, while in most of the countries the hospitals are mainly state owned. However, it should also be noted that even though the numbers of public and private hospitals could be equal, the private hospitals are generally much smaller than the public hospitals and, therefore, only a small fraction of all x-ray examinations may be carried out in private hospitals and clinics.

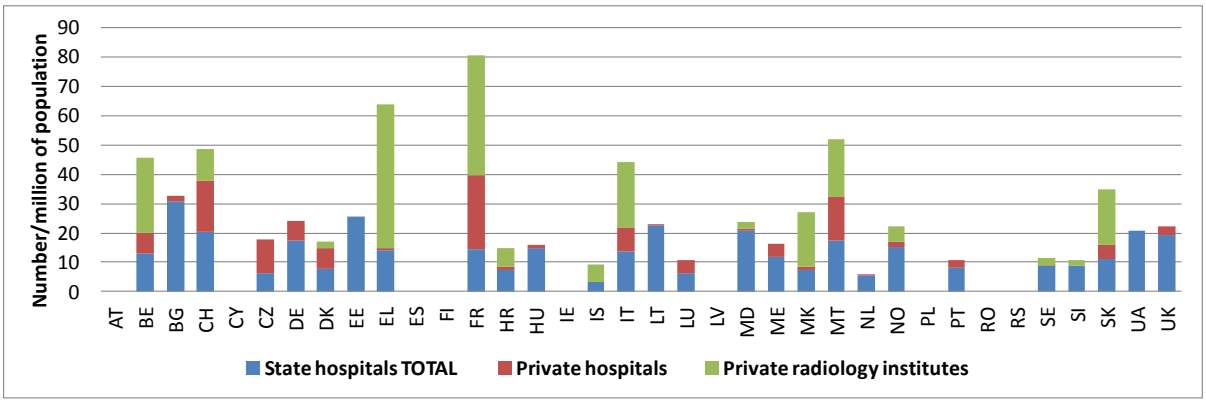


Figure 4.1. Numbers of state and private hospitals and private radiological institutes in the European countries, per million of population. State and private hospitals are health care units which provide radiological services besides other health care services. State hospitals include university hospitals. Private radiological institutes are focused on providing radiological services. In case of no number, no information from the country has been available.

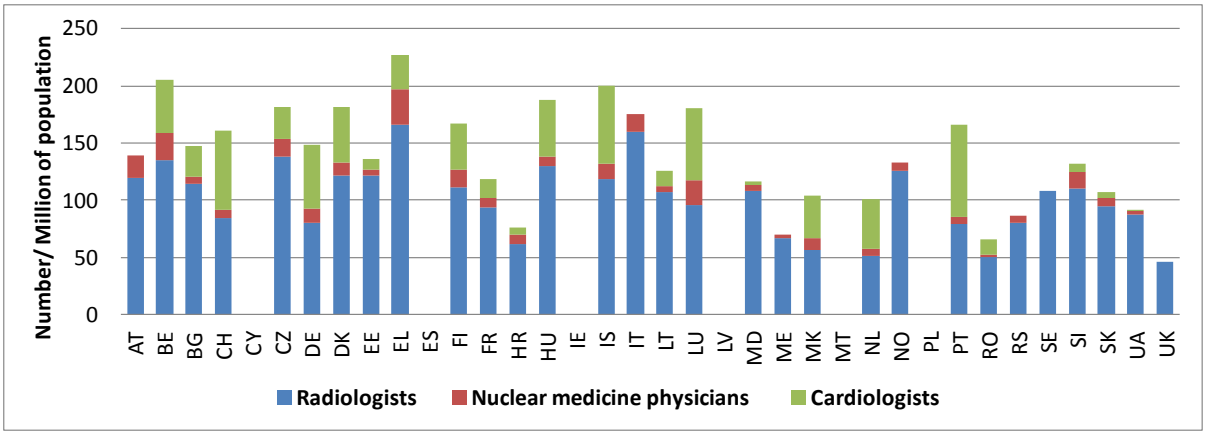


Figure 4.2. Numbers of specific health care professionals, per million of population. In case of no number, no information from the country has been available

There is also a high variation in the number of the key professional groups of physicians (Figure 4.2 and Table 4.3 (Annex 4).

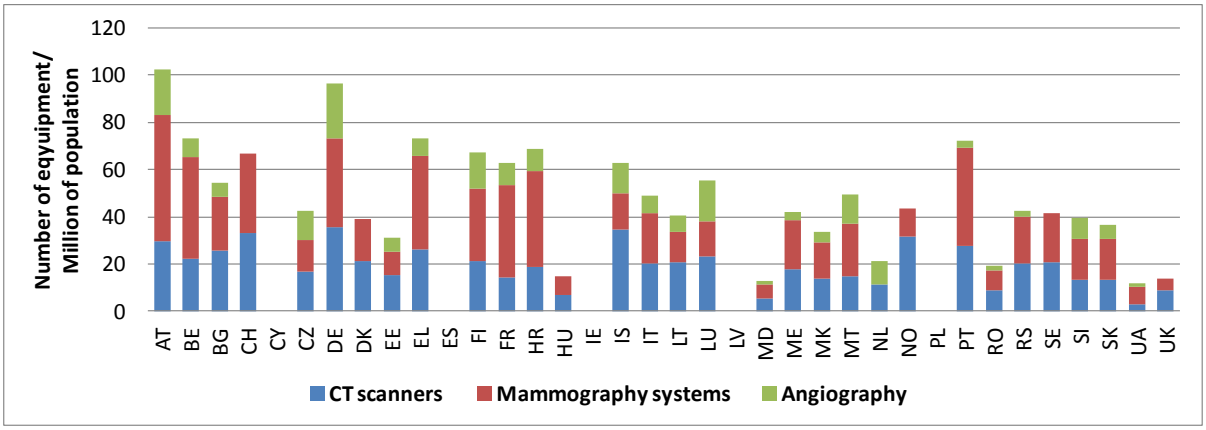


Figure 4.3. Number of specific imaging equipment per million of population in European countries. Countries with no numbers did not reply to the questionnaire.

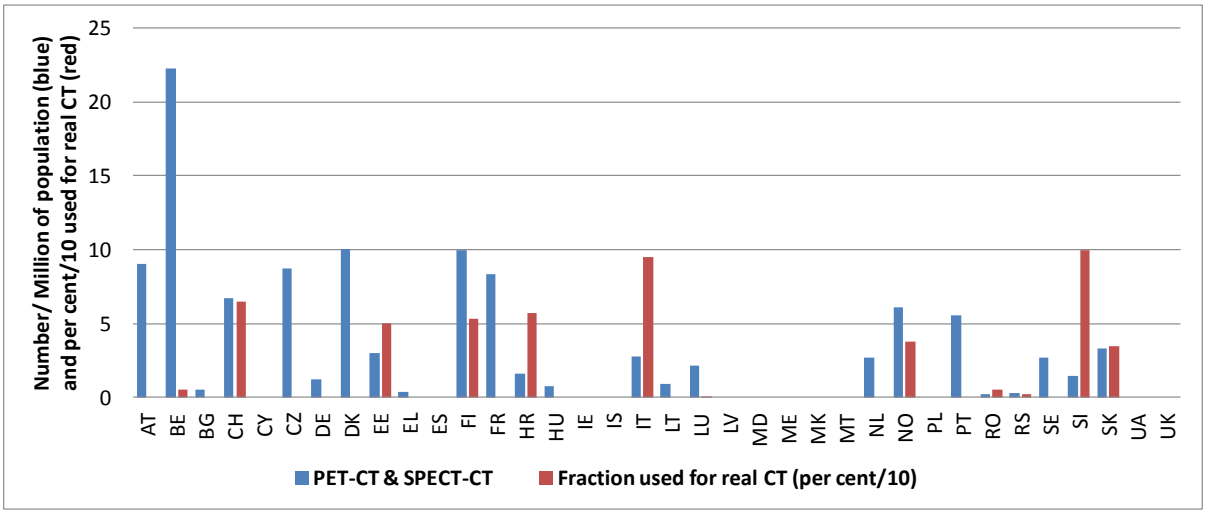


Figure. 4.4. Number of PET-CT and SPECT-CT equipment per million of population in European countries (blue) and the percentage (per cent/10) of their use for real CT (red). Countries with no numbers either had no equipment (e.g. IS) or did not reply to the questionnaire.

Figure 4.3 and Figure 4.4 present the number of selected groups of imaging equipment in the European countries. In Figure 4.4, it has also been indicated how many (in per cent/10) of

the CT scanners of the hybrid systems are used for real diagnostic CT (not only to determine the attenuation correction).

There is a considerable variation in the numbers of equipment and the numbers are not predictable on the basis of the size of the country. For example, the number of CT scanners per million of population is very high in small countries like Iceland, Norway and Switzerland, while it is considerably lower in some large countries like UK and France.

PET-CT and SPECT-CT hybrid systems are not yet very common in several European countries, and in some countries, the first hybrid systems have just recently been introduced. For these systems, on the average 32 % of the CT scanners are used for diagnostic CT, while there are high variations from country to country: in France, all CT scanners of the hybrid systems are used only for attenuation correction, while in Italy all are also used for diagnostic purposes. More than half the countries reported that the use of PET-CT for oncological imaging has increased and is considered to be good practice in this application (Figure 4.5) while some countries reported this to be only for certain indications.

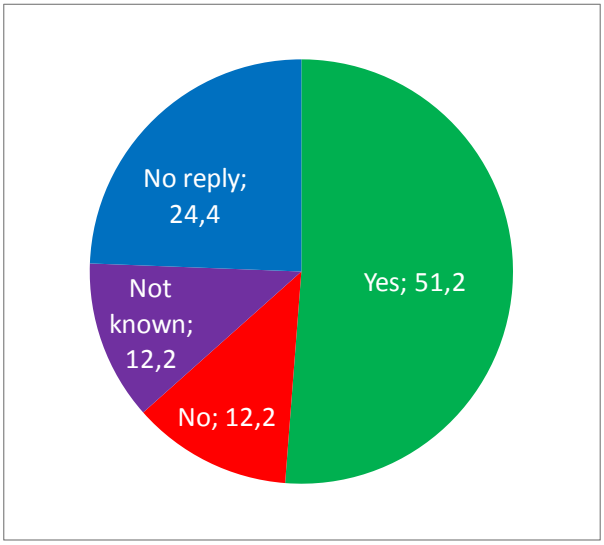


Figure 4.5 Increase in the use of PET-CT and its importance in oncological imaging in European countries.

The questionnaire to the European countries also addressed the fact that the lack of imaging equipment or alternative imaging modalities like MRI, or the lack of access to these modalities, might lead to a choice of the imaging modality and examination which does not correspond to the existing referral criteria or good practices defined by the professional societies. The results (Fig. 4.6) indicate that about one-third of the countries consider this to be possible. However, there are different views on this issue. For example, some studies of justification have revealed that the optimum method has not always been selected due to non-availability of MRI scanners (Oikarinen et al. 2009, Clarke et al. 2001). However, it has also been noted that there can be long waiting times for MRI and urgent investigations have to be done as soon as possible and, therefore, the use of CT instead of MRI can be considered justified if the latter is not available in time.

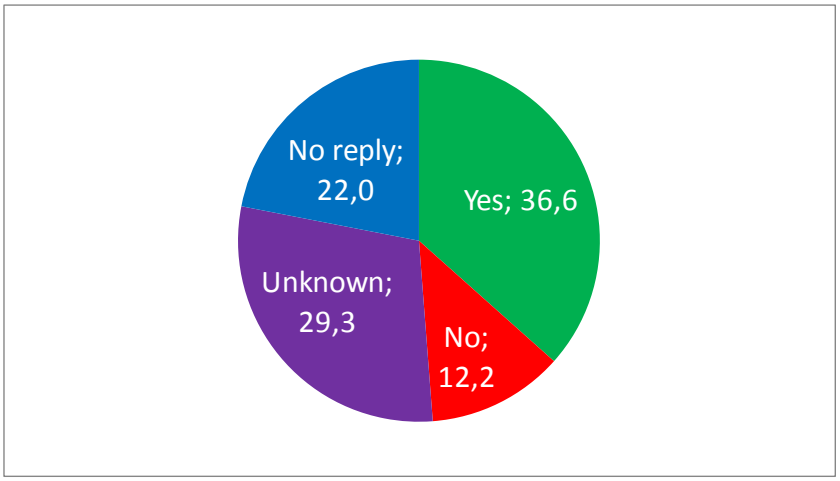


Figure 4.6. The replies of the European countries to the question "Does limited access to a given imaging modality affect the choice of the modality?"

There are also great differences in the national reimbursement and payment systems for radiological services in the European countries. A reimbursement has the meaning of a repayment for expense or loss incurred, and is given to a hospital, while the practitioners can be paid per procedure for a service. As can be seen from Figure 4.7 and Figure 4.8, in about half the countries hospitals are reimbursed for their radiological services and in most cases the reimbursement is 100 % of the cost. In about one third of the countries there is an annual upper limit to the reimbursement. The reimbursement is usually associated with the national coding of examinations, and might cover only part of the codes. About 17 % of the countries believe that this reimbursement system can affect the frequency of examinations (Figure 4.9).

In about 17 % of the countries, the practitioners get a payment per procedure, or in addition to a fixed salary, receive an additional payment depending on the number of procedures. For CT procedures, this is true only in a few countries (Bulgaria, former Yugoslav Republic of Macedonia, Netherlands and Switzerland), . However, for IR procedures, doctors are paid per procedure in several countries (Figure 4.10). About one- third of the countries believe that this payment system can affect the frequency of examinations, i.e. the number of examinations can increase because some examinations might not be well justified but carried out only due to the doctor's desire to earn more money (Figure 4.11).

As for the costs to the patients, in most countries there are varying systems of health insurance, both public and private insurances, which cover all costs or a given fraction of the costs of an examination to the patient. These systems can also mean that the reimbursement to the hospital or the payment to the practitioner is not relevant.

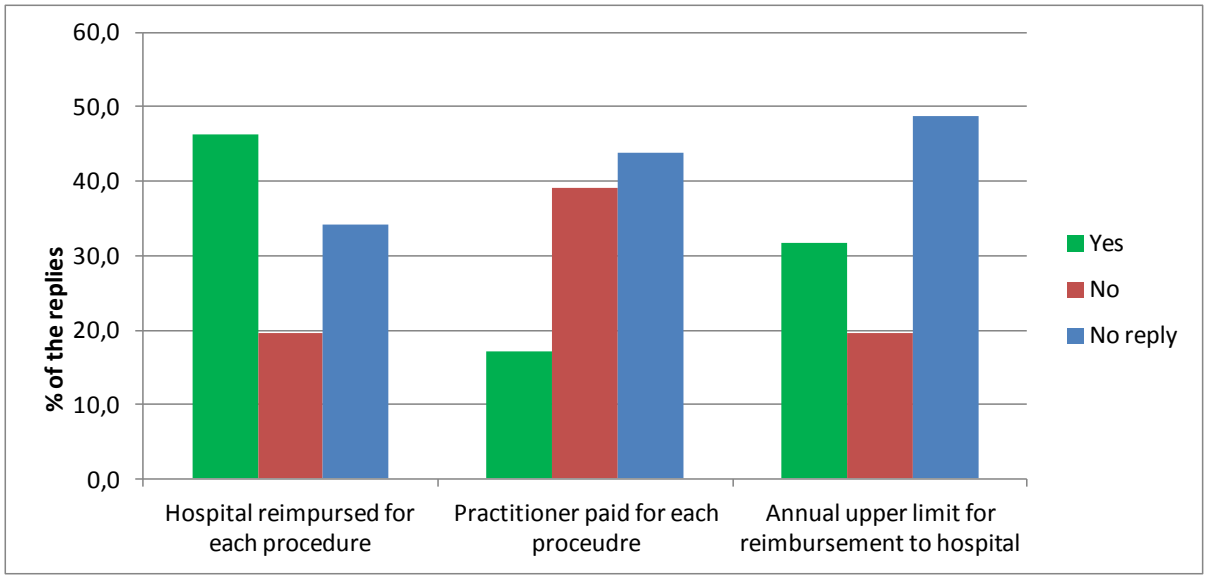


Figure 4.7. The reimbursement system for the radiological services in the European countries.

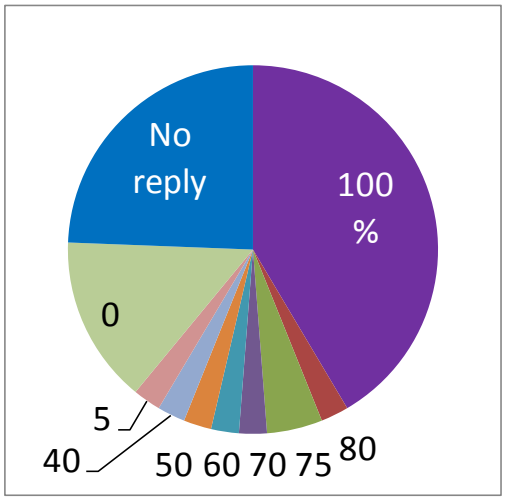


Figure 4.8. The percentage of the reimbursement of the total costs.

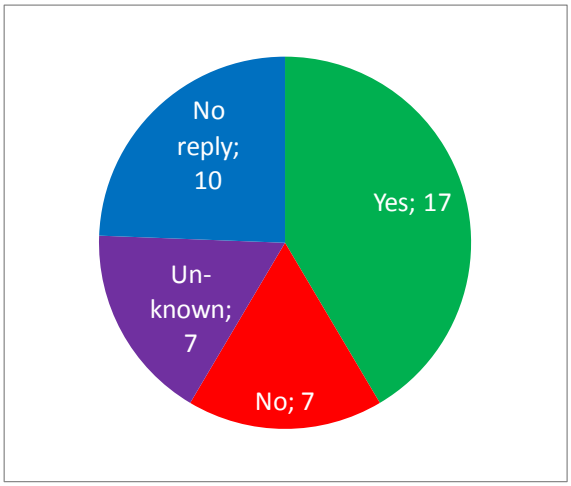


Figure 4.9. The replies of the European countries to the question "Does the reimbursement system affect the frequency of examinations?"

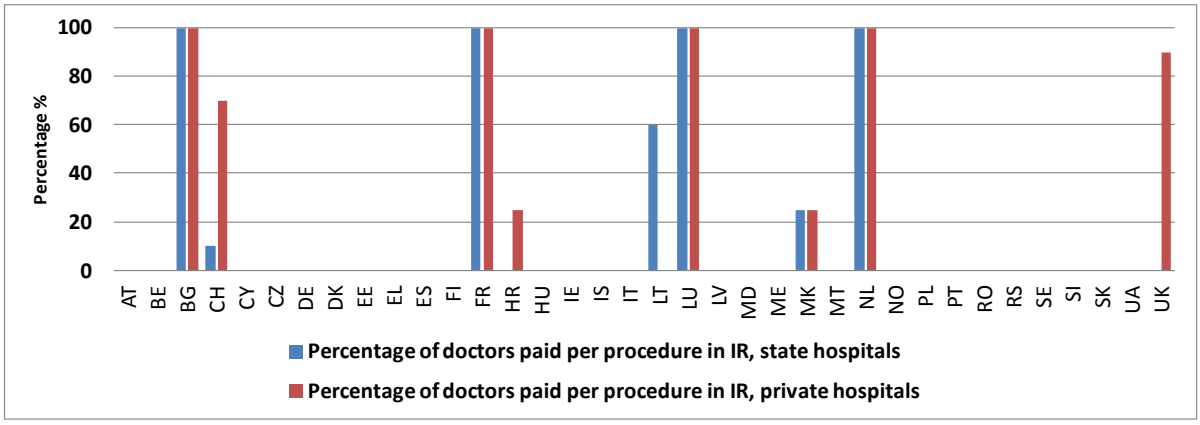


Figure 4.10. Percentage of doctors who are paid (not reimbursed) per procedure in IR procedures

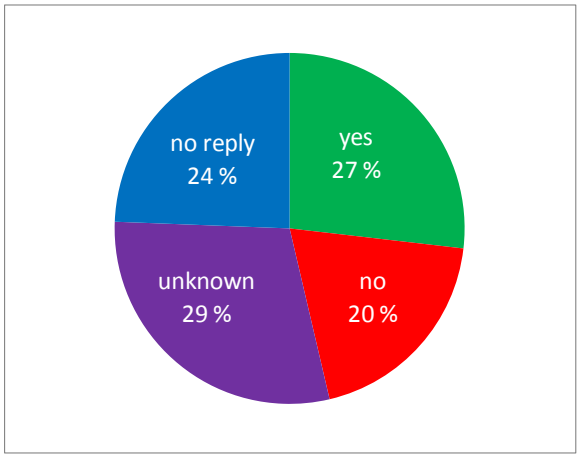


Figure 4.11. The replies of the European countries to the question "Does the payment system affect the frequency of examinations?"

4.2 Regulatory frameworks for estimation of population doses

4.2.1 Availability of regulations and/or recommendations

The availability of regulations and/or recommendations on the collection of examination frequencies and making population dose estimations, and on organizations assigned for this purpose, is summarized in

Table 4.1, based on the results of the first DDM2 questionnaire (carried out in spring 2011).

Concerning the frequency collection only 2 countries (MT and ES) among the 38 who provided data did not have regulations and/or recommendations. It is worth stressing that data on frequencies could be collected (partly by the impact of DDM2) despite the lack of national regulations and/or recommendations. Concerning population dose estimation, regulations and/or recommendations were lacking only in two countries (MT and NO) and were being prepared in two others (CZ and MD).

Regulations and/or recommendations existed in 28 countries concerning the organization for frequency collection and in 25 countries concerning the organization for making population

dose estimation. During the time of the questionnaires, they were being prepared in two countries: MD and RS (RS completed 2012).

4.2.2 Organizations responsible for frequency collection and population dose estimation

The organizations responsible for frequency collection and population dose estimation are summarized in Annex 4.

In two countries among the 38 that provided data no organization existed with the responsibility to collect the frequencies of examinations or to perform population dose assessment: ME and MD.

Table 4.1. Availability of regulations and/or recommendations.

Country	Collection of frequencies (number of examinations)	Population dose estimation	Organization for collection of frequencies	Organization for making population dose etimation
AT	Y	Y	N	N
BE	Y	Y	Y	Y
BG	Y	Y	Y	Y
CH	Y	Y	Y	Y
CY	Y	Y	Y	Y
CZ	Y	P	Y	–
DE	Y	Y	Y	Y
DK	Y	Y	Y	Y
EE	Y	Y	Y	Y
EL	Y	Y	Y	Y
ES	N	Y	N	N
FI	Y	Y	Y	Y
FR	Y	Y	Y	Y
HR	Y	Y	Y	Y
HU	Y	Y	Y	Y
IE	Y	Y	–	–
IS	Y	Y	Y	Y
IT	Y	Y	Y	Y
LT	Y	Y	Y	Y
LU	Y	Y	Y	N
LV	Y	Y	Y	Y
MD	P	P	P	P
ME	–	–	–	–
MK	Y	Y	Y	–
MT	N	N	N	N
NL	Y	Y	Y	Y
NO	Y	N	N	N
PL	Y	Y	Y	Y
PT	Y	Y	Y	N
RO	Y	Y	Y	Y
RS	Y	Y	P	P
SE	Y	Y	–	–
SI	Y	Y	N	N
SK	Y	Y	Y	Y
UA	Y	Y	Y	Y
UK	Y	Y	Y	Y

Y: exist, N: does not exist, P: in preparation, N/A: not available, - : no reply

4.2.3 Periodicity of frequency collection and population dose estimation

Figure 4.12. shows that the frequency with which data on examinations numbers was collected is in general higher than the frequency with which the population dose was estimated.. 17 countries repeated their frequency data collection every 1-2 years and 10

performed it every 3-5 years while 6 countries undertook population dose estimation with a period of 1-2 years and 16 performed it every 3-5 years.

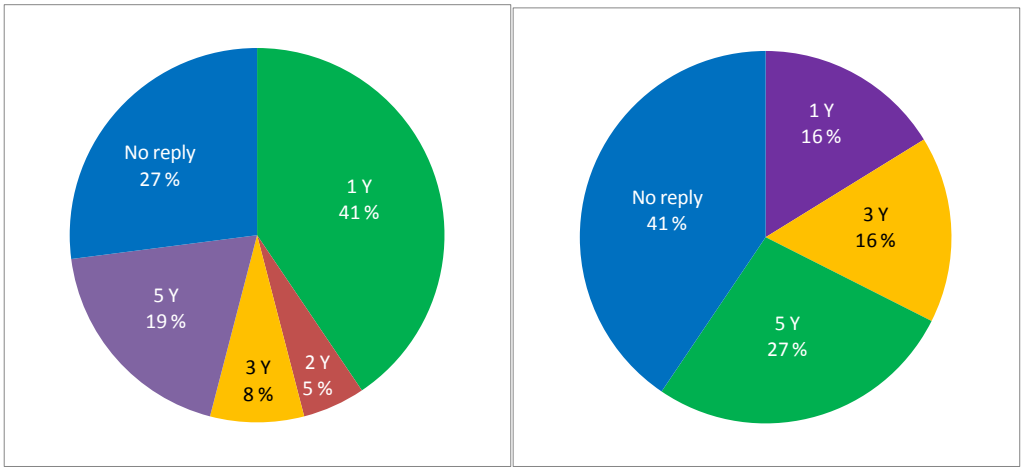


Figure 4.12. Periodicity of frequency collection (left pie chart) and population dose estimation (right pie chart).

4.2.4 Reporting to UNSCEAR

In general the official authority responsible for providing data on medical exposures to UNSCEAR was either the national public health ministry, nuclear safety agency or radiation protection authority. The official authority may be involved in frequency collection and population dose estimation or may delegate this task to a recognized scientific institution.

4.3 National coding systems

In order to compare x-ray examination frequency data between countries, and to assign typical effective dose values to examinations, it is crucial that an “x-ray examination” is defined and counted in a consistent way (EC, 2008). Due to the importance of the coding systems for the surveys and comparisons in DDM2 project, the existing systems for coding of the examinations were reviewed.

4.3.1 Existence of national systems for coding the examinations

As shown in Figure 4.13., 20 countries (51%) in spring 2011 had national radiological procedures code system to categorize procedures (x-ray and NM procedures) and 16 (41%) did not have such coding systems.

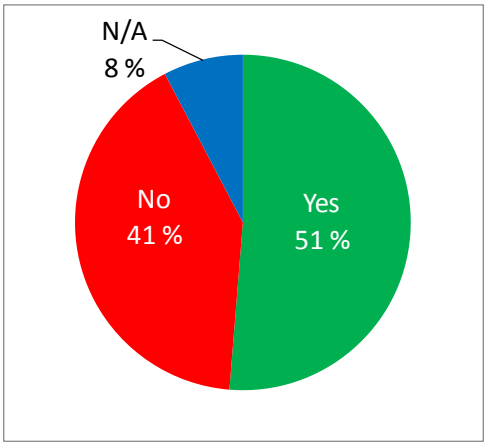


Figure 4.13. Percentage of countries having or not national systems for coding the examinations. N/A: no reply.

4.3.2 Number of codes

The number of codes for the 20 countries that had a coding system is shown in Figure 4.14. It ranges from about 100 to 400 except for 3 countries where it is relatively high: IS (830), FI (943) and UK (3220).

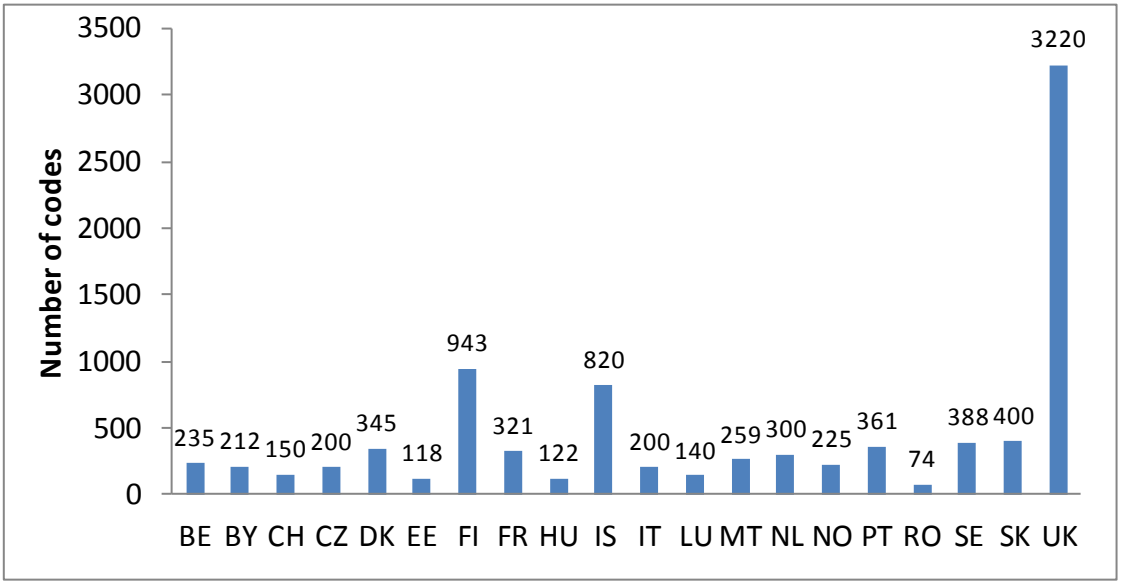


Figure 4.14. Number of codes.

4.3.3 Correspondence with RP154 categories

Fig. 4.15 shows the percentage of countries (from 39 countries: 36 countries as shown in Table 3.1, as well as BA, BY and TR (Turkey)) that reported in spring 2011 that they were able to provide data for x-ray procedures corresponding to the “20”, “70” and “225” DDM1 categories. As for the frequency data, according to Table 4.2 87 % of the countries (25 countries) were able to provide the data in the “top 20” format, 74 % (10 countries) were able to provide it in the “70” format, and 46 % (6 countries) were able to provide it in the “225” format and 26 % (3 countries) could provide it in a format of more than 225 types of examinations. National contact points in the DDM2 survey have explained the country specific methods on the population dose estimations in Annex 6.

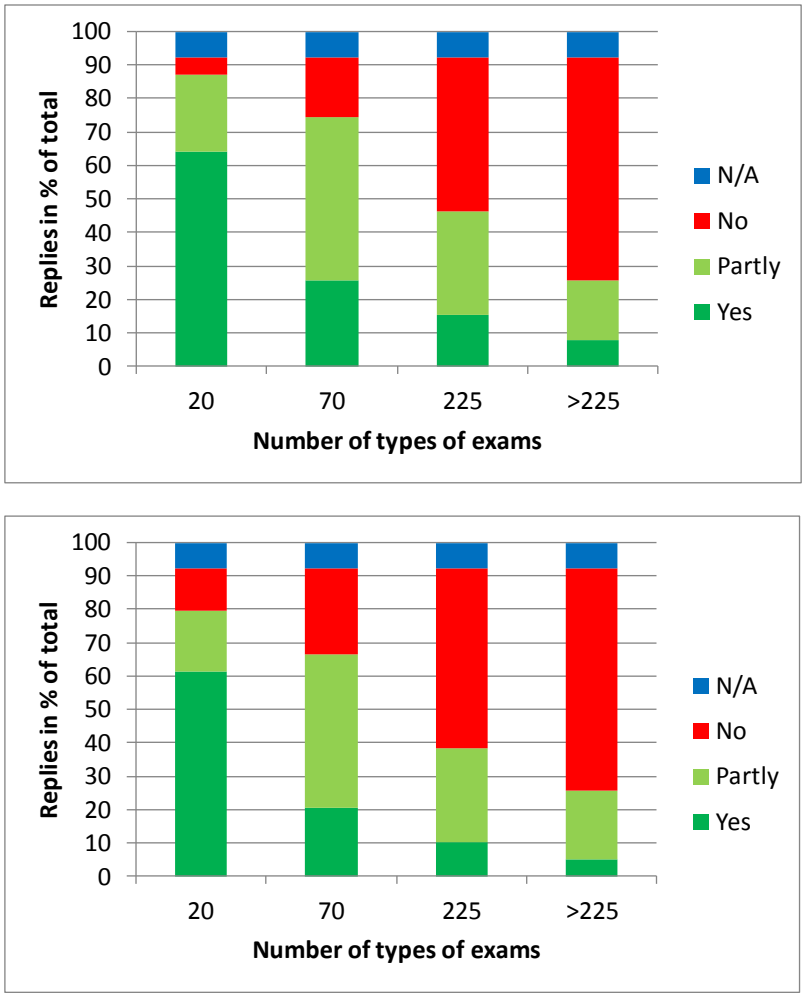


Fig. 4.15 Percentage of different replies (yes, partly, no and N/A = no reply) for the 39 countries, for "20" and "70" and "225" or more DDM1 categories (spring 2011), for frequency (upper graph) and effective dose (lower graph). The figure shows that it is easier to provide frequency data (relatively more "yes"or "partly" replies) than effective dose data – therefore fewer countries reported being able to provide effective dose data.

Table 4.2. Percentage of countries who reported being able to provide frequency or dose data fully or partly corresponding to the DDM1 categorization (spring 2011)

Number of types of exams (DDM1)	20	70	225	> 225
Frequency	87%	74%	46%	26%
Dose	80%	67%	39%	26%

4.4 Availability of frequency and population dose data

For the purpose of planning the efforts of the data collection in this project, the availability of frequency and population dose data in the European countries were reviewed as a part of the first general questionnaire of the project. This information was used to classify the countries in two groups:

- those that had carried out population dose estimations and were well prepared to provide the requested detailed data on the examination frequencies, typical effective doses and collective effective doses to population

- those that had less experience in the population dose estimation and who needed more time to establish and carry out necessary data collections.

From among the second group of countries, five countries were selected as the “test countries” which were particularly invited to the specific training course and subsequently provided with more focused advice and support (see Section 3.1).

For completeness, the results of this part of the general questionnaire have been summarized in Annex 7. However, conducting the questionnaires, organizing the training course and all other actions within this project have had a tremendous impact on the development of population dose estimations in those European countries which had little or no previous experiences of this topic (e.g. CZ, EE, MK, MD, PT, RS, and ES; see country-specific descriptions in Annex 6). As consequence, the data in Annex 7 has become partly out of date at the time of completion of the present European population dose estimation. Therefore, an additional questionnaire to review the present status of population dose estimations was conducted later, in connection with the request for checking the national data by the national contact points in spring 2012, preceding the Workshop where the summaries of the data were presented for discussion. Based on this additional questionnaire, the present status of population dose estimations (organization, methods) in several countries has been summarized in Annex 6, The results of the European population dose estimation presented and discussed in the next section are based on the latest estimations described in Annex 6.

5 EUROPEAN POPULATION DOSE FROM MEDICAL IMAGING

The countries in the following analysis are discussed in two groups (see Table 3.1):

Group 1: EU-countries and Norway, Iceland and Switzerland (31 countries)

Group 2: All European countries included in this survey (36 countries)

The data presented in this chapter is based on the DDM2 survey. The detailed information on national surveys including the year of the national survey is presented in the Annex 6 Table 6.1 for x-ray procedures and Table 6.2 for NM procedures.

5.1 X-ray procedures

5.1.1 Frequencies

The total annual frequency of x-ray procedures (including dental procedures) in the European countries is

Group 1: *590 million*, or 1100 examinations per 1000 of population, or 1,1 examinations per caput.

Group 2: *660 million*, or 1100 examinations per 1000 of population, or 1,1 examinations per caput.

The distribution of the total number per 1000 population for different countries is shown in Figure 5.1 and Table 5.1. The proportion of dental x-ray procedures from the total plain radiography is shown for some countries (that provided detailed data from all x-ray procedures) in Table 5.2.

In Fig. 5.1 and Table 5.1, the real reported data has been shown whenever available. For countries which reported only Top 20 data, the results have been obtained from the results of the evaluation of frequencies with the Top 20 method, using a correction factor that takes into account the procedures not included in the Top 20. This correction factor (Table 5.3) has been taken as the average ratio between the overall total frequency and the total frequency evaluated by the Top 20 approach (total overall/total Top 20), calculated from the results for the 11 countries of this survey which have reported *both* types of total frequencies (BG, CH, DE, DK [only for CT], EL, FI, FR, IS, RO, RS and UK). However, in this calculation, the frequency of plain radiography (with very large frequency of dental examinations) for IS has been excluded from the calculation of the average ratio, because this value was exceptionally high. In Figure 5.2, the distribution of the correction factors between these countries has been presented.

For LT and CZ, the overall total frequencies (sum values in the last column of Table 5.1) are reported real values, but the distribution in the four main groups has not been available and therefore, has been estimated based on the average relative propositions derived from the data for the above 11 European countries. For DK, the overall total frequency and the frequency of CT examinations are real, but the other values have been estimated as for LT and CZ. In UA, the fluorography (film and digital) is the most common x-ray examination, about 499 exams per 1000 population, but this x-ray examination is not included in the Top20. Therefore, for the calculation of the overall frequency of plain radiography in UA, the frequency of fluorography has been added to the overall frequency of plain radiography calculated from Top 20 data using the above correction factor. In HU, the high number of

radiography examinations is probably not real but partly explained by duplicated counting of some examinations.

In general, the variation in the total number of examinations between the countries is high, ranging from about 300 to about 2130 per 1000 population. The proportion of dental x-ray procedures is on the average about 32 % of all plain radiography procedures, but because of the low mean effective doses of these procedures their contribution to the collective effective dose is not significant, typically only 2-4 % of the total collective effective dose for plain radiography (see section 5.1.2.2).

Table 5.1. The overall total frequencies of x-ray procedures per 1000 population for all countries and for the main groups (plain radiography, fluoroscopy, computed tomography and interventional radiology). Plain radiography includes dental procedures. Real numbers (not estimated from Top 20) are in bold.

Country	Plain radiography	Fluoroscopy	Computed tomography	Interventional radiology	Overall total frequency per 1000 population
AT	1160,3	46,7	**98,0**	**7,8**	1313
BE	1098,9	32,4	185,3	37,1	1354
BG	**434,2**	**40,5**	**36,4**	**2,3**	**513**
CH	**1533,0**	**19,9**	**101,0**	**13,2**	**1667**
CY	729,5	22,1	107,8	6,2	866
CZ	901,9	29,7	78,8	5,4	**1016**
DE	**1247,9**	**45,7**	**131,9**	**11,1**	**1437**
DK	465,2	17,0	**94,7**	3,1	**580**
EE	809,2	22,7	161,5	4,4	998
EL	**608,5**	**28,1**	**93,8**	**3,8**	**734**
ES	1435,7	24,7	100,2	4,2	1565
FI	**1119,8**	**10,2**	**61,1**	**5,6**	**1197**
FR	**1002,6**	**20,2**	**118,7**	6,9	1148
HR	701,2	46,8	48,7	7,1	804
HU	1691,8	55,8	110,0	6,2	1864
IE	1218,5	20,3	66,8	13,0	1319
IS	**1956,8**	**20,1**	**147,2**	**5,1**	**2129**
IT	1034,3	31,5	131,1	8,0	1205
LT	941,6	70,9	56,4	12,5	**1081**
LU	915,1	21,0	188,6	2,9	1128
LV	**1104,3**	**30,7**	**116,4**	**3,7**	**1255**
MD	610,5	34,6	9,4	0,3	655
ME	723,3	17,4	106,5	2,7	850
MK	572,8	27,3	20,3	5,0	625
MT	638,9	52,4	58,4	6,4	756
NL	603,9	18,1	73,5	5,3	701
NO	728,2	21,9	150,5	8,2	909
PL	1091,9	18,0	49,3	5,9	1165
PT	1398,9	15,4	158,0	3,8	1576
RO	**227,9**	**41,1**	**27,5**	**0,2**	**297**
RS	**666,7**	**53,3**	**66,7**	**2,0**	**789**
SE	647,0	24,3	94,2	5,3	771
SI	903,0	14,9	52,7	6,1	977
SK	1232,6	18,0	69,3	3,8	1324
UA	1181,2	28,1	8,0	0,4	1218
UK	**668,2**	**17,5**	**55,4**	**5,1**	**746**

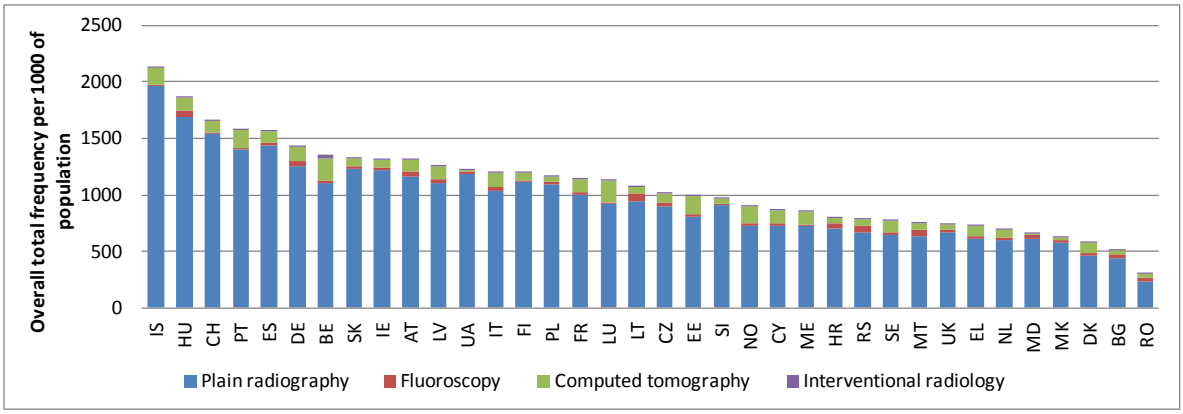


Figure 5.1. Overall total frequencies per 1000 of population for different countries. The relative contributions of the four main groups (plain radiography including dental, fluoroscopy, computed tomography and interventional radiology) are also shown. Plain radiography includes dental procedures.

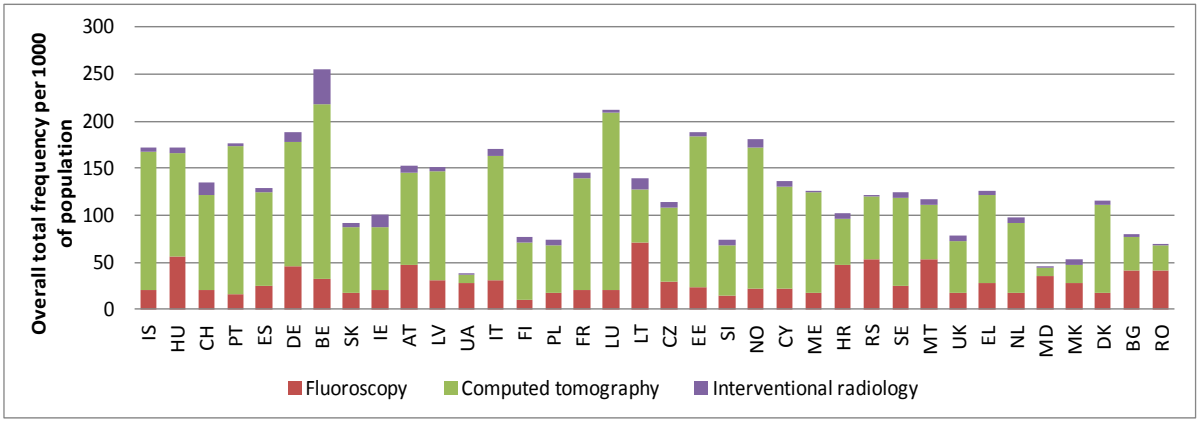


Figure 5.2. Same as Fig. 5.1 but without plain radiography

Table 5.2. Proportion of the frequencies of dental x-ray procedures from the frequencies of total plain radiography

Country	Total plain radiography per 1000 population	Total dental procedures per 1000 population	Dental procedures as a % of total plain radiography
BG	434	62	14,4
CH	1533	692	45,1
DE	1248	391	31,4
FI	1120	469	41,9
FR	1003	294	29,4
UK	668	204	30,5
Mean	1001	352	32,1

Table 5.3. Ratios of total overall/total Top 20 frequencies for 11 countries; the mean values for the main groups are used as corrections factors for each group to estimate the overall values from Top 20 values

Country	All Top 20 groups together	Plain radiography	Fluoroscopy	CT	IR
BG	1,72	1,75	2,61	1,09	2,97
CH	3,07	3,44	2,56	1,14	5,58
DE	2,91	3,49	1,61	1,26	4,01
DK				1,24	
EL	1,26	1,30	1,32	1,00	2,28
FI	2,77	3,05	2,05	1,05	4,10
FR	2,00	2,21	2,09	1,09	0,00
IS	4,30	5,74	1,69	1,05	2,13
RO	1,55	1,50	3,11	1,03	0,00
RS	1,26	1,24	1,62	1,31	1,27
UK	2,21	2,40	1,79	1,16	3,52
Mean for the main groups = Correction factors		2,25 (IS excluded)	2,04	1,13	3,23
Mean for all Top 20 groups together	2,08 (IS excluded)				
Top 20 frequency as a % of the overall frequency	48,1 (IS excluded)	44,4	48,9	88,7	30,9

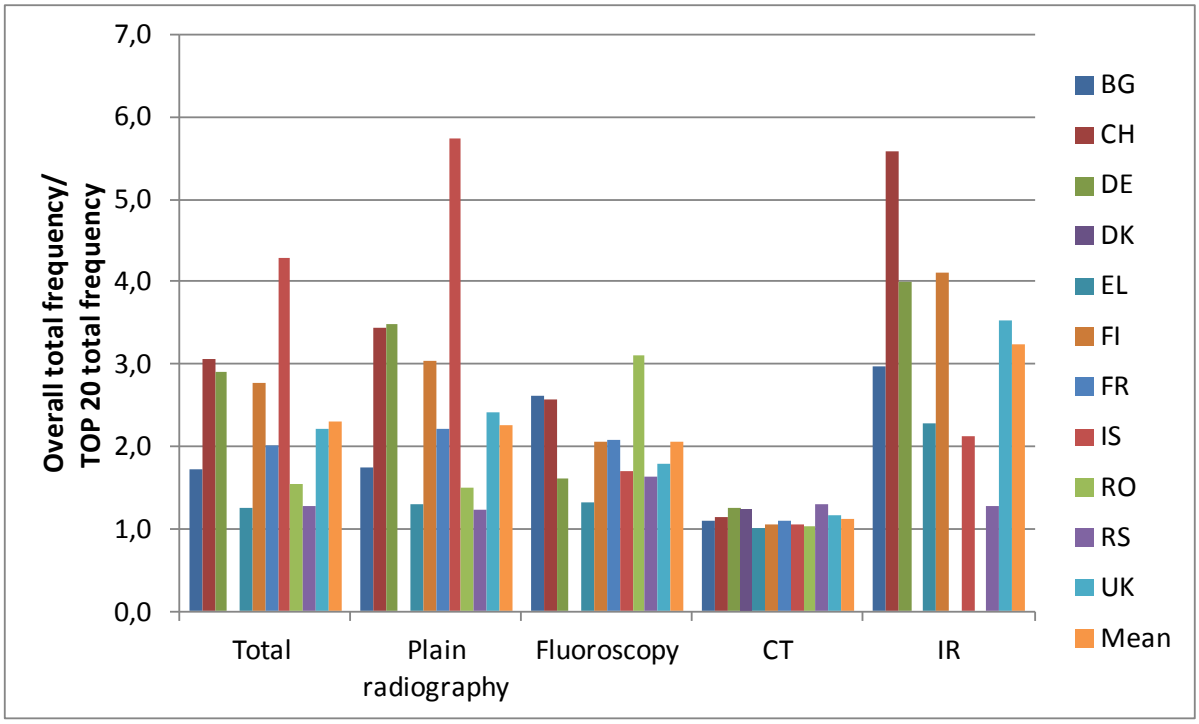


Figure 5.3. The distribution of the correction factors (overall total frequency/Top 20 total frequency) between the 12 countries, for all x-ray examinations and for the main groups

The total number of Top 20 x-ray examinations per year in the European countries is

Group 1: *270 million*, or 530 examinations per 1000 of population, or 0,53 examinations per caput.

Group 2: *290 million,* or 510 examinations per 1000 of population, or 0,51 examinations per caput.

The total numbers for all countries obtained by the Top 20 method are shown in Table 5.4 for the four main groups and for each Top 20 group in Table 5.5. to Table 5.7. Note that dental procedures are not included in the plain radiography groups of Top 20.

Table 5.3 represents a comparison of the overall total frequencies (including dental) and Top 20 total frequencies (not including dental), for the sum of all countries,. It can be seen that the Top 20 examinations as defined in RP 154 on the average contribute to about 48 % of the total. In the 10 European countries of the DDM1 project the contribution of Top 20 examinations to the total was between 50 and 70 %, but the total then did not include dental procedures. If the contribution of dental examinations to the total plain radiography examinations is assumed to be on the average 32.1 % (Table 5.2), the contribution of Top 20 examinations to the overall total excluding dental will become 65 % which is rather consistent with the comparable DDM1 data.

All 36 European countries included in this survey (28 Member States, 3 EFTA countries CH, NO and IS, and 5 other countries MK, MD, ME, RS and UA) could provide the Top 20 estimation, except for one Member State, LV, which only provided overall frequencies (Table 5.1). Some details of the evaluation of the frequencies for each country (sample sizes, extrapolations to the whole county etc.) are briefly described in Annex 6.

Table 5.4. The Top 20 total frequencies of x-ray procedures per 1000 of population for all countries and for the main groups (plain radiography, fluoroscopy, computed tomography and interventional radiology). LV: no Top 20 data provided. Plain radiography of the Top 20 method does not include dental procedures.

Country	Plain radiography	Fluoroscopy	Computed tomography	Interventional radiology	TOP 20 total frequency per 1000
AT	514,9	22,8	63,4	0,4	602
BE	487,6	15,9	164,3	11,5	679
BG	248,7	15,5	33,3	0,8	298
CH	445,2	7,8	88,5	2,4	544
CY	323,7	10,8	95,6	1,9	432
CZ	617,1	13,1	87,4	5,2	723
DE	357,5	28,4	104,9	2,8	494
DK	274,2	3,7	76,5	1,6	356
EE	359,1	11,1	143,2	1,4	515
EL	466,9	21,3	93,8	1,7	584
ES	637,1	12,1	88,8	1,3	739
FI	367,7	5,0	58,4	1,4	432
FR	452,9	9,7	108,9	2,0	573
HR	311,1	22,9	43,2	2,2	379
HU	750,7	27,3	97,5	1,9	877
IE	540,7	9,9	59,2	4,0	614
IS	340,9	11,9	140,4	2,4	496
IT	459,0	15,4	116,2	2,5	593
LT	650,5	34,7	51,2	1,4	738
LU	406,1	10,3	167,3	0,9	584
LV					
MD	270,9	16,9	8,3	0,1	296
ME	321,0	8,5	94,5	0,8	425
MK	254,2	13,4	18,0	1,5	287
MT	283,5	25,6	51,8	2,0	363
NL	268,0	8,9	65,2	1,6	344
NO	323,1	10,7	133,4	2,5	470
PL	484,5	8,8	43,7	1,8	539
PT	620,8	7,5	140,1	1,2	770
RO	151,5	13,2	26,8	0,2	192
RS	538,0	32,8	51,0	1,6	623
SE	287,1	11,9	83,5	1,6	384
SI	400,7	7,3	46,7	1,9	457
SK	546,9	8,8	61,4	1,2	618
UA	302,8	13,7	7,1	0,1	324
UK	278,1	9,8	47,9	1,4	337

Table 5.5. Frequencies of x-ray procedures per 1000 of population for all countries and for Top 20 groups 1-7. na: not available, 0.00: zero examinations reported.

Country Code	Chest/ Thorax	Cervical spine	Thoracic spine	Lumbar spine (inc.LSJ)	Mammo-graphy	Abdomen	Pelvis & hip
AT	235,37	39,47	26,47	47,67	88,08	18,51	59,31
BE	229,47	20,11	13,68	37,34	68,10	31,84	87,09
BG	159,81	14,73	7,99	19,99	15,22	10,39	20,55
CH	232,84	25,32	11,19	49,24	50,26	19,61	56,75
CY	194,42	20,23	10,26	29,14	19,97	29,95	19,73
CZ	234,89	35,11	64,25	0,00	210,24	24,67	47,95
DE	37,47	33,99	18,01	58,17	127,05	19,87	62,93
DK	118,65	6,36	7,80	21,41	76,21	5,01	38,78
EE	178,03	26,36	13,18	26,36	81,82	10,98	22,35
EL	297,70	na	na	77,03	47,31	14,19	30,64
ES	315,96	40,84	34,13	65,34	80,21	46,59	54,03
FI	209,93	14,06	6,26	26,52	59,08	9,52	42,35
FR	176,87	18,25	6,98	44,70	79,69	37,21	89,21
HR	146,92	15,81	7,61	18,84	58,51	20,18	43,28
HU	281,75	30,09	61,30	52,67	170,80	44,80	109,30
IE	298,96	35,97	15,87	57,66	23,11	40,40	68,73
IS	175,33	8,91	8,02	19,43	68,29	15,67	45,20
IT	196,99	29,84	15,87	45,76	74,80	26,60	69,10
LT	317,31	40,48	22,43	67,84	83,70	29,54	89,17
LU	173,58	24,73	15,06	40,58	64,77	15,91	71,43
LV	na	na	na	na	na	na	na
MD	128,19	34,30	31,12	34,93	3,40	14,19	24,77
ME	180,68	24,50	12,14	32,08	18,78	23,67	29,11
MK	133,34	17,82	9,88	24,31	7,16	11,24	50,43
MT	154,97	9,83	3,26	19,64	19,75	48,40	27,64
NL	142,24	11,05	7,75	25,54	22,85	18,81	39,76
NO	145,72	9,99	5,76	20,84	71,92	9,53	59,38
PL	271,77	55,15	23,81	46,37	27,50	11,14	48,77
PT	346,58	45,28	24,45	50,28	65,04	44,55	44,59
RO	75,96	11,85	10,13	27,34	8,98	6,73	10,50
SE	105,38	10,22	8,07	22,79	85,53	5,94	49,17
SI	187,07	39,56	17,40	54,31	46,35	18,89	37,13
SK	198,18	41,90	5,99	71,83	182,32	22,64	24,09
SP	205,31	55,45	46,79	80,17	50,56	29,75	70,00
UA	141,99	25,90	19,72	49,45	12,89	29,29	23,55
UK	146,72	9,34	3,85	15,46	43,64	20,07	39,03

Table 5.6. Frequencies of x-ray procedures per 1000 of population for all countries and for Top 20 groups 8-12 and 20. na: not available, 0.00: zero examinations reported.

Country Code	Ba meal	Ba enema	Ba follow-through	IVU	Cardiac angiography	PTCA
AT	5,69	8,59	0,90	0,88	6,78	0,44
BE	4,79	1,76	0,57	2,63	6,11	11,47
BG	6,92	2,99	0,88	1,89	2,84	0,78
CH	1,18	0,68	0,32	1,14	4,44	2,36
CY	3,06	1,82	0,10	3,66	2,19	1,92
CZ	4,26	1,94	0,46	4,39	2,10	5,24
DE	0,35	2,00	0,18	8,94	16,92	2,77
DK	1,00	0,70	0,82	0,30	0,84	1,64
EE	1,48	1,01	1,29	1,67	5,68	1,36
EL	9,85	7,05	na	0,53	3,90	1,68
ES	3,79	2,58	1,04	3,22	1,45	1,30
FI	0,04	0,21	0,81	0,38	3,54	1,35
FR	1,73	1,12	0,45	2,03	4,36	1,96
HR	8,96	3,09	1,44	4,51	4,91	2,20
HU	7,11	3,38	3,16	10,16	3,48	1,92
IE	0,00	1,68	0,90	0,38	6,96	4,03
IS	3,29	0,77	1,75	2,20	3,84	2,41
IT	2,87	4,53	na	3,65	4,35	2,46
LT	0,77	11,49	1,64	12,58	8,21	1,44
LU	2,97	0,60	0,28	1,91	4,53	0,89
LV	na	na	na	na	na	na
MD	9,12	1,70	2,28	3,15	0,66	0,08
ME	2,73	1,24	0,24	2,63	1,64	0,84
MK	7,00	0,23	1,39	3,00	1,74	1,54
MT	3,16	6,93	8,64	0,98	5,93	1,98
NL	1,10	1,34	0,21	0,19	6,04	1,65
NO	0,74	1,16	1,22	1,25	6,33	2,53
PL	1,05	0,26	0,66	3,34	3,52	1,83
PT	2,83	1,27	0,34	0,07	3,01	1,16
RO	7,26	1,91	0,73	2,91	0,39	0,17
SE	0,55	3,26	1,79	3,07	3,23	1,63
SI	1,01	0,70	0,53	1,26	3,80	1,88
SK	1,02	0,66	1,56	2,34	3,20	1,17
SP	16,88	5,89	1,38	4,09	4,59	1,58
UA	7,31	2,37	1,08	2,17	0,81	0,12
UK	0,62	3,80	0,73	1,37	3,30	1,44

Table 5.7. Frequencies of x-ray procedures per 1000 of population for all countries and for Top 20 groups 13-19. na: not available, nc: not counted (included in other groups; e.g. in EE besides CT head, all other CT examinations are categorized in CT trunk), 0.00: zero examinations reported

Country Code	CT head	CT neck	CT chest	CT spine	CT abdomen	CT pelvis	CT trunk
AT	25,39	0,81	12,07	4,78	11,45	5,24	3,64
BE	50,68	0,94	29,54	35,35	47,83	nc	nc
BG	16,48	nc	4,22	4,23	6,01	2,08	0,23
CH	23,92	5,70	17,51	3,95	24,08	3,17	10,18
CY	16,55	4,07	13,60	10,11	15,34	8,37	27,52
CZ	39,34	0,00	9,62	12,24	16,61	9,62	0,00
DE	31,45	2,55	17,81	21,44	25,04	1,35	5,23
DK	21,96	4,34	20,03	0,92	24,32	4,34	0,55
EE	31,06	nc	nc	nc	nc	nc	112,12
EL	19,67	5,00	18,27	8,70	40,59	na	1,55
ES	22,51	4,72	18,59	10,44	15,14	8,16	9,28
FI	27,97	2,55	10,45	1,46	7,65	1,61	6,75
FR	30,25	2,39	25,44	14,39	34,18	1,25	1,00
HR	22,98	0,76	4,36	2,07	6,26	1,25	5,55
HU	38,22	1,28	22,70	10,03	23,27	2,02	nc
IE	22,93	0,93	8,32	0,00	14,60	0,00	12,42
IS	49,66	6,98	28,24	13,21	40,07	2,27	nc
IT	48,41	2,56	21,01	12,13	29,85	2,29	na
LT	25,78	2,26	5,18	10,25	4,36	3,37	nc
LU	47,94	26,94	0,00	41,83	45,84	0,00	4,69
LV	na	na	na	na	na	na	na
MD	3,74	0,21	0,62	0,84	0,85	0,30	1,76
ME	15,70	19,62	14,88	16,00	17,79	10,47	0,00
MK	9,97	1,07	2,06	1,27	2,33	0,43	0,90
MT	21,73	0,77	4,83	0,62	12,81	8,64	2,39
NL	21,74	nc	17,08	3,23	22,08	1,08	nc
NO	36,05	7,34	24,64	4,81	35,71	24,85	nc
PL	23,24	na	7,88	4,81	7,76	na	na
PT	47,74	1,88	21,24	21,24	20,96	13,81	13,24
RO	14,53	0,89	3,24	1,15	4,88	2,13	0,00
SE	36,39	4,29	15,01	0,90	25,86	0,59	0,47
SI	23,99	1,42	6,45	3,14	8,71	0,53	2,47
SK	26,37	1,52	8,22	7,07	10,25	3,40	4,61
SP	23,46	4,59	7,49	2,76	7,71	3,59	1,42
UA	3,36	0,11	1,33	0,56	1,44	0,28	0,06
UK	18,71	1,64	6,36	0,47	4,34	1,51	14,89

The relative overall total frequencies (% of the frequency of all x-ray examinations), for the main groups of plain radiography, fluoroscopy, CT and IR, are shown in Table 5.8 and in Figure 5.4 and Figure 5.5. It can be seen that plain radiography is by far the most common x-ray examination in all countries (from 76,8 to 97 %), while the relative frequencies of CT (from 0,7 to 16,7 %), fluoroscopy (from 0,9 to 13,9 %) and IR (from 0,03 to 2,7 %) vary a lot between the countries.

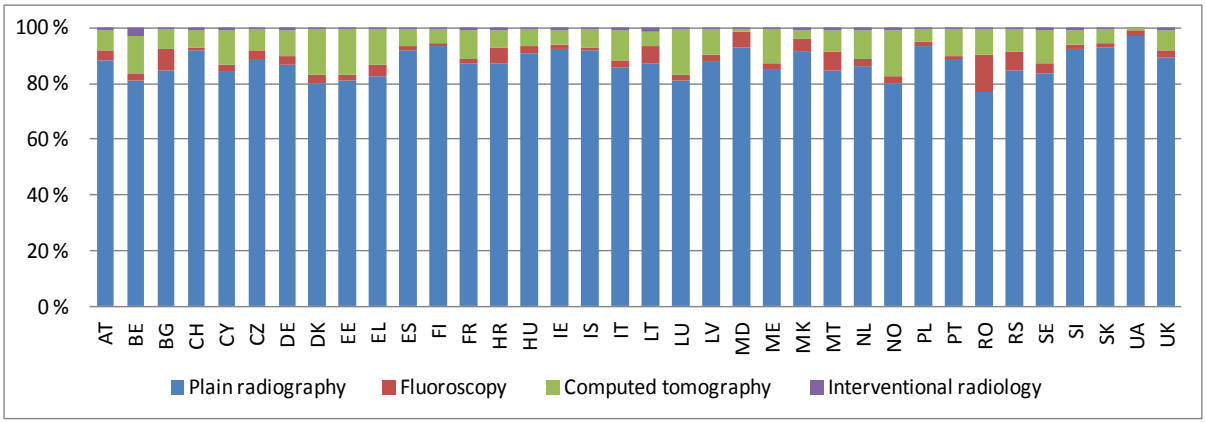


Figure 5.4. Relative frequencies as a percentage of the overall total frequency of all x-ray examinations. Plain radiography includes dental procedures.

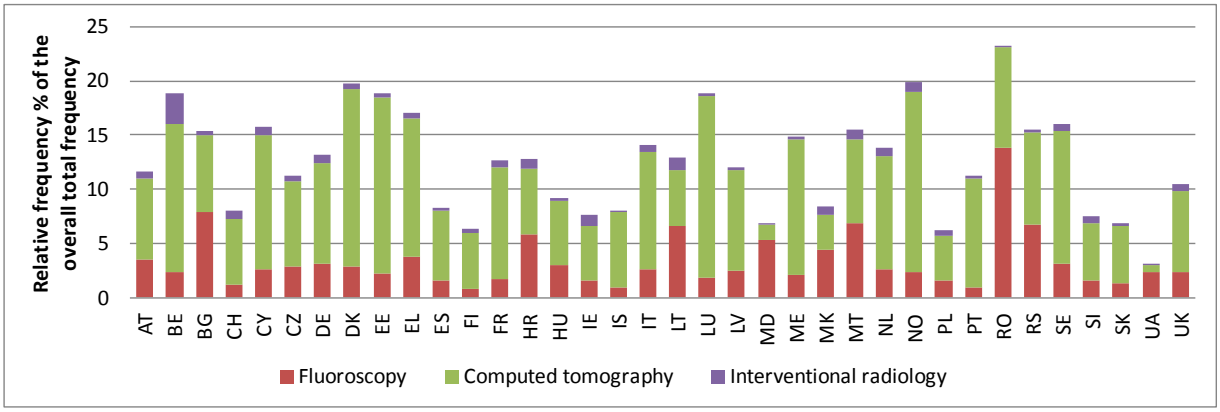


Figure 5.5. Relative frequencies as a percentage of the overall total frequency of all x-ray examinations except plain radiography

Table 5.8. Relative frequencies as a percentage of the overall total frequency (Table 5.1) of all x-ray examinations, for all countries. Plain radiography includes dental procedures.

Country	Plain radiography	Fluoroscopy	Computed tomography	Interventional radiology
AT	88,4	3,6	7,5	0,59
BE	81,2	2,4	13,7	2,74
BG	84,6	7,9	7,1	0,45
CH	92,0	1,2	6,1	0,79
CY	84,3	2,6	12,5	0,72
CZ	88,8	2,9	7,8	0,53
DE	86,9	3,2	9,2	0,77
DK	80,2	2,9	16,3	0,53
EE	81,1	2,3	16,2	0,44
EL	82,9	3,8	12,8	0,52
ES	91,7	1,6	6,4	0,27
FI	93,6	0,9	5,1	0,46
FR	87,3	1,8	10,3	0,60
HR	87,2	5,8	6,1	0,88
HU	90,8	3,0	5,9	0,33
IE	92,4	1,5	5,1	0,99
IS	91,9	0,9	6,9	0,24
IT	85,8	2,6	10,9	0,66
LT	87,1	6,6	5,2	1,15
LU	81,2	1,9	16,7	0,26
LV	88,0	2,4	9,3	0,29
MD	93,2	5,3	1,4	0,04
ME	85,1	2,0	12,5	0,32
MK	91,6	4,4	3,3	0,80
MT	84,5	6,9	7,7	0,84
NL	86,2	2,6	10,5	0,76
NO	80,1	2,4	16,6	0,90
PL	93,7	1,5	4,2	0,51
PT	88,8	1,0	10,0	0,24
RO	76,8	13,9	9,3	0,06
RS	84,5	6,8	8,5	0,25
SE	83,9	3,2	12,2	0,68
SI	92,5	1,5	5,4	0,62
SK	93,1	1,4	5,2	0,29
UA	97,0	2,3	0,7	0,03
UK	89,5	2,4	7,4	0,68
Max	97,0	13,9	16,7	2,7
Min	76,8	0,9	0,7	0,03
Mean	87,4	3,3	8,7	0,6

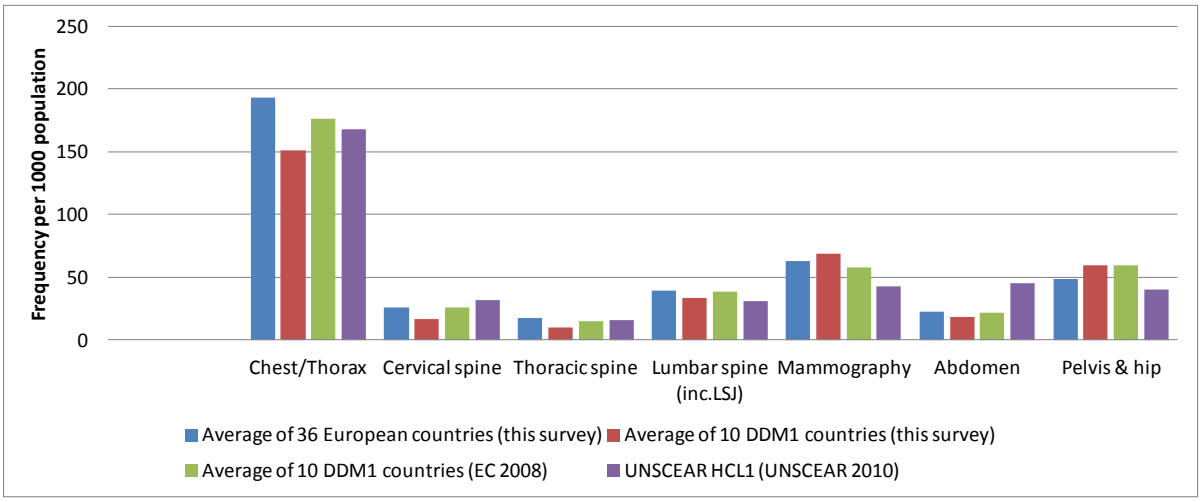
The average frequencies per 1000 of population obtained in this study, for the Top 20 groups, are compared in Table 5.9 and Figure 5.6 with similar data from the 10 European

countries in DDM1 project and UNSCEAR Health Care Level 1 (HCL1) countries. The average values are simple mean values for the countries in question, without weighting of the country values by the population numbers. The data in Table 5.9 should be used only to indicate differences in the frequency (how common is the examination) between the groups of countries given in the Table, and for DDM1 countries, the tendency of frequency between DDM1 study and this new DDM2 study. These average frequencies should not be used to anyway estimate European population dose; the European population dose in this study has been estimated based on reported frequencies and reported typical effective doses per procedure from each country, and summing up the obtained collective effective doses.

Table 5.9. Average frequencies per 1000 of population obtained in this study, for TOP 20 groups, compared with similar data from the 10 European countries in DDM1 project and UNSCEAR Health Care Level 1 (HCL1) countries

TOP 20 Group	Average of 36 European countries (this survey)	Average for 10 DDM1 countries (this survey)	Average for 10 DDM1 countries (EC 2008)	UNSCEAR HCL1 (UNSCEAR 2010)
Chest/Thorax	194	151	177	168
Cervical spine	26,0	16,9	26,1	32
Thoracic spine	17,5	9,8	15,0	16
Lumbar spine (inc.LSJ)	39,5	33,6	38,2	31
Mammography	63,3	69,0	58,2	43
Abdomen	22,5	18,4	21,4	45
Pelvis & hip	48,7	59,4	59,3	40
Ba meal	3,8	1,5	3,6	
Ba enema	2,6	1,6	4,7	9,3
Ba follow-through	1,2	0,7	1,1	
IVU	2,8	2,3	7,0	8,5
Cardiac angiography	4,2	5,6	5,4	1,5
CT head	26,9	31,9	26,3	40
CT neck	3,9	6,2	2,9	
CT chest	12,6	17,3	8,9	24
CT spine	8,4	12,7	10,5	11
CT abdomen	18,1	28,9	14,4	30
CT pelvis	4,1	4,8	3,5	19
CT trunk	9,0	5,3	1,8	
PTCA	2,0	2,8	1,2	0,9

(a)



(b)

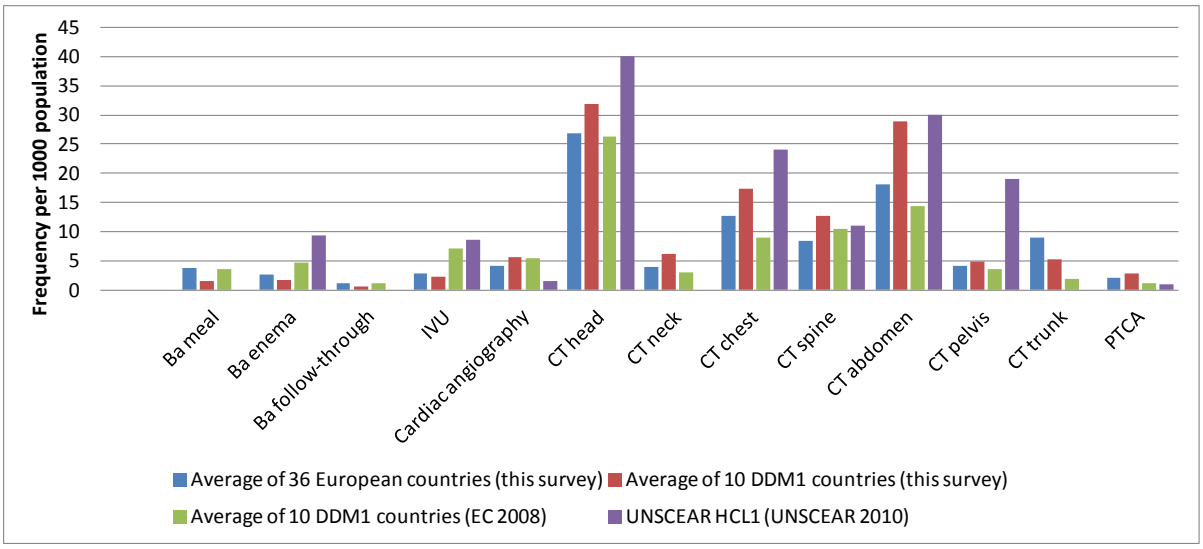


Figure 5.6. Average frequencies per 1000 of population obtained in this study, for TOP 20 groups, , compared with similar data from the 10 European countries in DDM1 project and UNSCEAR Health Care Level 1 (HCL1) countries; (a) plain radiography (b) other Top 20 groups.

It can be seen from Table 5.9 that for several groups of plain radiography and fluoroscopy, the average frequency of DDM1 countries is lower that the average of all 36 countries, while for CA, PTCA and most of the CT groups, the reverse is true. In the DDM1 countries, the average frequencies for several groups of plain radiography and fluoroscopy have decreased significantly from the results of an earlier study (EC 2008), while the frequencies of the CA, PTCA and all CT groups have significantly increased, in some cases more than doubled (for CT trunk about threefold increase). Because the latter groups represent the high-dose procedures (Table 5.14) the net effect is that the population dose seems to have increased in the DDM1 countries (see Table 5.18). Comparison of the results of this survey with the UNSCEAR data shows that the frequencies of the most conventional examinations in this survey are lower than in the UNSCEAR data for HCL 1 countries, while the frequencies for some more complex examinations (CA, PTCA) are higher; this can be understandable, as the UNSCEAR data is worldwide and generally older than the data of this survey.

The above comparisons of average values (Table 5.9) can give some indication of the trends. However, comparison of the trends on a country level should not be done without careful considerations of the origins of the reported values, which can only be done at the

country level. As an example, comparison of frequency data for CT trunk in UK from Table 5.7. with the earlier data reported (EC, 2008), indicates about 37-fold increase; while the reported trend in UK for this CT examination in 2001 was upwards, the huge increase might be partly explainable also if there has been a change in the practice of grouping CT trunk examinations.

It could be assumed that the higher is the frequency of x-ray procedure, the higher is the number of key professionals, e.g. radiologists in the country. Figure 5.7 does indicate that there is some statistical significance in the correlation ($p<0,05$) between the two variables. There is stronger correlation ($p<0,01$) between the number of CT and the number of CT examinations., as can be seen from an example in Figure 5.8. On the basis of the data collected in this project conclusions on reasons can not be drawn if the number of CTs promotes to make more examinations or if the diagnostic need is higher then more CTs have been purchased.

Figure 5.9 shows the correlation between the overall frequency of the x-ray procedures and the reimbursement system. The mean frequency per million of population is not much different in the two groups of countries, where hospital is reimbursed or not reimbursed for each procedure. However, it seems to be significantly higher in those countries where the practitioner is reimbursed for each procedure, compared with countries where the practitioner is not reimbursed for each procedure. This observation is supported by the result of the questionnaire shown in Figure 4.9, i.e., the majority of replies believed that the reimbursement system affects the frequency of x-ray examinations. This suggests that the reimbursement system might encourage practitioners to carry out x-ray examinations more than might be justified.

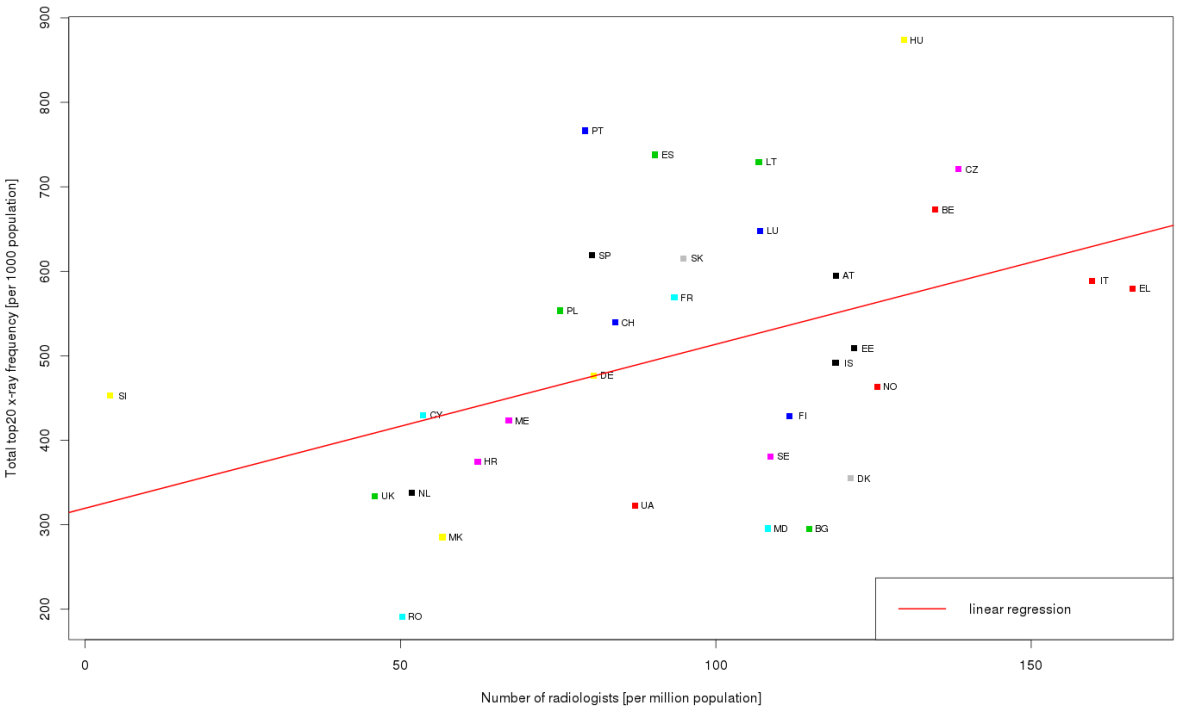


Figure 5.7. Correlation between the frequency of Top 20 x-ray procedures per 1000 of population and the number of radiologists per million of population in the countries.

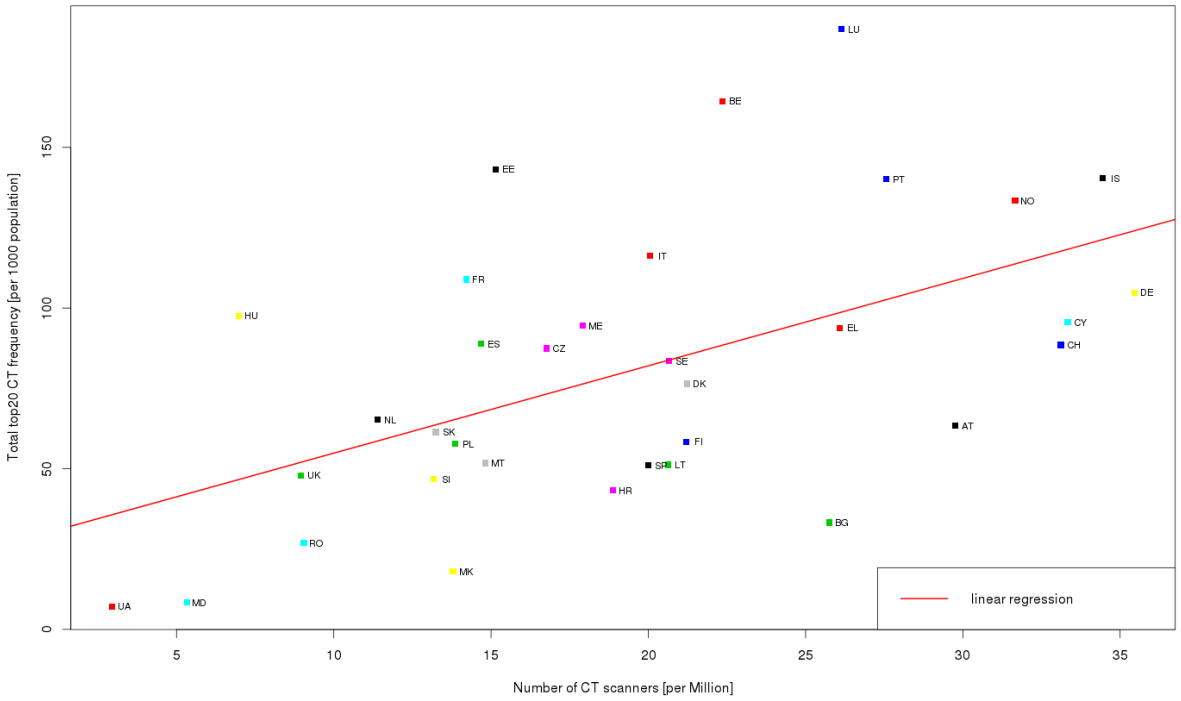


Figure 5.8. Correlation between the frequency of Top 20 CT procedures per 1000 of population and the number of CT equipment per million of population in the countries.

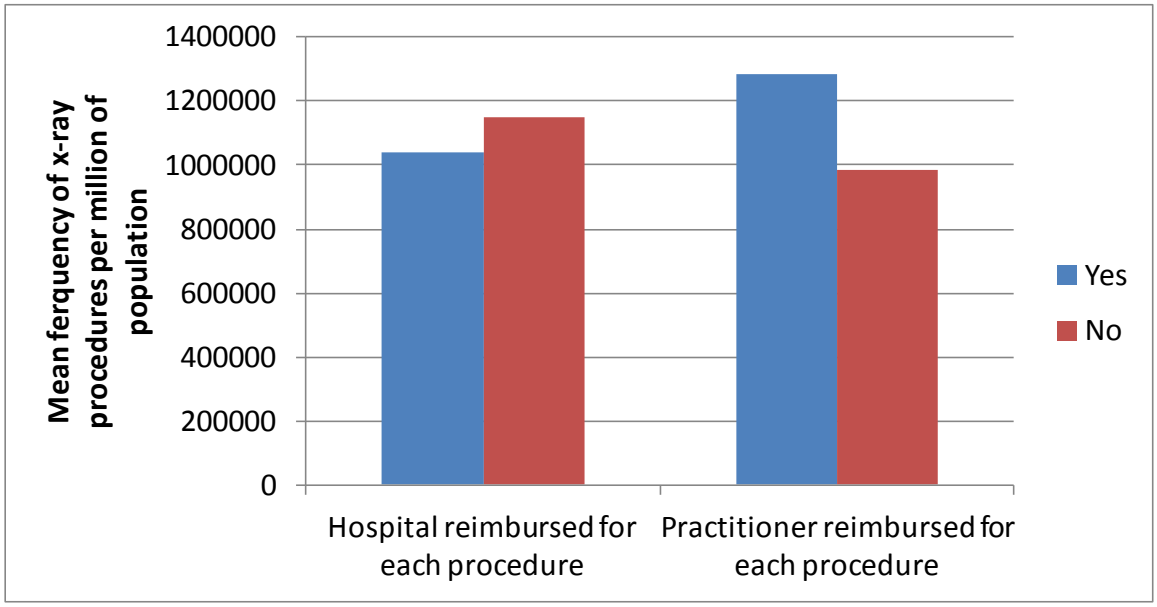


Figure 5.9. Correlation of the overall frequency of x-ray examinations and the reimbursement system.

5.1.2 Effective doses

5.1.2.1 Typical effective doses

For the Top 20 groups of examinations, the typical effective doses estimated in European countries are shown in Table 5.10., Table 5.11. and Table 5.12. The different countries have used their particular approaches to estimate effective doses for x-ray examinations. Nearly all values correspond to the use of tissue weighting factors from ICRP 60. There is only 2 % increase in the overall effective dose in using tissue weighting factors from ICRP 103 (Hart, 2008). The variation of the typical effective dose between the countries is shown by graphs for all Top 20 groups in Annex 5. The variation of the typical effective dose, (range, max/min), together with its average values calculated as the mean for all countries, for each Top 20 group are shown in Table 5.13.

In Table 5.14. and Figure 5.10, the typical effective doses obtained in this study are compared with the earlier data from 10 European countries and UNSCEAR Health Care Level 1 (HCL1) countries. There are not very large differences between the various data sets. The average values reported in this study from the 10 DDM1 countries are typically lower than the similar values reported in the earlier study (EC 2008).

Table 5.10. The typical effective doses (mSv) estimated in European countries for plain radiography (Top 20 groups 1-7) (na: data not available)

Country	Chest/ Thorax	Cervical spine	Thoracic spine	Lumbar spine (inc.LSJ)	Mammography	Abdomen	Pelvis & hip
AT	0,13	0,05	0,40	0,68	0,35	0,31	0,38
BE	0,09	0,17	0,48	3,15	0,02	0,68	0,73
BG	0,06	0,27	0,50	0,85	0,18	1,50	0,70
CH	0,05	0,10	0,44	1,63	0,16	0,78	0,94
CY	0,04	0,02	0,17	0,45	0,17	0,52	0,57
CZ	0,06	0,35	0,80	2,00	0,36	1,10	1,40
DE	0,22	0,29	0,54	1,35	0,12	0,86	0,69
DK	0,07	0,04	0,40	1,08	0,28	0,50	0,55
EE	0,10	0,27	1,00	1,90	0,33	1,50	0,90
EL	0,07	na	na	1,27	0,56	na	0,66
ES	0,06	0,09	0,23	0,89	0,28	0,69	0,55
FI	0,07	0,11	0,39	0,81	0,20	0,80	0,34
FR	0,05	0,30	0,50	1,55	0,15	1,90	1,10
HR	0,18	0,08	0,33	0,97	0,47	0,50	0,60
HU	0,25	0,40	1,20	1,50	0,40	1,50	1,50
IE	0,02	0,04	0,20	0,29	0,54	0,39	0,27
IS	0,14	0,14	0,77	1,98	0,22	2,93	0,75
IT	0,09	0,20	0,60	0,53	0,25	0,66	0,77
LT	0,16	0,27	0,76	1,09	0,03	0,17	0,28
LU	0,13	0,20	0,70	1,04	0,50	1,00	0,77
LV	na	na	na	na	na	na	na
MD	0,22	0,06	0,61	0,99	0,06	0,11	0,21
ME	0,26	0,11	0,38	0,75	na	0,51	0,80
MK	0,25	0,70	2,00	2,80	0,40	1,80	1,35
MT	0,02	0,33	1,45	1,24	0,13	0,26	0,53
NL	0,04	0,02	0,30	0,44	0,35	0,44	0,37
NO	0,07	0,07	0,49	1,36	0,15	1,25	0,41
PL	0,20	0,30	0,50	1,70	0,60	1,70	2,00
PT	0,06	0,05	0,57	1,07	0,13	0,72	0,82
RO	0,10	0,09	0,14	1,27	0,12	0,22	0,29
RS	0,04	0,12	0,62	0,93	0,22	0,44	0,30
SE	0,05	0,27	1,00	1,05	0,08	1,50	0,38
SI	0,05	0,07	0,37	0,80	0,41	0,42	0,52
SK	0,05	0,08	0,42	0,55	0,17	0,64	0,58
UA	0,10	0,70	2,00	2,50	0,40	1,80	1,60
UK	0,01	0,03	0,38	0,60	0,50	0,43	0,22
MEAN	0,102	0,188	0,636	1,230	0,273	0,898	0,709
MAX	0,26	0,70	2,00	3,15	0,60	2,93	2,00
MIN	0,01	0,02	0,14	0,29	0,02	0,11	0,21
MAX/MIN	18,6	41,2	14,2	10,9	35,3	27,9	9,7

Table 5.11. The typical effective doses (mSv) estimated in European countries for fluoroscopy and interventional radiology (Top 20 groups 8-12 and 20) (na: data not available)

Country	Ba meal	Ba enema	Ba follow-through	IVU	Cardiac angio-graphy	PTCA
AT	1,8	5,3	7,9	1,7	11,2	18,1
BE	6,2	10,4	6,8	5,6	10,0	10,0
BG	3,1	8,7	10,0	4,0	6,4	14,0
CH	12,0	12,0	3,8	2,1	11,2	17,0
CY	2,1	2,4	4,7	2,7	7,7	14,4
CZ	1,9	3,5	3,5	2,9	9,2	18,2
DE	12,5	11,4	7,0	3,1	9,0	11,7
DK	2,6	5,3	4,4	2,7	5,3	11,7
EE	7,7	8,6	10,0	4,0	9,1	14,0
EL	na	na	na	na	na	na
ES	4,9	8,3	7,7	2,5	4,9	19,0
FI	2,6	2,6	0,6	2,4	7,8	19,4
FR	12,0	12,0	4,1	2,6	11,2	22,0
HR	7,7	8,6	10,0	4,0	5,1	11,0
HU	10,9	12,2	9,2	4,2	7,3	21,0
IE	na	4,6	1,5	1,9	6,0	17,1
IS	3,4	25,2	6,6	3,4	4,6	11,9
IT	2,0	6,5	na	1,6	8,0	20,9
LT	3,1	7,2	1,9	3,3	9,5	13,0
LU	9,0	8,9	8,8	3,5	3,3	6,6
LV	na	na	na	na	na	na
MD	3,6	3,6	7,8	0,4	10,8	4,0
ME	8,6	7,2	5,3	3,6	8,0	29,0
MK	15,0	12,5	24,5	3,5	11,3	15,4
MT	0,8	4,0	1,2	1,5	8,8	15,2
NL	3,0	6,3	5,5	3,0	4,3	11,7
NO	5,2	7,3	4,8	2,4	7,6	16,9
PL	11,6	15,9	15,5	4,0	10,0	23,0
PT	7,8	13,3	na	4,2	6,8	14,5
RO	12,6	10,0	2,4	3,7	4,8	8,7
RS	2,4	6,7	2,9	2,5	10,0	26,0
SE	7,7	5,6	10,0	2,2	6,6	14,0
SI	1,4	7,8	5,3	0,9	4,3	12,4
SK	3,8	9,7	12,4	2,9	9,5	12,8
UA	12,0	12,5	24,5	3,5	8,6	15,4
UK	2,0	2,2	1,3	2,1	3,9	7,8
MEAN	6,16	8,48	7,25	2,90	7,71	15,2
MAX	15,0	25,2	24,5	5,63	11,3	29,0
MIN	0,80	2,2	0,63	0,43	3,3	4,0
MAX/MIN	18,8	11,5	38,9	13,0	3,5	7,3

Table 5.12. The typical effective doses (mSv) estimated in European countries for computed tomography (Top 20 groups 13-19) (na: data not available)

Country	CT head	CT neck	CT chest	CT spine	CT abdomen	CT pelvis	CT trunk
AT	2,3	2,3	6,7	5,0	14,7	8,0	4,0
BE	1,3	2,9	4,2	10,1	8,6	na	na
BG	1,3	na	5,5	5,3	11,2	11,2	14,0
CH	1,4	2,9	5,6	9,2	11,3	8,0	10,5
CY	4,0	2,3	4,3	8,7	10,4	6,3	8,0
CZ	1,3	na	5,1	2,5	6,7	5,0	na
DE	1,6	2,0	5,8	6,3	12,2	6,1	17,8
DK	2,2	2,5	8,2	13,4	12,2	6,4	50,5
EE	2,0	na	na	na	na	na	7,2
EL	2,1	3,4	10,9	7,1	7,0	na	13,1
ES	2,0	1,8	4,4	8,9	10,0	7,8	15,8
FI	1,2	1,3	3,9	5,6	6,7	14,5	8,8
FR	1,8	5,0	6,4	9,1	9,4	0,8	33,0
HR	1,8	2,5	5,0	6,2	7,5	4,8	15,7
HU	1,0	2,9	6,8	12,0	12,1	7,0	12,0
IE	1,7	1,9	7,3	na	8,4	na	12,9
IS	2,5	5,4	6,4	11,8	14,1	9,3	na
IT	1,6	2,2	7,9	6,3	8,6	7,8	na
LT	1,9	2,5	5,6	6,9	28,7	6,5	na
LU	2,7	2,5	3,9	11,8	10,5	na	7,9
LV	na	na	na	na	na	na	na
MD	0,3	0,4	20,4	16,3	17,2	4,2	2,4
ME	1,9	2,1	na	na	20,1	7,1	na
MK	2,4	2,8	8,2	6,0	13,5	8,8	24,4
MT	1,0	1,0	11,2	na	12,4	6,7	7,1
NL	1,2	na	5,5	3,1	10,6	7,4	na
NO	1,5	2,6	4,7	5,6	10,0	7,3	na
PL	2,5	na	8,0	10,0	17,0	na	na
PT	1,9	1,7	4,9	9,3	6,7	4,1	7,7
RO	3,9	2,5	2,0	2,4	2,6	2,1	na
RS	1,9	1,9	5,6	4,8	8,2	7,3	17,0
SE	2,0	2,5	5,1	7,7	9,7	8,7	14,0
SI	2,9	3,0	6,7	9,9	15,3	9,8	17,6
SK	2,4	3,4	6,8	5,2	12,6	12,7	15,5
UA	2,4	2,8	8,2	6,0	13,5	8,8	24,4
UK	1,4	2,4	5,3	6,9	5,6	6,0	8,0
MEAN	1,92	2,52	6,56	7,72	11,3	7,26	14,8
MAX	3,98	5,38	20,4	16,3	28,7	14,5	50,5
MIN	0,28	0,42	2,0	2,4	2,6	0,80	2,4
MAX/MIN	14,3	13,0	10,0	6,9	11,0	18,1	21,5

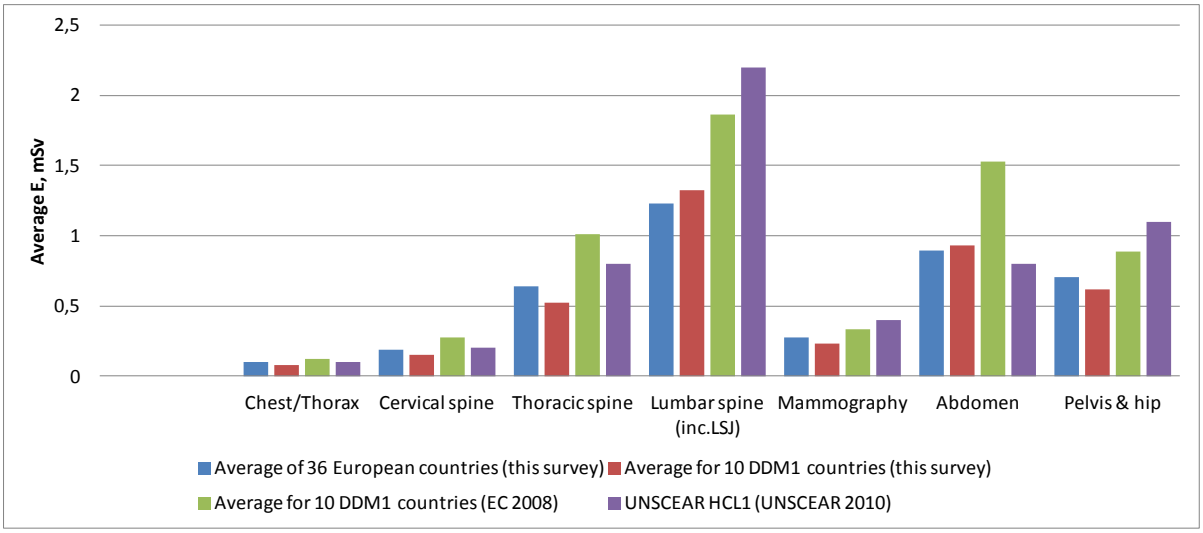
Table 5.13. The average values of typical effective doses (E) for TOP 20 groups, calculated as a mean of all countries. In France the only CT pelvis procedure is pelvimetry.

TOP 20 group	E, mSv	Range, mSv	Max/min
Chest/Thorax	0,1	0,014-0,26	18,6
Cervical spine	0,2	0,02-0,7	41,2
Thoracic spine	0,6	0,14-2,0	14,2
Lumbar spine (inc.LSJ)	1,2	0,29-3,15	10,9
Mammography	0,3	0,02-0,6	35,3
Abdomen	0,9	0,11-2,9	27,9
Pelvis & hip	0,7	0,21-2,0	9,7
Ba meal	6,2	0,8-15.0	18,8
Ba enema	8,5	2,2-25,2	11,5
Ba follow-through	7,2	0,63-24,5	38,9
IVU	2,9	0,43-5,63	13,0
Cardiac angio-graphy	7,7	3,25-11,25	3,5
CT head	1,9	0,28-3,98	14,3
CT neck	2,5	0,42-5,38	13,0
CT chest	6,6	2,03-20,4	10,0
CT spine	7,7	2,38-16,3	6,9
CT abdomen	11,3	2,61-28,7	11,0
CT pelvis	7,3	0,8-14,5	18,1
CT trunk	14,8	2,35-50,5	21,5
PTCA	15,2	4,0-29,0	7,3

Table 5.14. Average values of the typical effective doses (mSv) obtained in this study, compared with earlier data from 10 European countries and UNSCEAR Health Care Level 1 (HCL1) countries.

TOP 20 Group	Average of 36 European countries (this survey)	Average for 10 DDM1 countries (this survey)	Average for 10 DDM1 countries (EC 2008)	UNSCEAR HCL1 (UNSCEAR 2010)
Chest/Thorax	0,1	0,1	0,1	0,1
Cervical spine	0,2	0,1	0,3	0,2
Thoracic spine	0,6	0,5	1,0	0,8
Lumbar spine (inc.LSJ)	1,2	1,3	1,9	2,2
Mammography	0,3	0,2	0,3	0,4
Abdomen	0,9	0,9	1,5	0,8
Pelvis & hip	0,7	0,6	0,9	1,1
Ba meal	6,2	7,2	7,7	
Ba enema	8,5	8,1	8,6	7,4
Ba follow-through	7,2	5,7	10,5	
IVU	2,9	2,9	4,0	2,6
Cardiac angiography	7,7	7,2	9,1	11,2
CT head	1,9	1,7	2,0	2,4
CT neck	2,5	2,8	2,5	
CT chest	6,6	5,5	8,0	7,8
CT spine	7,7	8,3	5,3	5
CT abdomen	11,3	10,0	11,8	12,4
CT pelvis	7,3	6,3	8,7	9,4
CT trunk	14,8	20,2	13,5	
PTCA	15,2	12,9	14,1	11,9

(a)



(b)

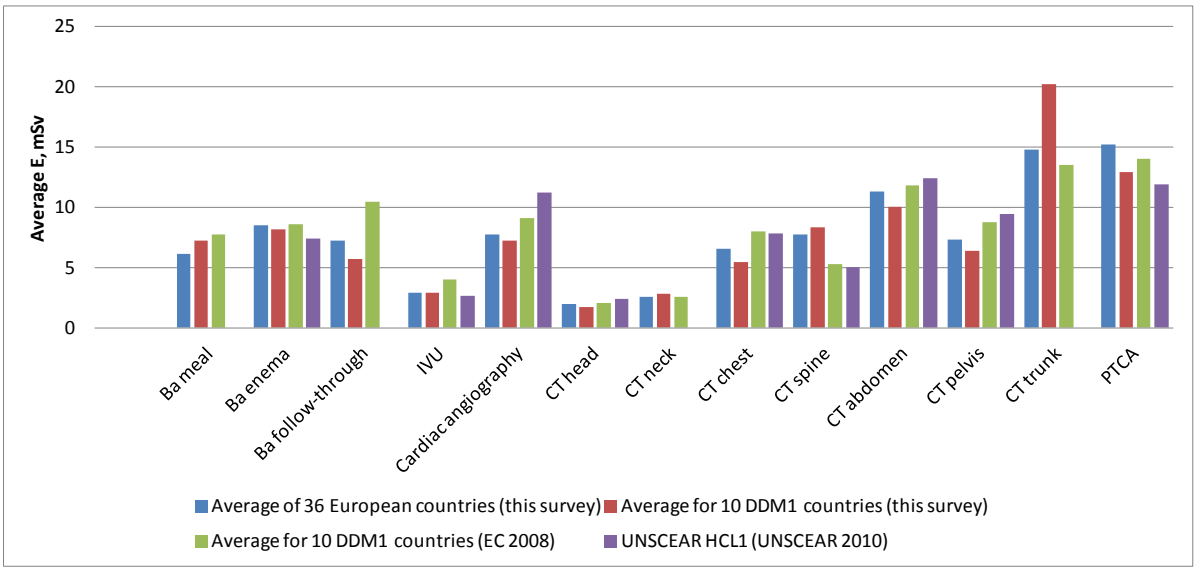


Figure 5.10. Average values of the typical effective doses (mSv) obtained in this study, compared with the earlier data from 10 European countries and UNSCEAR Health Care Level 1 (HCL1) countries; (a) plain radiography, (b) other Top 20 groups.

5.1.2.2 Collective effective doses and per caput effective doses

The overall total collective effective dose of x-ray procedures in European countries is

Group 1: *547500* man Sv, resulting in a mean effective dose of *1,06 mSv per caput*.

Group 2: *605000* man Sv, resulting in a mean effective dose of *1,05 mSv per caput*.

The overall collective effective doses from x-ray procedures (man Sv) for the main groups (plain radiography, fluoroscopy, computed tomography and interventional radiology) for each country are shown in Table 5.15. The variation of the mean effective dose per caput between the countries is presented in Figure 5.11 and Table 5.14.

The overall collective effective dose is the real reported dose for only six countries (BG, CH, DE, FI, FR, UK). For the other countries, which could report only Top 20 data, the overall

collective effective dose have been obtained from the Top 20 total collective effective dose by using a correction factor that takes into account the procedures not included in the Top 20. This correction factor (Table 5.17.) has been taken as the average ratio between the overall total collective effective dose and the Top 20 total collective effective dose (total overall/total Top 20), for each main group of x-ray procedures (plain radiography, fluoroscopy, computed tomography and interventional radiology), calculated from the results for the 6 countries of this survey which have reported both types of total collective effective doses (BG, CH, DE, FI, FR, UK). In Figure 5.12, the distribution of the correction factors between the 6 countries has been presented.

In Table 5.17 and Fig. 5.12, two values of the correction factor less than 1.0 appear (plain radiography for FI and fluoroscopy for CH), which requires an explanation. For FI, the correction factor is indeed <1 (0,99) and caused by the characteristics of Top 20 method: the collective effective dose for each Top 20 group was calculated using the typical effective dose for the most common type of examination in this Top 20 group but using the total frequency of all types of examination in this Top 20 group (otherwise it would have been the same as the most comprehensive overall calculation). In this process, the Top 20 collective effective doe became higher than the value if all types of examinations had been calculated separately with their own effective dose values, and more than compensated the collective effective dose from the types of plain radiography examinations outside this Top 20 group (limbs etc). For CH, the explanation is more simple as CH updated their overall frequency and collective effective dose values in December 2012, but the Top 20 values remained the same; new collective effective dose for fluoroscopy was significantly lower than the old value causing the correction factor to become <1 (0.71). Compared with earlier data, the effect of this is about 1,5 % on the total effective dose for those countries using the TOP20 correction; due to the high inherent uncertainty of the correction factor, it was agreed to accept this additional uncertainty and no change of the values for other countries were implemented.

For LV, no Top 20 data was available; in this case, because the total frequency data was available and was close to the average values for Europe, the collective effective doses were estimated as an average of the six countries providing complete data. For plain radiography at UA, the total collective dose was estimated by applying correction factor 1.12 for radiography, PLUS adding collective dose for chest fluorography, because of the very high frequency of this exam (498,8 per 1000 of population), much higher than that of diagnostic chest radiography (142 per 1000 of population), and also because of its relatively high contribution to the overall collective effective dose (450 mSv per 1000 of population or about 42 %).

Table 5.16 indicates high variation in the per caput mean effective dose between the countries. However, no comparison between countries or comments on the differences are made because only for six countries the values are based on calculations with real reported overall frequencies and the data for other countries is based on a rough estimation from Top 20 calculations.

It can be seen from Table 5.17 that the Top 20 examinations as defined in RP 154, on the average contribute about 77 % to the total collective effective dose, which is rather consistent with that obtained earlier for the 10 European countries of the DDM1 project, i.e. between 70 and 90 %. It can also be seen that the collective effective dose from interventional radiology is greatly underestimated by use of the Top 20 but, due to relatively small frequency of IR procedures, the effect on the overall total value is not significant.

The overall per caput effective doses for 10 countries which participated both in the earlier DDM1 project (EC 2008) and in the present project (DDM2) have been compared in Table 5.18. Because the data for only CH, DE, FR and UK is based on real reported overall frequencies and the data for other countries is based on a rough estimation from Top 20 calculations, no strict conclusions about the trends can be drawn. However, there seems to be an upward trend which could be anticipated from the increased frequencies (Table 5.9.),

in particular for CT examinations, because the typical effective dose for these countries has not significantly decreased (Table 5.14).

Table 5.15. The overall collective effective doses (man Sv) of x-ray procedures for all 36 countries and for the main groups (plain radiography, fluoroscopy, computed tomography and interventional radiology). Real data (not estimated from Top 20) given in bold. na: data not available.

Country	Overall	Plain radiography	Fluoroscopy	Computed tomography	Interventional radiology
AT	7139	1274	1654	4012	199
BE	21304	2861	1943	12797	3703
BG	**3076**	**607**	**921**	**1345**	**202**
CH	**9092**	**1444**	**415**	**6152**	**1080**
CY	998	60	53	803	82
CZ	10354	2926	713	3743	2972
DE	**136839**	**19947**	**24131**	**82618**	**10143**
DK	4953	499	118	4021	316
EE	1885	225	169	1416	75
EL	10439	2039	na	8399	na
ES	50830	9149	4153	34076	3452
FI	**2422**	**389**	**290**	**1409**	**334**
FR	79555	**18639**	**7988**	**47297**	5631
HR	2915	540	918	1149	309
HU	17778	6021	3026	7534	1197
IE	2872	290	249	1627	706
IS	541	59	30	425	27
IT	70432	10020	6422	44720	9269
LT	2996	672	944	1200	181
LU	840	97	37	698	8
LV	1847	322	239	1124	163
MD	900	362	326	208	4
ME	601	86	53	414	48
MK	1416	513	489	271	143
MT	274	30	54	155	36
NL	10311	936	914	7517	944
NO	5934	475	460	4398	601
PL	35525	12640	4006	14106	4773
PT	12390	1984	884	8996	527
RO	7167	1188	3673	2216	91
RS	5809	1379	1471	2047	912
SE	7123	772	880	4850	621
SI	1301	251	78	830	142
SK	4150	701	509	2697	242
UA	48670	35674	10166	2585	245
UK	**24194**	**3422**	**2519**	**16390**	**1862**
Total	604871	138492	80892	334246	51241

Table 5.16. The per caput mean effective doses (mSv) of x-ray procedures for all 36 countries and for the main groups (plain radiography, fluoroscopy, computed tomography and interventional radiology). Real data (not estimated from Top 20) given in bold. na: data not available.

Country	Plain radiography	Fluoroscopy	Computed tomography	Interventional radiology	Overall
AT	0,15	0,20	0,48	0,02	0,85
BE	0,26	0,18	1,18	0,34	1,96
BG	**0,08**	**0,12**	**0,18**	**0,03**	**0,41**
CH	**0,19**	**0,05**	**0,80**	**0,14**	**1,18**
CY	0,06	0,05	0,80	0,08	1,00
CZ	0,28	0,07	0,36	0,28	0,99
DE	**0,24**	**0,30**	**1,01**	**0,12**	**1,67**
DK	0,09	0,02	0,72	0,06	0,89
EE	0,17	0,13	1,07	0,06	1,43
EL	0,19	na	0,77	na	0,95
ES	0,19	0,09	0,72	0,07	1,08
FI	**0,07**	**0,05**	**0,26**	**0,06**	**0,45**
FR	**0,29**	**0,13**	**0,74**	0,09	1,25
HR	0,13	0,21	0,27	0,07	0,68
HU	0,60	0,30	0,75	0,12	1,78
IE	0,08	0,07	0,47	0,20	0,83
IS	0,18	0,09	1,33	0,09	1,70
IT	0,17	0,11	0,74	0,15	1,16
LT	0,21	0,29	0,37	0,06	0,92
LU	0,21	0,08	1,49	0,02	1,79
LV	0,16	0,12	0,54	0,08	0,89
MD	0,10	0,09	0,06	0,001	0,25
ME	0,13	0,08	0,62	0,07	0,90
MK	0,25	0,24	0,13	0,07	0,70
MT	0,07	0,13	0,38	0,09	0,68
NL	0,06	0,06	0,46	0,06	0,63
NO	0,10	0,10	0,93	0,13	1,25
PL	0,33	0,11	0,37	0,13	0,93
PT	0,19	0,08	0,85	0,05	1,17
RO	0,06	0,17	0,11	0,004	0,34
RS	0,18	0,20	0,27	0,12	0,77
SE	0,08	0,10	0,53	0,07	0,77
SI	0,12	0,04	0,40	0,07	0,63
SK	0,13	0,09	0,50	0,04	0,76
UA	0,78	0,22	0,06	0,01	1,06
UK	**0,06**	**0,04**	**0,27**	**0,03**	**0,39**
Mean	0,18	0,13	0,58	0,09	0,98
Max	0,78	0,30	1,49	0,34	1,96
Min	0,06	0,02	0,06	0,001	0,25
Max/min	13,9	14,3	26,4	338,6	7,8

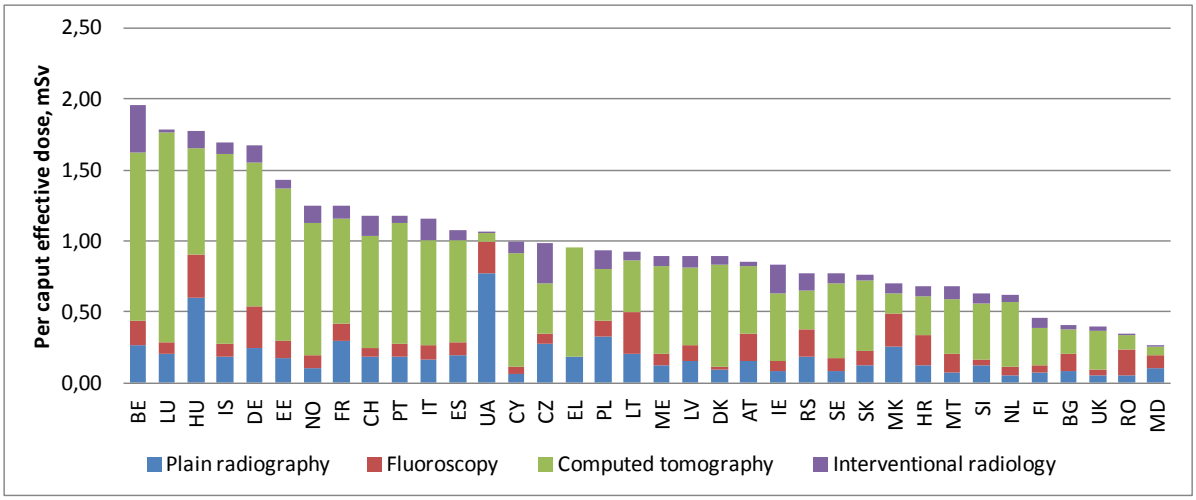


Figure 5.11. Per caput effective doses for different countries. The relative contributions of the four main groups (plain radiography, fluoroscopy, computed tomography and interventional radiology) are also shown (for more details on relative contributions, see Table 5.22). For EL, data for the contributions of fluoroscopy and IR were not available.

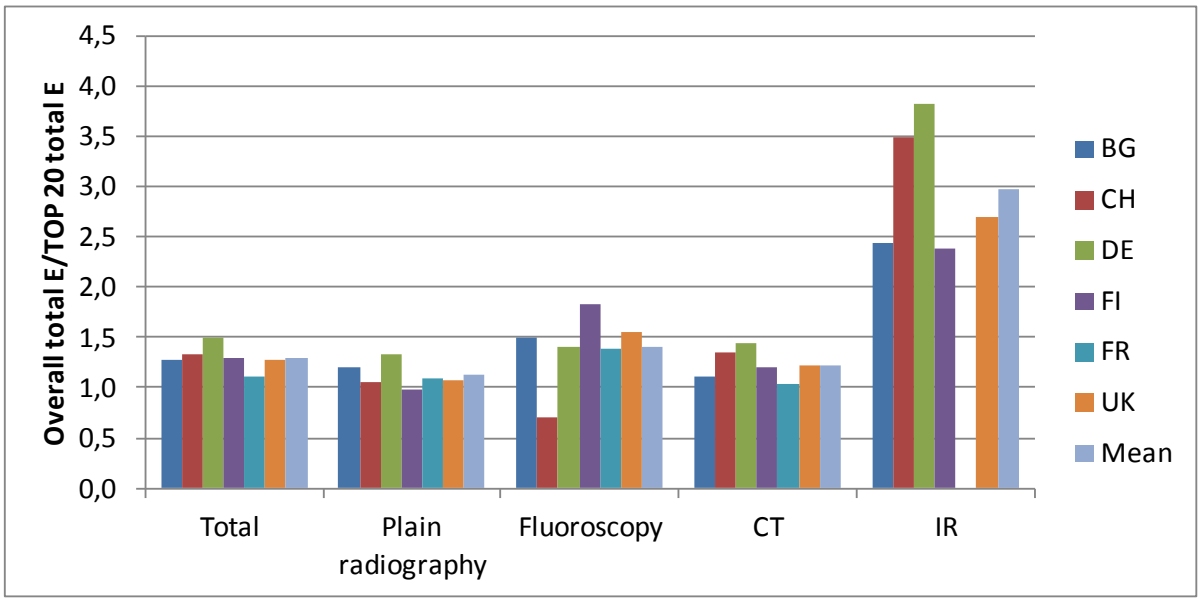


Figure 5.12. The distribution of the correction factors between the 6 countries. For the two values less than 1,0, see the explanation on page 38.

Table 5.17. Ratios of total overall/total Top 20 collective effective doses for 6 countries ; the mean values for the main groups are used as corrections factors for each group to estimate the overall values from Top 20 values.

Country	All Top 20 groups together	Plain radiography	Fluoroscopy	CT	IR
BG	1,27	1,20	1,49	1,11	2,44
CH	1,34	1,06	0,71	1,36	3,49
DE	1,49	1,34	1,41	1,45	3,83
FI	1,30	0,99	1,83	1,20	2,38
FR	1,12	1,09	1,39	1,04	
UK	1,27	1,07	1,56	1,22	2,70
Mean for the main groups = Correction factors		1,12	1,40	1,23	2,97
Mean for all Top 20 groups together	1,30				
Top 20 collective effective dose as a % of overall collective effective dose	77,0	88,9	71,4	81,4	33,7

Table 5.18. Comparison of the overall per caput effective doses (mSv) between the results of DDM1 and DDM2 studies, for 10 countries participating in both studies.

Country	DDM1 (EC 2008), mSv	DDM2 (this study), mSv	Ratio DDM2/DDM1
BE	1,77	1,96	1,11
DK	0,46	0,89	1,92
FR	0,70	1,25	1,78
DE	1,66	1,67	1,01
LU	1,82	1,79	0,98
NL	0,45	0,63	1,39
NO	1,10	1,25	1,14
SE	0,68	0,77	1,14
CH	1,00	1,18	1,18
UK	0,38	0,39	1,04
Mean	1,00	1,18	1,27

The total collective effective doses for all countries for each TOP 20 group are given in Table 5.19., Table 5.20 and Table 5.21.

Table 5.19. The TOP 20 collective effective doses (man Sv) of x-ray procedures for all countries and for TOP 20 groups 1-7 (na: values not available).

Country	Chest/ Thorax	Cervical spine	Thoracic spine	Lumbar spine (inc.LSJ)	Mammo-graphy	Abdomen	Pelvis & hip
AT	265	15	88	271	259	48	187
BE	224	37	71	1279	13	234	686
BG	72	30	30	128	21	117	108
CH	90	20	37	619	62	118	412
CY	7,8	0,3	1,7	13	3,5	16	11
CZ	148	129	540	0	795	285	705
DE	674	806	796	6424	1247	1398	3552
DK	46	1,4	17	129	117	14	119
EE	24	9,4	17	66	36	22	27
EL	228	na	na	1072	290	na	222
ES	891	173	369	2734	1056	1512	1397
FI	78	8,2	13	114	63	41	77
FR	563	349	222	4414	761	4503	6251
HR	113	5,4	11	78	117	43	111
HU	705	121	737	791	684	673	1642
IE	25	4,6	11	57	43	55	63
IS	7,6	0,4	2,0	12	4,8	15	11
IT	1075	362	577	1470	1134	1064	3226
LT	163	36	55	239	8,7	16	80
LU	11	2,3	5,0	20	15	7,5	26
LV	na	na	na	na	na	na	na
MD	99	7,3	67	124	0,8	5,3	18
ME	31	1,8	3,1	16	na	8,1	16
MK	68	25	40	138	5,8	41	138
MT	1,4	1,3	1,9	10	1,0	5,2	5,9
NL	94	3,6	38	185	132	136	243
NO	50	3,3	13	134	51	56	114
PL	2073	631	454	3007	629	722	3720
PT	212	26	146	566	88	340	385
RO	155	22	30	732	23	30	65
RS	60	50	218	559	83	98	158
SE	51	25	74	220	63	82	171
SI	21	5,4	13	89	39	16	40
SK	50	19	14	216	171	79	75
UA	652	832	1810	5674	237	2420	1729
UK	126	17	90	569	1340	530	527

Table 5.20. The TOP 20 collective effective doses (man Sv) of x-ray procedures for all countries and for TOP 20 groups 8-12 and 20 (na: values not available).

Country	Ba meal	Ba enema	Ba follow-through	IVU	Cardiac angio-graphy	PTCA
AT	87	385	60	12	638	67
BE	323	198	42	161	664	1247
BG	162	196	66	57	137	83
CH	109	63	10	19	383	309
CY	6,4	4,4	0,5	10	16,8	28
CZ	85	71	17	134	202	1001
DE	360	1862	103	2245	12510	2650
DK	15	20,5	20	4,4	25	106
EE	15	11,4	17	8,8	68	25
EL	na	na	na	na	na	na
ES	879	1001	375	379	333	1163
FI	0,5	3,0	2,7	4,9	147	140
FR	1319	858	116	336	3112	2750
HR	296	114,0	62	77	106	104
HU	776	413	291	427	254	403
IE	0	26,7	4,8	2,5	144	238
IS	3,6	6,2	3,7	2,4	5,6	9,2
IT	347	1787	na	354	2100	3122
LT	7,8	268	10	136	253,3	61
LU	13	2,5	1,1	3,1	6,9	2,8
LV	na	na	na	na	na	na
MD	118	21,8	63	4,9	25,3	1,2
ME	16	6,0	0,8	6,4	8,8	16,2
MK	213	5,7	69	21	39,8	48
MT	1,0	11,4	4,3	0,6	21,2	12,1
NL	54	139,0	19	9,4	432	318
NO	18	40,2	28	14	228	202
PL	464	159	388	510	1342	1608
PT	234	178	na	3,2	216	177
RO	1923	399	37	225	40	30
RS	304	296	30	77	345	307
SE	39	168	165	61	196	209
SI	2,9	11,2	5,8	2,4	33	48
SK	21	35	105	36	166	82
UA	4029	1358	1210	348	319	83
UK	76	513	58	177	789	690

Table 5.21. The TOP 20 collective effective doses (man Sv) of x-ray procedures for all countries and for TOP 20 groups 13-19 (na: values not available, nc: not counted, included in other groups).

Country	CT head	CT neck	CT chest	CT spine	CT abdomen	CT pelvis	CT trunk
AT	480	16	681	200	1413	353	122
BE	702	29	1358	3867	4460	nc	nc
BG	161	nc	175	169	508	175	24
CH	258	126	749	280	2097	195	827
CY	66	9,5	58	88	159	53	220
CZ	537	0	515	321	1169	505	0
DE	3988	417	8448	11047	24906	673	7616
DK	271	60	910	69	1655	154	154
EE	82	nc	nc	nc	nc	nc	1071
EL	453	186	2183	677	3115	na	223
ES	2085	406	3873	4379	7126	2981	6888
FI	183	18	215	43	272	124	316
FR	3468	761	10372	8343	20467	64	2104
HR	179	8,2	94	54	200	26	374
HU	383	37	1546	1205	2820	142	nc
IE	134	6,1	209	0	423	0	552
IS	40	12	57	50	180,5	6,7	nc
IT	4696	348	10087	4611	15580	1082	na
LT	157	18	94	230	406	71	nc
LU	61	32	0	232	226	0	17
LV	na	na	na	na	na	na	na
MD	3,7	0,3	45	49	52	4,5	15
ME	20	28	na	na	240	50	0
MK	49	6,1	34	15	64	7,7	45
MT	9,2	0,3	22	na	64	23	6,9
NL	419	nc	1537	166	3865	132	nc
NO	262	90	554	128	1687	858	nc
PL	2215	na	2404	1834	5029	na	na
PT	954	34	1095	2085	1487	597	1071
RO	1197	47	138	58	268	96	0
RS	334	65	315	99	474	197	182
SE	674	99	698	64	2305	47	60
SI	142	8,6	89	64	273	11	89
SK	337	28	305	201	700	235	389
UA	370	14	500	154	890	113	63
UK	1608	241	2069	201	1494	556	7315

The relative overall collective effective doses (percentage of the collective effective dose of all x-ray examinations), for the main groups of plain radiography, fluoroscopy, CT and IR, are shown in Table 5.22. and Figure 5.13. It can be seen that computed tomography yields by far the highest contribution, on the average 57,0 % (range 5,31 – 83,1 %), to the population dose in most countries, while the relative contributions of all main groups vary greatly between the countries. The relative contributions of the main groups plain radiography, fluoroscopy, CT and IR are further illustrated in Figure 5.14 and Figure 5.15.

In the above analysis of the overall collective effective dose, dental x-ray procedures are included in the main group plain radiography. While the frequency of dental x-ray procedures can be very high (See Table 5.2 in Section 5.1.1), their contribution to the overall population dose from plain radiography is typically only 2-4 % as shown in Table 5.23.

Table 5.22. Relative contributions of the main groups (plain radiography, fluoroscopy, CT and IR) to the overall collective effective dose from all x-ray examinations. na: data not available.

Country	Plain radiography	Fluoroscopy	Computed tomography	Interventional radiology
AT	17,8	23,2	56,2	2,8
BE	13,4	9,1	60,1	17,4
BG	19,7	29,9	43,7	6,6
CH	15,9	4,6	67,7	11,9
CY	6,0	5,3	80,4	8,2
CZ	28,3	6,9	36,2	28,7
DE	14,6	17,6	60,4	7,4
DK	10,1	2,4	81,2	6,4
EE	12,0	8,9	75,1	4,0
EL	19,5	na	80,5	na
ES	18,0	8,2	67,0	6,8
FI	16,1	12,0	58,2	13,8
FR	23,4	10,0	59,5	7,1
HR	18,5	31,5	39,4	10,6
HU	33,9	17,0	42,4	6,7
IE	10,1	8,7	56,6	24,6
IS	10,9	5,6	78,5	5,0
IT	14,2	9,1	63,5	13,2
LT	22,4	31,5	40,1	6,0
LU	11,6	4,4	83,1	1,0
LV	17,4	12,9	60,9	8,8
MD	40,3	36,2	23,1	0,4
ME	14,3	8,8	68,9	8,0
MK	36,3	34,5	19,1	10,1
MT	10,9	19,6	56,3	13,1
NL	9,1	8,9	72,9	9,2
NO	8,0	7,8	74,1	10,1
PL	35,6	11,3	39,7	13,4
PT	16,0	7,1	72,6	4,3
RO	16,6	51,2	30,9	1,3
RS	23,7	25,3	35,2	15,7
SE	10,8	12,4	68,1	8,7
SI	19,3	6,0	63,8	10,9
SK	16,9	12,3	65,0	5,8
UA	73,3	20,9	5,3	0,5
UK	14,1	10,4	67,7	7,7
MAX	73,3	51,2	83,1	28,7
MIN	6,0	2,4	5,3	0,4

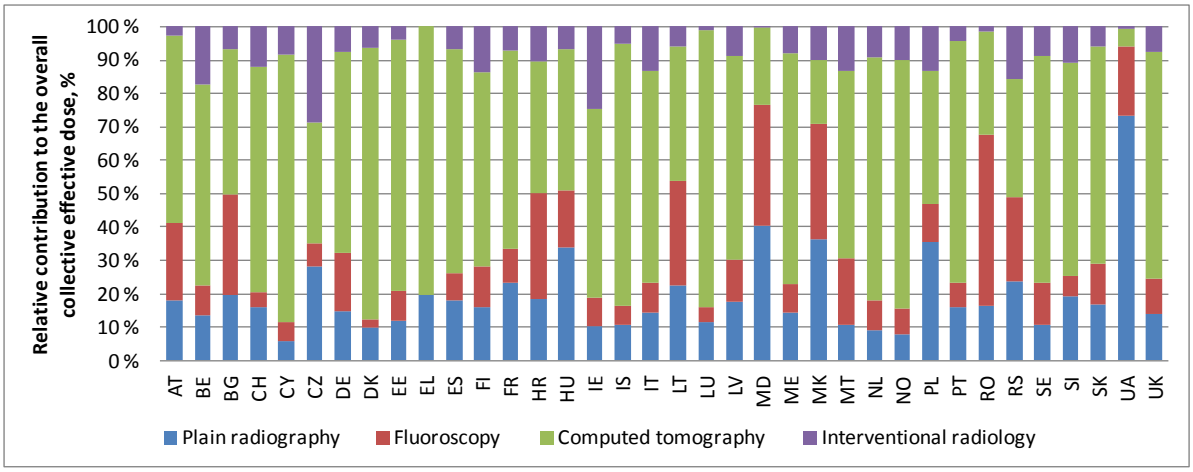


Figure 5.13. The relative collective effective doses (% of the collective effective dose of all x-ray examinations), for the main groups of plain radiography, fluoroscopy, CT and IR. For EL, data for fluoroscopy and IR were not available.

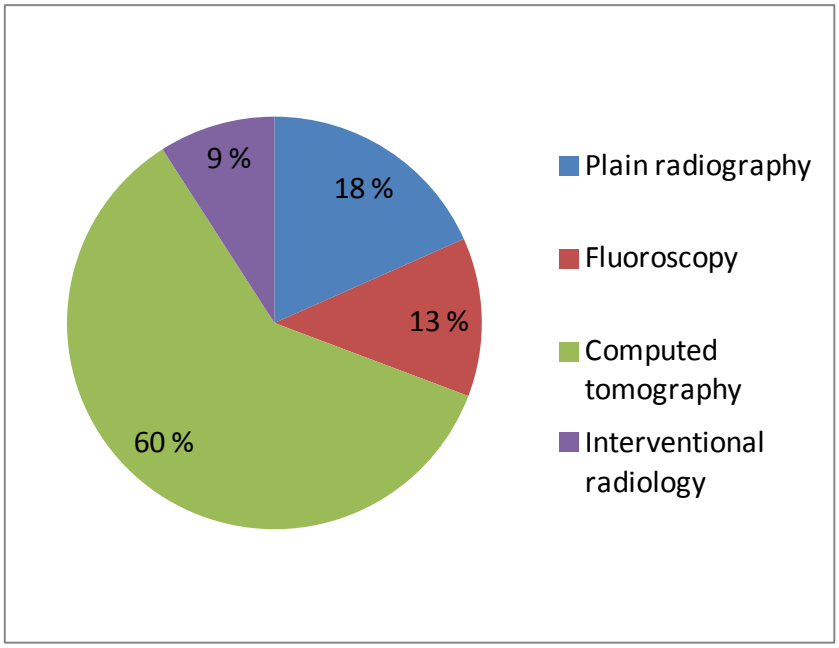


Figure 5.14. Relative contributions of the four main groups to the overall collective effective dose in Group 1 countries (EU Member States + CH, IS, NO).

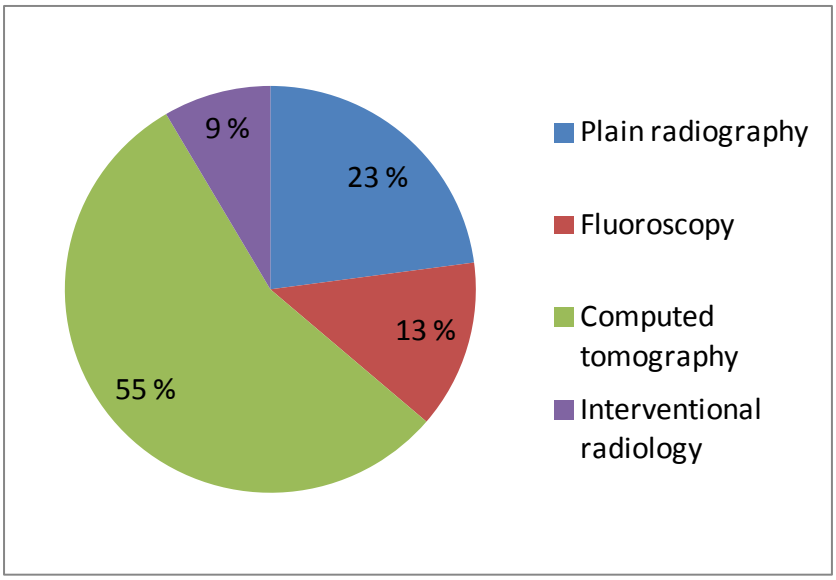


Figure 5.15. Relative contributions of the four main groups to the overall collective effective dose in Group 2 countries (All countries).

Table 5.23. Contribution of dental x-ray procedures to the overall collective effective dose from plain radiography and from all x-ray procedures

Country	Dental procedures as a % of total plain radiography	Dental procedures as a % of total x-ray procedures
BG	1,5	0,3
CH	4,2	0,7
DE	2,0	0,3
FI	4,2	0,7
FR	1,9	0,4
UK	3,2	0,4
Mean	2,8	0,5

5.2 Nuclear Medicine procedures

5.2.1 Frequencies

The total frequency of diagnostic NM procedures in the European countries is

Group 1 (30 countries): *7,9 million*, or 15 examinations per 1000 of population, or 0,015 examinations per caput.

Group 2 (35 countries): *8,1 million*, or 14 examinations per 1000 of population, or 0,014 examinations per caput.

The total frequencies are somewhat lower than the HCL 1 countries mean rate of 19 per 1000 of population for 1997-2007, according to UNSCEAR 2008 report. The distribution of the total number per 1000 of population for different countries is shown in Figure 5.16, Figure 5.17, Figure 5.18a,b and 5.19. The variation of the total number of NM examinations between the countries is high, ranging from about 0,5 to about 38 per 1000 of population. The relative annual frequencies of the main groups are shown in Fig 5.20. The distribution

per million of population according to the isotope used is shown in Table 5.24. and Table 5.25.

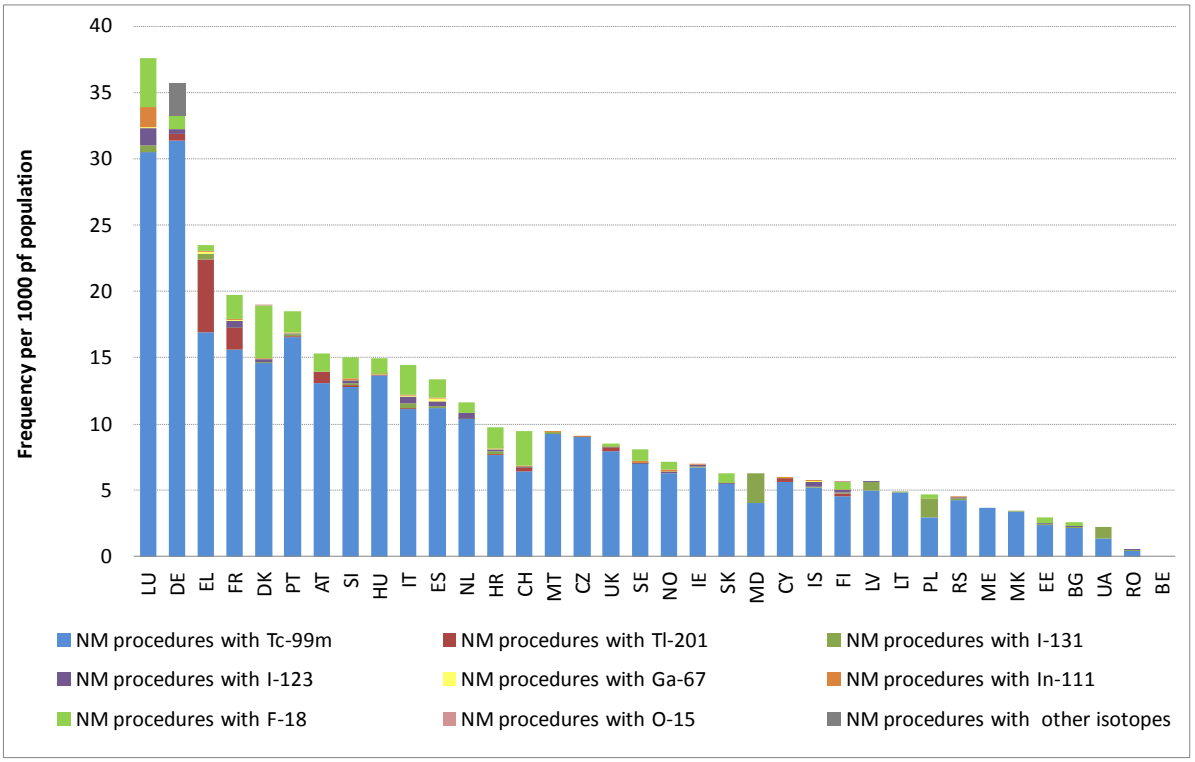


Figure 5.16. Annual frequencies of NM examinations per 1000 of population, according to the isotope used (BE: No data available).

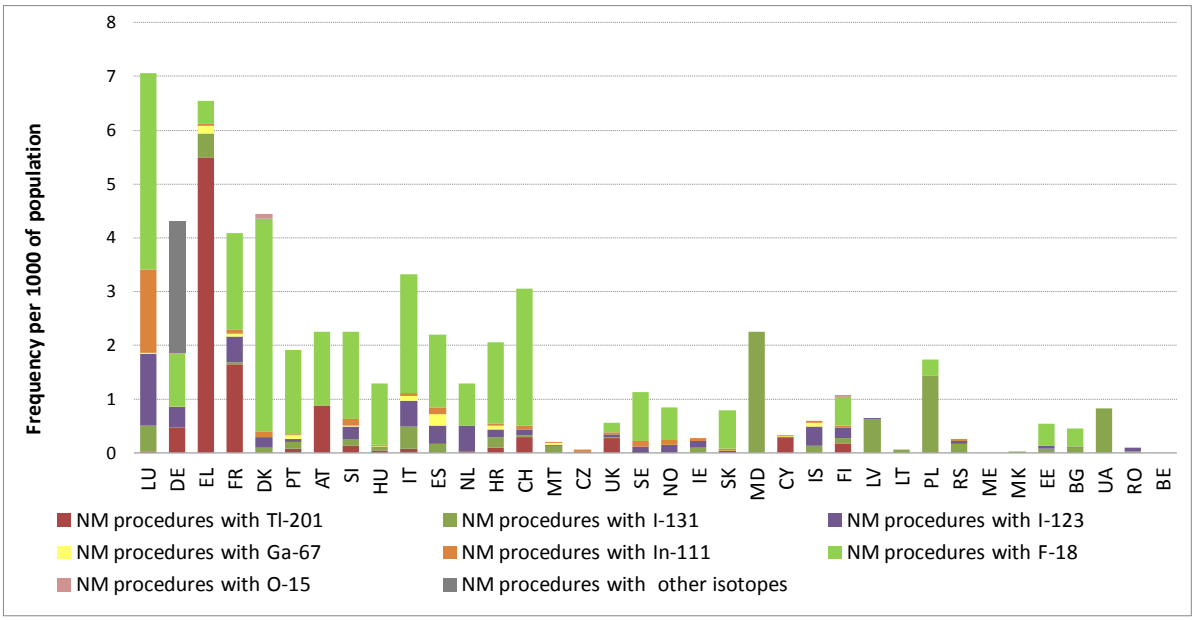


Figure 5.17 Annual frequencies of NM examinations per 1000 of population, according to the isotope used but procedures with Tc-99m removed (BE: no data available)

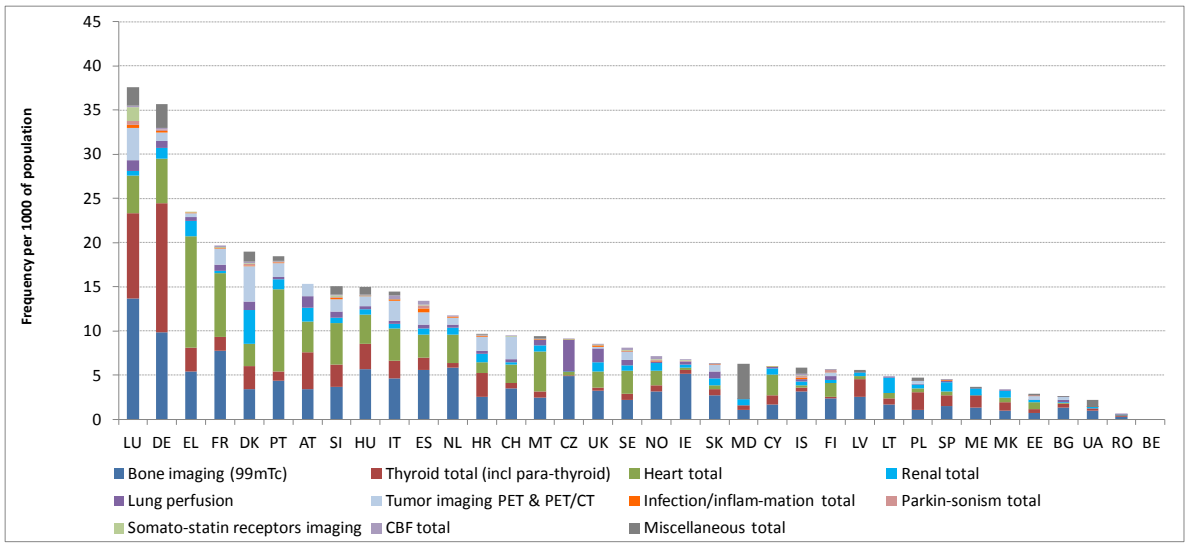


Figure 5.18a. Annual frequencies of NM examinations per 1000 of population, according to the main groups (one or more types of examinations of the same organ, the same target or closely similar objectives grouped together) (BE: No data available).

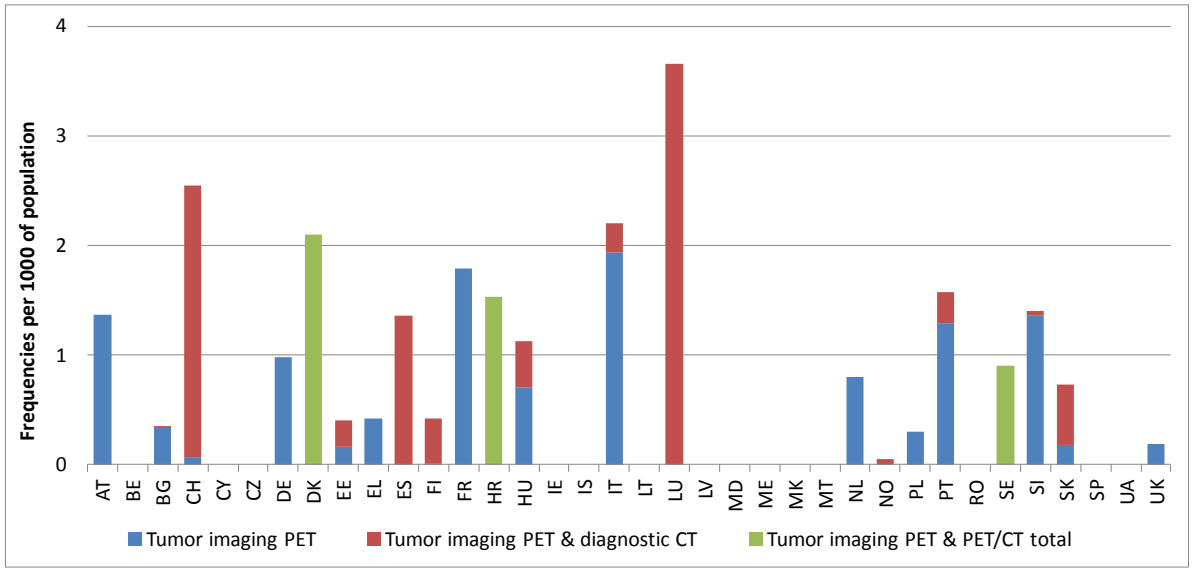


Figure 5.18b. Annual frequencies of NM examinations per 1000 of population, for tumor imaging with PET and PET associated with a diagnostic CT.

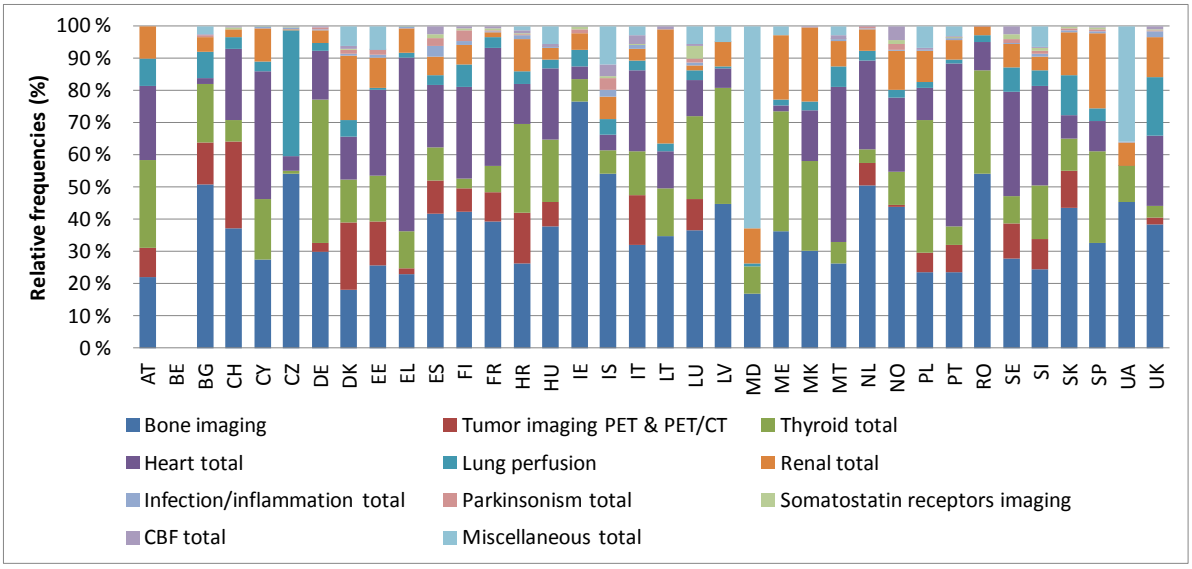


Figure 5.19. Relative annual frequencies of NM examinations according to the main groups (BE: No data available).

Table 5.24. Annual frequencies of diagnostic NM examinations in European countries, per million of population, according to the isotope used (na: not available, nc: not counted, included in other groups).

Country	NM procedures with Tc-99m	NM procedures with Tl-201	NM procedures with I-131	NM procedures with I-123	NM procedures with Ga-67	NM procedures with In-111	NM procedures with F-18	NM procedures with O-15	NM procedures with other isotopes
AT	13060	881	0	0	0	0	1369	0	0
BE	na	na	na	na	na	na	na	na	0
BG	2163	0	89	14	0	0	342	0	0
CH	6390	286	35	105	na	71	2555	na	0
CY	5631	286	7	0	6	8	0	0	0
CZ	8995	24	nc	nc	0	28	0	nc	0
DE	31385	471	na	379	1	na	987	24	2445
DK	14576	0	91	204	0	100	3963	78	0
EE	2389	0	73	60	0	0	403	0	0
EL	16927	5496	443	na	135	47	416	0	0
ES	11171	0	158	340	219	128	1360	0	0
FI	4566	168	101	199	0	32	543	25	0
FR	15624	1635	38	492	53	74	1785	0	0
HR	7656	92	193	143	79	23	1529	0	0
HU	13649	46	64	1	13	30	1127	0	0
IE	6693	0	92	124	0	46	0	0	0
IS	5170	0	128	354	81	25	0	0	0
IT	11115	79	397	490	80	61	2206	na	0
LT	4795	0	48	0	0	0	0	0	0
LU	30511	28	468	1336	32	1543	3655	0	0
LV	4979	0	627	9	0	0	0	0	0
MD	3999	0	2247	0	0	0	0	0	0
ME	3646	0	0	0	0	0	0	0	0
MK	3354	0	24	0	0	0	0	0	0
MT	9242	0	126	12	40	10	0	0	0
NL	10362	11	3	481	0	0	798	nc	0
NO	6301	0	na	149	2	80	602	0	0
PL	2981	0	1426	0	2	0	301	0	0
PT	16576	72	120	62	66	26	1571	0	0
RO	436	0	28	63	0	0	0	0	0
RS	4240	0	160	60	0	40	0	0	0
SE	6965	1	2	112	0	103	899	0	0
SI	12800	122	123	244	7	129	1630	0	0
SK	5507	na	na	29	3	35	726	na	0
UA	1393	0	826	0	0	0	0	0	0
UK	7966	264	31	37	15	23	182	0	0

Table 5.25. Annual frequencies of NM examinations in European countries, per million of population, according to the main groups (one or more examinations of the same organ, the same target or closely similar objectives grouped together). (na: not available, nc: not counted, included in other groups).

Country	Bone imaging (^{99m}Tc)	Myocardial perfusion total (no PET)	Myocardial perfusion total (incl PET)	Tumor imaging PET & PET/CT	Thyroid total (incl para-thyroid)	MUGA total	Heart total	Lung perfusion	Renal total	Infection/ inflam-mation total	Parkin-sonism total	Somato-statin receptors imaging	CBF total	Miscella-neous total
AT	3393	3512	3512	1369	4167	0	3512	1333	1536	0	0	0	0	0
BE	na	na	na	na	na	na	na	na	na	na	na	na	na	na
BG	1326	48	48	342	472	2	50	206	124	0	14	0	5	69
CH	3519	2091	2097	2549	604	na	2097	338	232	na	na	71	31	0
CY	1637	2345	2345	0	1102	18	2363	174	621	32	0	8	0	0
CZ	4892	416	416	nc	91	3	419	3527	21	67	nc	28	2	0
DE	9808	4864	4897	978	14685	73	4970	724	1292	150	226	na	115	2744
DK	3430	2406	2406	3963	2556	124	2530	965	3842	103	196	100	153	1174
EE	751	780	782	402	412	0	782	20	270	27	44	0	6	212
EL	5387	12324	12324	416	2692	314	12638	392	1758	135	na	47	na	0
ES	5591	2193	2193	1360	1402	362	2554	418	778	448	340	128	356	0
FI	2378	1263	1412	419	170	194	1606	394	332	65	199	32	39	0
FR	7755	6533	6533	1785	1580	683	7216	676	289	79	75	74	172	0
HR	2547	1163	1163	1529	2693	39	1201	368	970	138	34	23	74	138
HU	5649	3016	3016	1127	2901	304	3320	371	559	34	1	30	115	835
IE	5141	257	257	0	461	0	257	358	333	0	95	46	16	0
IS	3175	241	241	0	426	50	291	276	410	122	225	25	225	695
IT	4627	3493	3495	2204	2006	120	3615	409	532	177	na	61	386	410
LT	1680	563	563	0	719	na	563	108	1729	0	0	0	44	0
LU	13702	4145	4145	3655	9647	132	4277	1149	513	394	400	1543	189	2104
LV	2520	334	334	0	2023	0	334	26	428	0	9	0	0	276
MD	1053	0	0	0	538	0	0	58	675	0	0	0	0	3921
ME	1324	0	0	0	1360	66	66	61	733	0	0	0	0	103
MK	1016	529	529	0	947	1	531	89	779	0	0	0	15	0
MT	2486	4301	4301	0	632	232	4533	598	748	40	0	10	123	259
NL	5887	2330	2330	798	503	904	3234	352	757	26	93	0	6	0
NO	3128	915	1466	50	728	167	1634	187	851	19	149	80	309	0
PL	1105	461	462	294	1929	11	473	90	460	15	0	0	24	320
PT	4346	8699	8699	1571	1086	626	9326	230	1103	109	55	26	54	588
RO	286	46	46	0	168	0	46	12	14	0	0	0	1	0
SE	2236	2547	2547	899	676	82	2629	607	595	25	95	103	218	0
SI	3679	4264	4278	1399	2547	353	4631	740	603	179	109	129	69	970
SK	2743	449	449	726	632	na	449	795	829	46	29	35	17	0
SP	1467	373	373	0	1287	40	413	187	1040	27	27	40	13	0
UA	1006	0	0	0	247	0	0	0	161	11	0	0	0	793
UK	3272	1696	1696	182	294	163	1859	1556	1061	165	26	23	81	0

Frequency data of NM procedures have been grouped into broader categories to enable comparison between DDM2 and DDM1 data and with similar data from UNSCEAR Health Care Level 1 (HCL1; UNSCEAR 2008) (Table 5.26a and 5.26b). On the average, the frequencies of the NM examinations in eight DDM1 countries seem to have decreased from the earlier study (DDM1), while these are still a little higher than in the UNSCEAR HCL1 countries. However, the average for all European countries in this study is lower than that for the HCL1 countries.

Table 5.26 a. Average frequencies per 1000 of population of this study, for the European countries and DDM1 countries, compared with similar data from an earlier DDM1 study and UNSCEAR Health Care Level 1 (HCL1; UNSCEAR 2008) countries (N is the number of countries that reported data)

NM procedure	Average frequencies per 1000 of population for European countries (this survey)	Average frequencies per 1000 of population for DDM1 countries (N=8) (this survey)	Average frequencies per 1000 of population for DDM1 countries (N=8) (1998-2005)	Average frequencies per 1000 of population for UNSCEAR HCL I countries (1997-2007)
Bone scan (Tc99m)	3,5 (N=35)	5,9	9	5,5 (N=27)
Heart total	2,6 (N=33)	3,0	4	2,6 (N=27)
Lung perfusion (Tc99m)	0,5 (N=35)	0,7	2	0,9 (N=25)
Thyroid total	1,8 (N=35)	3,9	5	3,6 (N=27)
Renal total	0,8 (N=35)	0,8	2	1,1 (N=26)
Brain	0,1 (N=28)			0,5 (N=21)
PET	0,4 (N=17)			0,5 (N=15)
PET & diagnostic CT	0,4 (N=15)			0,4 (N=9)
Total (for the five first procedures)	9,2	14,2	22,0	13,7

Table 5.26b. Comparison of frequency data between DDM1 and DDM2 studies, for eight DDM1 countries and for a few NM examination groups available from the DDM1 report (EC, 2008).

Country	Bone scan (Tc99m)		Heart total		Thyroid total		Lung perfusion (Tc099m)		Renal total	
	DDM1	DDM2	DDM1	DDM2	DDM1	DDM2	DDM1	DDM2	DDM1	DDM2
BE	25	na	10	na	10	na	5	na	2	na
CH	5	4	3	2	1	0,6	1	0,3	1	0,2
DE	11	10	5	5	17	15	3	0,7	3	1
LU	13	14	6	4	11	10	2	1	1	0,5
NL	6	6	4	3	1	0,5	3	0,4	1	0,8
NO	4	3	3	2	1	0,7	1	0,2	1	0,9
SE	3	2	2	3	1	0,7	1	0,6	2	0,6
UK	3	3	2	2	0,3	0,3	3	2	2	1

5.2.2 Effective doses

5.2.2.1 Typical effective doses

The administered mean activities for different diagnostic NM examination in European countries are presented in Table 5.27 to Table 5.30. The variation of the mean activities between European countries for selected NM examinations is given in graphs in Annex 5. In Table 5.28 there are a few very low values (for thyroid imaging and MUGA) compared with the rest of the data. The values have been checked to be the reported values, while no explanation has been available from the country level.e comparison of mean activities between DDM1 and DDM2 studies, for a few examinations (where data from DDM1 was available) in eight DDM1 countries, is shown in Table 5.31. It can be seen that the mean activities have not changed considerably since the DDM1 study (1998-2005).

The typical effective doses for the NM examinations were calculated from the mean activities using the conversion factors shown in Table 5.32. Most of the conversion factors are from ICRP 53 and 80 and some new and updated ones are from ICRP 106.

Two examples of the variation of the typical effective doses per NM procedure in European countries are shown in Figure 5.20 and Figure 5.21. The average typical effective doses per NM procedure are compared with UNSCEAR HCL1 countries in Table 5.33. The average typical effective doses in this survey seem generally lower than that in the UNSCEAR data for HCL1 countries. No clear explanation for this can be given, but the UNSCEAR data is

older and worldwide, while the data from this survey is newer and based on European countries only.

Table 5.27. Administered mean activities (MBq) for different NM examination in European countries. (na: data not available).

	Tc-99m	Tl-201	Tc-99m	Tc-99m	Tc-99m	Tc-99m	F-18	O-15
Country	Bone imaging	Myocardial perfusion (Chloride)	Myocardial perfusion, rest (Tetrofosmin)	Myocardial perfusion, exercise (Tetrofosmin)	Myocardial perfusion, rest (MIBI)	Myocardial perfusion, exercise (MIBI)	Myocardial perfusion (PET) (FDG)	Myocardial perfusion (PET) (H2O)
AT	740	110	na	1200	na	na	na	na
BE	na	na	na	na	na	na	na	na
BG	605	na	na	na	703	555	185	na
CH	710	110	850	430	690	610	240	na
CY	666	74	814	333	na	na	na	na
CZ	766	137	795	823	830	839	na	na
DE	600	43	377	511	418	485	240	815
DK	679	na	na	na	na	na	na	na
EE	550	na	740	250	740	400	350	na
EL	679	116	601	295	717	430	na	na
ES	771	na	742	701	804	718	na	na
FI	642	111	687	317	891	274	354	900
FR	668	130	na	na	340	710	na	na
HR	592	75	572	500	608	636	na	na
HU	740	74	450	740	450	740	na	na
IE	619	na	na	na	na	na	na	na
IS	770	na	na	na	833	807	na	na
IT	741	104	630	na	668	684	397	na
LT	542	na	na	na	na	na	na	na
LU	740	111	740	740	740	740	na	na
LV	600	na	700	300	na	na	na	na
MD	550	na	na	na	na	na	na	na
ME	660	na	na	na	na	na	na	na
MK	740	na	250	750	555	955	na	na
MT	550	na	na	na	480	350	na	na
NL	623	108	576	1108	633	1060	na	na
NO	697	na	710	470	480	506	331	na
PL	740	na	na	na	1000	1000	300	na
PT	724	106	588	665	479	520	185	na
RO	669	na	735	na	na	na	na	na
RS	680	na	na	na	850	880	na	na
SE	518	81	602	478	580	505	na	na
SI	683	111	591	580	582	583	300	na
SK	759	na	na	393	na	na	na	na
UA	550	na	na	na	na	na	na	na
UK	598	75	406	na	414	na	190	na
MEAN	662	99	626	579	645	652	279	858
MAX	771	137	850	1200	1000	1060	397	900
MIN	518	43	250	250	340	274	185	815

Table 5.28. Administered mean activities (MBq) for different NM examination in European countries (na: data not available).

	F-18	F-18	I-131	Tc-99m	I-123	Tc-99m	Tc-99m
Country	Tumor imaging (PET)	Tumor imaging (PET) + Diagnostic CT	Thyroid metastases (after ablation, uptake 0%)	Thyroid imaging (oral administration, no blocking)	Thyroid imaging (thyroid uptake 35%)	MUGA, cardiac blood pool, cardiac blood flow (equilibrium)	MUGA, cardiac blood pool, cardiac blood flow (equilibrium)(Tc-99m)
AT	400	400	370	110	20	na	740
BE	na	na	na	na	na	na	na
BG	337	370	129	93	na	na	3
CH	380	340	4	90	11	na	na
CY	na	na	110	148	na	na	592
CZ	na	na	na	na	na	na	800
DE	309	na	na	69	14	na	710
DK	332	na	108	157	184	na	690
EE	300	240	185	70	na	na	na
EL	370	na	170	na	na	na	702
ES	na	336	178	202	na	na	787
FI	360	363	243	141	na	502	746
FR	na	352	40	153	8	na	749
HR	na	na	185	117	2	384	802
HU	370	370	100	140	na	na	740
IE	na	na	126	101	185	na	na
IS	na	na	68	1358	2	na	925
IT	433	370	55	126	81	739	797
LT	na	na	145	104	na	na	na
LU	na	296	111	111	20	na	740
LV	na	na	na	na	na	na	na
MD	na	na	na	na	na	na	na
ME	na	na	na	150	na	na	610
MK	na	na	185	74	na	na	400
MT	na	na	185	180	na	na	550
NL	249	na	3	116	18	740	696
NO	na	331	na	135	5	na	804
PL	400	na	130	80	na	na	740
PT	327	348	97	179	5	na	706
RO	na	na	16	131	3	na	na
RS	na	370	115	120	2	na	860
SE	289	289	119	110	76	504	628
SI	370	370	148	97	15	740	923
SK	368	368	na	105	na	na	na
UA	na	na	75	70	na	na	na
UK	370	na	169	75	18	350	665
MEAN	351	345	127	158	37	566	696
MAX	433	400	370	1358	185	740	925
MIN	249	240	3	69	2	350	3

Table 5.29. Administered mean activities (MBq) for different NM examination in European countries. (na: data not available).

	I-123	I-123	Tc-99m	In-111	Tc-99m	Tc-99m	Tc-99m
Country	Dopamine transporter imaging (parkinsonism)(β-CIT)	Dopamine transporter imaging (parkinsonism)(Ioflupane)	Lung perfusion	Neuroendocrine tumors/somatostatin receptors imaging	Renal imaging (DMSA)	Renal imaging (MAG 3)	Renal imaging (DTPA)
AT	185	185	150	200	110	110	185
BE	na	na	na	na	na	na	na
BG	na	185	150	na	117	185	227
CH	na	na	190	170	80	110	na
CY	na	na	148	148	111	111	185
CZ	na	na	219	155	131	na	na
DE	na	180	150	na	85	100	85
DK	na	197	171	216	46	66	217
EE	na	185	100	na	75	30	150
EL	na	na	175	155	157	na	368
ES	na	186	208	156	136	158	220
FI	176	172	140	134	103	111	299
FR	na	156	202	162	112	153	135
HR	na	122	149	240	105	120	142
HU	na	185	250	222	140	140	140
IE	na	175	118	173	na	104	221
IS	167	na	281	222	96	188	na
IT	na	na	176	149	130	133	187
LT	na	na	na	na	na	147	85
LU	na	185	288	185	123	150	111
LV	na	146	100	na	na	na	150
MD	na	na	90	na	160	na	110
ME	na	na	90	na	930	na	170
MK	na	na	185	na	185	111	265
MT	na	na	100	185	100	na	200
NL	184	184	75	na	97	67	na
NO	185	184	219	138	61	98	77
PL	na	na	na	na	185	na	200
PT	na	183	170	166	119	161	133
RO	na	na	127	na	na	100	241
RS	na	130	115	740	130	115	220
SE	171	171	112	161	57	87	113
SI	na	121	143	429	91	116	185
SK	na	185	110	170	103	na	120
UA	na	na	200	na	150	na	na
UK	na	180	89	151	77	90	210
MEAN	178	171	157	210	139	118	178
MAX	185	197	288	740	930	188	368
MIN	167	121	75	134	46	30	77

Table 5.30. Administered mean activities (MBq) for different NM examination in European countries. (na: data not available).

	Tc-99m	Tc-99m	Tc-99m	Ga-67	Tc-99m	Tc-99m
Country	Parathyroid imaging (MIBI)	Cerebral blood flow (HMPAO, Ceretec)	Cerebral blood flow (ECD)	Infection/ inflammation imaging (Gallium citrate)	Infection/ inflammation imaging (Tc-labbelled white blood cells)	Infection/ inflammation imaging (Monoclonal antibody)
AT	740	740	na	185	740	na
BE	na	na	na	na	na	na
BG	435	666	na	na	na	na
CH	620	na	710	na	na	na
CY	666	na	na	111	na	592
CZ	629	698	na	na	na	714
DE	540	551	560	na	700	720
DK	723	843	na	na	362	na
EE	550	700	450	na	na	740
EL	na	na	na	173	na	na
ES	697	734	na	230	372	na
FI	747	792	557	na	169	914
FR	660	760	na	128	882	na
HR	536	740	850	72	740	555
HU	740	740	na	220	200	na
IE	na	665	na	na	na	na
IS	na	1243	na	218	244	na
IT	611	209	266	72	562	na
LT	347	651	555	na	na	na
LU	466	na	740	111	555	740
LV	450	na	na	na	na	na
MD	na	na	na	na	na	na
ME	680	na	na	na	na	na
MK	740	740	na	na	na	na
MT	180	550	na	250	na	na
NL	542	740	na	na	485	na
NO	753	749	876	113	264	na
PL	750	740	na	400	na	750
PT	732	707	741	256	281	1051
RO	400	518	na	na	na	na
RS	630	925	na	na	740	740
SE	586	825	763	na	198	665
SI	624	700	657	177	483	553
SK	600	600	na	150	400	na
UA	na	na	na	na	277	na
UK	576	483	500	136	200	691
MEAN	598	704	633	177	443	725
MAX	753	1243	876	400	882	1051
MIN	180	209	266	72	169	553

Table 5.31. Comparison of mean activities per examination between DDM1 and DDM2, for 8 DDM1 countries.

Country	Bone scan (Tc99m)		Thyroid (Tc99m)		Lung (MAA)		Kidney (MAG3)	
	DDM1	DDM2	DDM1	DDM2	DDM1	DDM2	DDM1	DDM2
BE	720	na	130	na	190	na	160	na
CH	720	710	96	90	190	190	95	110
DE	616	600	51	69	142	150	81	100
LU	na	740	na	111	na	288	na	150
NL	550	623	100	116	100	75	75	67
NO	689	697	141	135	194	219	86	98
SE	505	518	120	110	120	112	80	87
UK	598	598	75	75	89	89	89	90

Table 5.32. Conversion factors to calculate mean effective dose from the mean activity.

Procedure	Isotope	Conversion factor mSv/MBq	Reference
Bone imaging	Tc-99m	0,0057	ICRP 53/80
Myocardial perfusion (Chloride)	Tl-201	0,14	ICRP 106
Myocardial perfusion, rest (Tetrofosmin)	Tc-99m	0,0069	ICRP 106
(Tetrofosmin)	Tc-99m	0,0069	ICRP 106
Myocardial perfusion, rest (MIBI)	Tc-99m	0,009	ICRP 53/80
Myocardial perfusion, exercise (MIBI)	Tc-99m	0,0079	ICRP 53/80
Myocardial perfusion (PET) (FDG)	F-18	0,019	ICRP 106
Myocardial perfusion (PET) (H2O)	O-15	0,0011	ICRP 106
Tumor imaging (PET)	F-18	0,019	ICRP 106
Tumor imaging (PET) + Diagnostic CT	F-18	0,019	ICRP 106
Thyroid metastases (after ablation,	I-131	0,061	ICRP 53/80
Thyroid imaging (oral administration, no blocking)	Tc-99m	0,013	ICRP 53/80
Thyroid imaging (thyroid uptake 35%)	I-123	0,22	ICRP 106
flow (equilibrium)	Tc-99m	0,0049	ICRP 53/80
MUGA, cardiac blood pool, cardiac blood	Tc-99m	0,007	ICRP 53/80
Dopamine transporter imaging (parkinsonism)(β-CIT)	I-123	0,05	ICRP 106
Dopamine transporter imaging (parkinsonism)(Ioflupane)	I-123	0,024	Manufacturer's specification
Lung perfusion	Tc-99m	0,011	ICRP 53/80
Neuroendocrine tumors/somatostatin receptors imaging	In-111	0,054	ICRP 106
Renal imaging (DMSA)	Tc-99m	0,0088	ICRP 53/80
Renal imaging (MAG 3)	Tc-99m	0,007	ICRP 53/80
Renal imaging (DTPA)	Tc-99m	0,0049	ICRP 53/80
Parathyroid imaging (MIBI)	Tc-99m	0,009	ICRP 53/80
Cerebral blood flow (HMPAO, Ceretec)	Tc-99m	0,0093	ICRP 53/80
Cerebral blood flow (ECD)	Tc-99m	0,0077	ICRP 106
Infection/inflammation imaging (Gallium citrate)	Ga-67	0,1	ICRP 53/80
Infection/inflammation imaging (Tc-labbelled white blood cells)	Tc-99m	0,011	ICRP 53/80
Infection/inflammation imaging (Monoclonal antibody)	Tc-99m	0,0098	ICRP 106

Table 5.33. Average typical effective dose per diagnostic NM procedure (mSv) in the European countries of this study, compared with similar data from UNSCEAR Health Care Level 1 (HCL1; UNSCEAR 2008) countries.

NM procedure	Average effective dose (mSv) of European countries (this survey)	Average effective dose (mSv) of UNSCEAR HCL I countries (1997-2007)
Bone scan (Tc-99m)	3,8 (max/min:1,5)	4,74
Myocardial perfusion (Tl-201 chloride)	13,8 (max/min:3,2)	40,7
Myocardial perfusion, rest (Tc-99m Tetrofosmin)	4,1 (max/min:3,4)	
Myocardial perfusion, exercise (Tc-99m Tetrofosmin)	3,8 (max/min:4,8)	
Myocardial perfusion, rest (Tc-99m MIBI)	5,5 (max/min:3,5)	
Myocardial perfusion, exercise (Tc-99m MIBI)	4,8 (max/min:3,9)	
Heart Total (Tc-99m)		7,97
PET Myocardial perfusion (F-18 FDG)	5,3 (max/min:2,1)	
PET Myocardial perfusion (O-15 H2O)	0,8 (max/min:1,1)	
PET Tumor imaging (F-18 FDG)	6,7 (max/min:1,7)	
PET		6,42
PET & diagnostic CT	6,5 (max/min:1,7)	7,88
Lung perfusion (Tc-99m)	1,8 (max/min:4,9)	3,52
Thyroid scan (Tc-99m)	2,0 (max/min:19,7)	3,75
Thyroid scan (I-131)	7,8 (max/min:123)	
Thyroid scan (I-123)	8,2 (max/min:92,5)	
Thyroid scan (I-131/ I-123)		30,5
Renal scan (Tc-99m DMSA)	1,2 (max/min:20,2)	
Renal scan (Tc-99m MAG3)	0,8 (max/min:6,3)	
Renal scan (Tc-99m DTPA)	0,9 (max/min:4,8)	
Renal Total		1,89
CBF (Tc-99m HMPAO, Ceretec)	6,5 (max/min:5,9)	
CBF (Tc-99m ECD)	4,9 (max/min:3.3)	
Brain		6,09

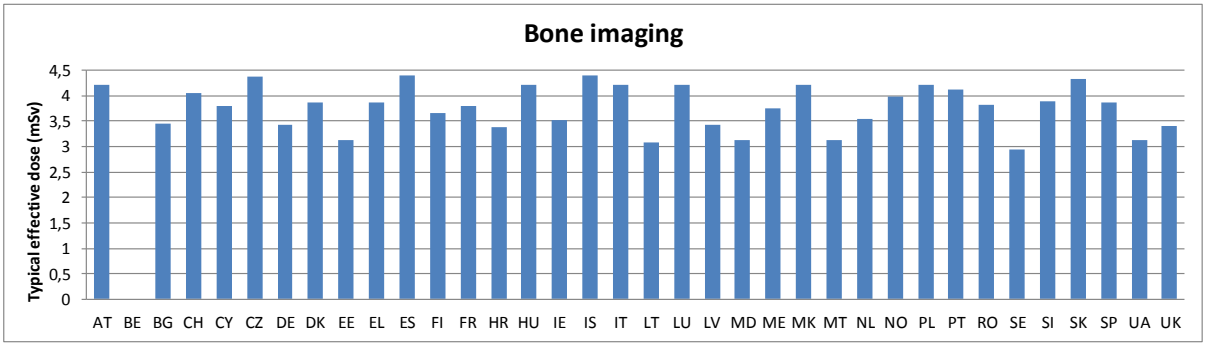


Figure 5.20. Typical effective doses (mSv) in various countries for bone imaging with Tc-99m.

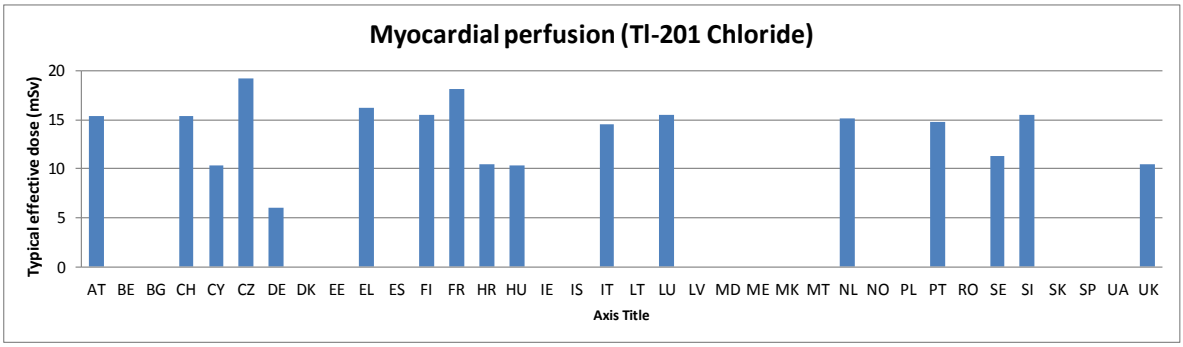


Figure 5.21. Typical effective doses (mSv) in various countries for myocardial perfusion (Tl-201 Chloride).

5.2.2.2 Collective effective doses

The total collective effective dose of diagnostic NM procedures in European countries is

Group 1: *30700* man Sv, resulting in a mean effective dose of *0,060 mSv per caput*.

Group 2: *31100* man Sv, resulting in a mean effective dose of *0,054 mSv per caput*.

The variation in the total collective effective dose per 1000 of population between the countries, for the groups of diagnostic NM examinations, is presented in Figure 5.22.

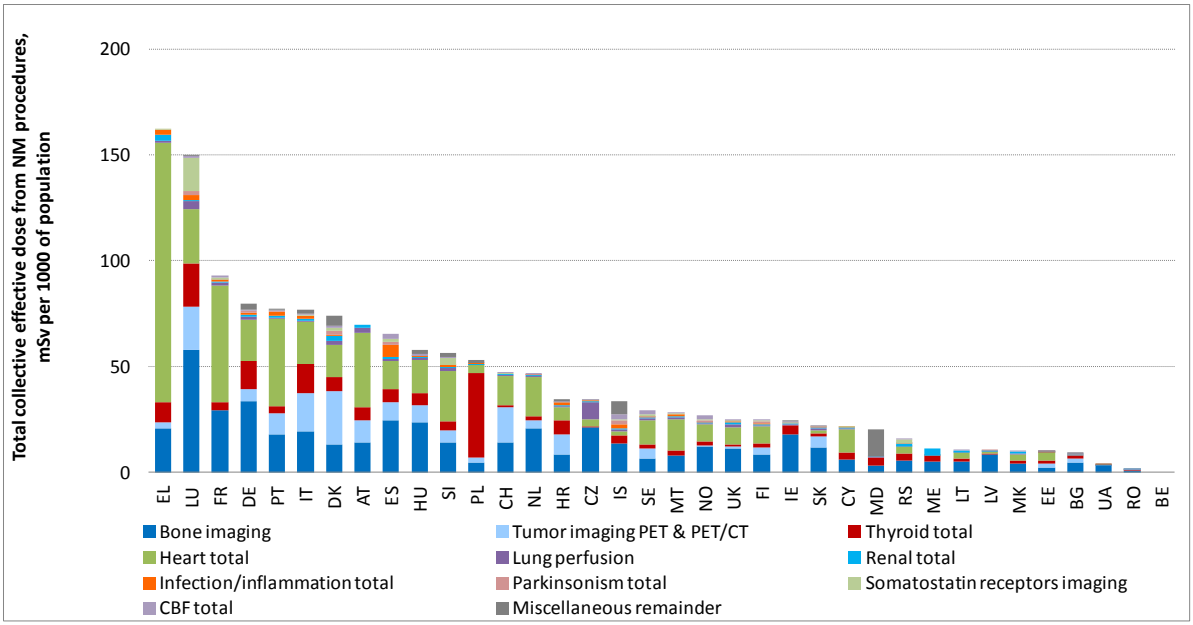


Figure 5.22. Total collective effective dose per 1000 of population, for the groups of NM examinations (one or more examinations of the same organ, the same target or closely similar objectives grouped together).

The average annual effective dose per head of population (per caput) was calculated for each country from the frequency, the size of the population and the effective dose per examination. The total average annual effective dose per caput ranges from 0,002 mSv in RO to 0,162 mSv in EL. Although large national differences in the average population dose from NM procedures have been observed, the 7 procedures (Top 7) shown in Table 5.34 have been identified as being among the highest contributors to the collective effective dose in all DDM2 countries.

The relative contribution of NM procedures (e.g. bone imaging) to the total average annual effective dose per caput (mSv) was calculated for each country and then min, max and median were estimated for the NM procedures. They are presented in the right column of Table 5.34 The newly proposed NM Top 7 has been based on those values. That is to say (a) In the 3rd column appear only the NM procedures for which median contribution is higher than 1,5 % and (b) in an effort to keep uncertainties as low as possible, it seems better to avoid grouping together heart or thyroid procedures performed with different radioisotopes (N.b. lung perfusion could also be excluded as the median is only 1,6 %, but the max 24,9 % is quite similar to the tumor imaging PET max value 24,6 %).

In Table 5.35average annual effective dose per caput per NM procedure (mSv) of the European countries of this study are compared with similar data from DDM1 countries. In Table 5.36 the annual effective dose per caput (mSv), for eight DDM1 countries and for a few examination groups are compared with the earlier data from DDM1 study. There seems to be not much difference between the DDM1 countries and all countries in the present (DDM2) survey of data, while on the average the annual per caput effective dose in DDM1 countries seem to be reduced from the time of the DDM1 survey.

Table 5.34. 7 procedures (Top 7) identified as being amongst the highest contributors to the total collective effective dose of NM procedures in all DDM2 countries.

Top 7 group		NM procedure	Radiopharmaceutical	Median (min-max) contribution to total per caput effective dose %
1	Bone	Bone imaging	Tc-99m phosphates/phosphonates	38,7 (6,4-85,6)
2	Heart (Tl-201)	Myocardial perfusion	Tl-201 Chloride	3,8 (0,3-55,1)
3	Heart (Tc-99m)	Myocardial perfusion, exercise & rest	Tc-99m MIBI	14,2 (1,6-50,2)
		Myocardial perfusion, exercise & rest	Tc-99m Tetrofosmin	10,2 (2,0-37,8)
4	Tumor imaging PET & PET/CT	Tumor imaging PET	F-18 FDG	8,1 (0,2-24,6)
		Tumor imaging PET & diagnostic CT	F-18 FDG	8,1 (0,4-33,9)
5	Thyroid (Tc-99m)	Thyroid imaging (no blocking)	Tc-99m pertechnetate	3,9 (0,1-51,5)
6	Thyroid (I-131)	Thyroid metastases(after ablation, uptake 0 %)	I-131	2,7 (0,1-75,2)
7	Lung	Lung perfusion	Tc-99m	1,6 (0,2-24,9)
Total median				91,3

Table 5.35. Average annual effective dose per caput per NM procedure (mSv) of this study, for all European countries compared with similar data for 8 DDM1 countries.

NM procedure	Average annual effective dose per caput (mSv) of all European contries	Range	Average annual effective dose per caput (mSv) of 8 DDM1 countries	Range
Bone imaging	0,014	0,001-0,06	0,02	0,008-0,1
Myocardial perfusion (Chloride)	0,009	0,00001-0,09	0,01	0,008-0,03
Myocardial perfusion, rest (Tetrofosmin)	0,003	0,00007-0,01		
Myocardial perfusion, exercise (Tetrofosmin)	0,003	0,00012-0,02		
Myocardial perfusion, rest (MIBI)	0,004	0,00005-0,02		
Myocardial perfusion, exercise (MIBI)	0,004	0,00008-0,01		
Lung perfusion	0,001	0,000001-0,008	0,001	0,001-0,006
Thyroid metastases (after ablation, uptake 0%)	0,002	0,000001-0,04	0,004	0,0006-0,02
Thyroid imaging (oral administration, no blocking)	0,002	0,00002-0,01		
Thyroid imaging (thyroid uptake 35%)	0,001	0,000001-0,01		
Renal imaging (DMSA)	0,0003	0,0000005-0,003	0,0004	0,0004-0,02
Renal imaging (MAG 3)	0,0003	0,0000004-0,001		
Renal imaging (DTPA)	0,0003	0,0000005-0,002		
Total of the above NM procedures	0,044	0,0000004-0,09	0,043	0,0006-0,1

Table 5.36. Comparison of per caput effective doses between DDM1 and DDM2 studies, for 8 DDM1 countries and for a few examination groups available in the DDM1 Report (EC, 2008).

Country	Bone scan (Tc99m)		Heart (total)		Thyroid (Tc99m)		Lung (MAA)		Kidney (MAG3)		Total of 5 groups	
	DDM1	DDM2	DDM1	DDM2	DDM1	DDM2	DDM1	DDM2	DDM1	DDM2	DDM1	DDM2
BE	0,1	na	0,09	na	0,02	na	0,006	na	0,002	na	0,218	na
CH	0,02	0,01	0,03	0,01	0,004	0,0005	0,001	0,0007	0,0005	0,0002	0,056	0,029
DE	0,04	0,03	0,04	0,02	0,01	0,01	0,003	0,001	0,001	0,0009	0,094	0,068
LU	0,05	0,06	0,08	0,03	0,01	0,01	0,004	0,004	0,0005	0,0003	0,145	0,098
NL	0,02	0,02	0,04	0,02	0,004	0,00004	0,002	0,0003	0,0004	0,0003	0,066	0,040
NO	0,01	0,01	0,02	0,01	0,002	0,001	0,001	0,0005	0,0006	0,0003	0,034	0,022
SE	0,008	0,007	0,01	0,01	0,004	0,001	0,002	0,0007	0,0006	0,0003	0,025	0,020
UK	0,01	0,01	0,009	0,008	0,0006	0,0002	0,002	0,002	0,0008	0,0003	0,022	0,021

5.3 Collective effective dose for all medical imaging

The total collective effective dose of diagnostic x-ray and NM procedures in European countries is:

Group 1: 578200 man Sv, resulting in a mean effective dose of 1,12 mSv per caput.

Group 2: 636000 man Sv, resulting in a mean effective dose of 1,10 mSv per caput.

The contribution of NM examinations to the total collective effective dose of diagnostic x-ray and NM procedures in European countries is:

Group 1: 5,3 %

Group 2: 4,9 %.

The total European population dose from X-ray and NM procedures is summarized and compared in Table 5.37. The per caput mean doses from X-ray and NM procedures is compared in Table 5.38 and Fig. 5.23, where also the contribution of the NM examinations to the total per caput effective dose from all medical imaging can be seen. The contribution of the main groups of x-ray procedures and NM procedures to the total population dose is illustrated in Figure 5.23 and Figure 5.24.

The contribution of the NM examinations to the total per caput effective dose from all medical imaging is relatively small, on the average 5 %, while there are high variations in the contribution between the countries, from 0,4 to 14,5 %.

The total collective effective dose from x-ray procedures is about half of the recent value of collective effective dose estimated in Australia (Wallace 2012) and about one third of the corresponding value in the USA (NCRP 2009). A relatively low value of population dose can be a good sign for a successful implementation of the justification and optimization principles in radiation protection, but it can also be related to the lack of imaging resources. A relatively high value, on the other hand, should imply considerations on whether the justification and optimization are properly implemented.

Table 5.37. Comparison of European population dose for x-ray and NM procedures.

(a)

Group 1 countries: Member States + CH, NO, IS	X-ray procedures	NM procedures	Total	x-ray procedures as a % of total	NM procedures as a % of total
Total collective effective dose, manSv	547500	30700	578200	94,7	5,3
Effective dose per caput, mSv	1,06	0,060	1,12		

(b)

Group 2 countries: All European countries (36)	X-ray procedures	NM procedures	Total	x-ray procedures as a % of total	NM procedures as a % of total
Total collective effective dose, manSv	604900	31100	636000	95,1	4,9
Effective dose per caput, mSv	1,05	0,054	1,10		

Table 5.38. Comparison of European mean per caput effective dose for x-ray and NM procedures.

Country	Overall per caput E, x-rays, mSv	Overall per caput E, NM, mSv	Overall per caput E, x-rays+NM, mSv	Contribution of NM to the overall x-rays+NM, %
AT	0,850	0,070	0,919	7,6
BE	1,960	na	na	na
BG	0,408	0,009	0,417	2,2
CH	1,181	0,047	1,228	3,8
CY	0,998	0,022	1,020	2,1
CZ	0,986	0,034	1,020	3,3
DE	1,673	0,080	1,753	4,6
DK	0,891	0,074	0,965	7,6
EE	1,428	0,010	1,438	0,7
EL	0,952	0,162	1,114	14,5
ES	1,081	0,065	1,146	5,7
FI	0,455	0,025	0,479	5,2
FR	1,249	0,093	1,342	6,9
HR	0,679	0,034	0,714	4,8
HU	1,775	0,058	1,833	3,2
IE	0,833	0,024	0,858	2,8
IS	1,695	0,034	1,729	1,9
IT	1,162	0,077	1,239	6,2
LT	0,922	0,010	0,933	1,1
LU	1,787	0,149	1,937	7,7
LV	0,893	0,010	0,904	1,1
MD	0,252	0,020	0,272	7,4
ME	0,897	0,012	0,908	1,3
MK	0,697	0,010	0,707	1,4
MT	0,678	0,028	0,706	4,0
NL	0,625	0,047	0,672	7,0
NO	1,253	0,027	1,280	2,1
PL	0,931	0,053	0,984	5,4
PT	1,174	0,077	1,251	6,2
RO	0,341	0,002	0,343	0,5
RS	0,775	0,016	0,790	2,0
SE	0,774	0,029	0,804	3,6
SI	0,634	0,057	0,691	8,2
SK	0,763	0,022	0,785	2,8
UA	1,060	0,004	1,065	0,4
UK	0,394	0,025	0,419	5,9

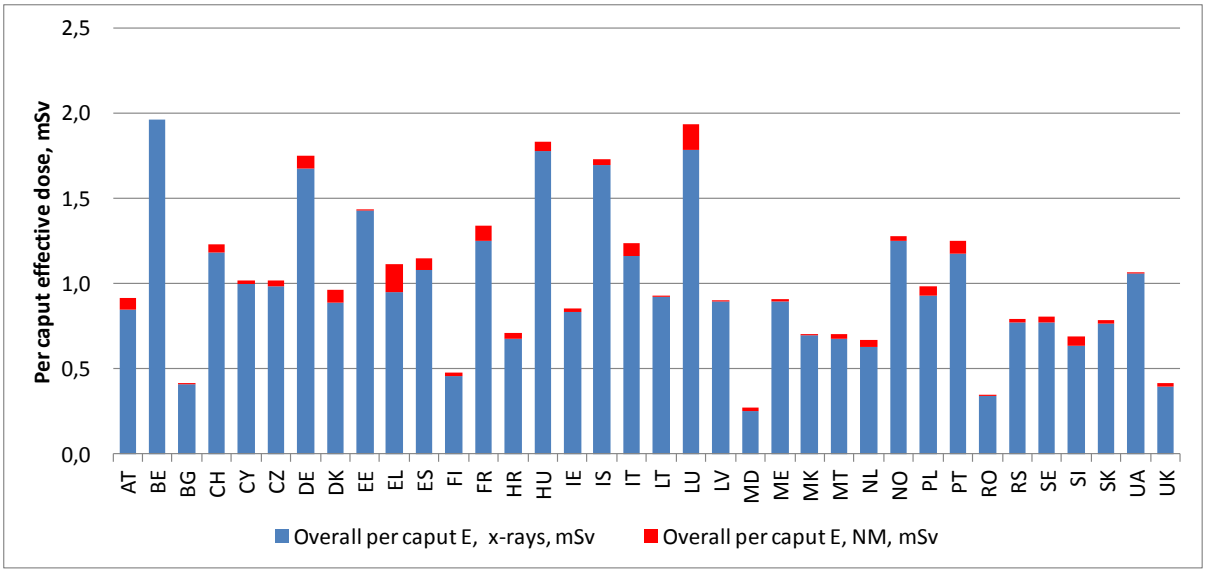


Figure 5.23. Variation of per caput effective dose for European countries.

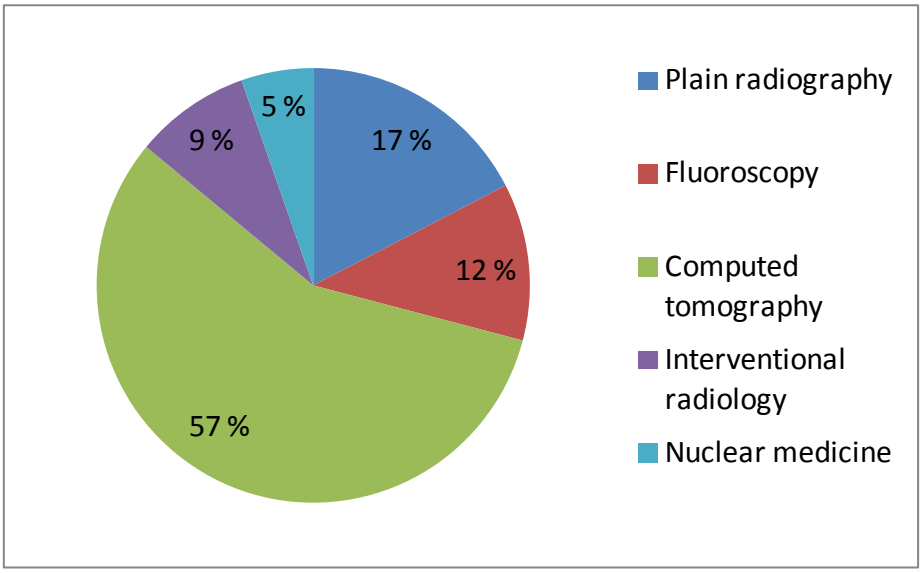


Figure 5.24. Contribution of the main groups of x-ray procedures and NM procedures to the total collective effective dose for Group 1 countries (EU Member States + CH, IS, NO).

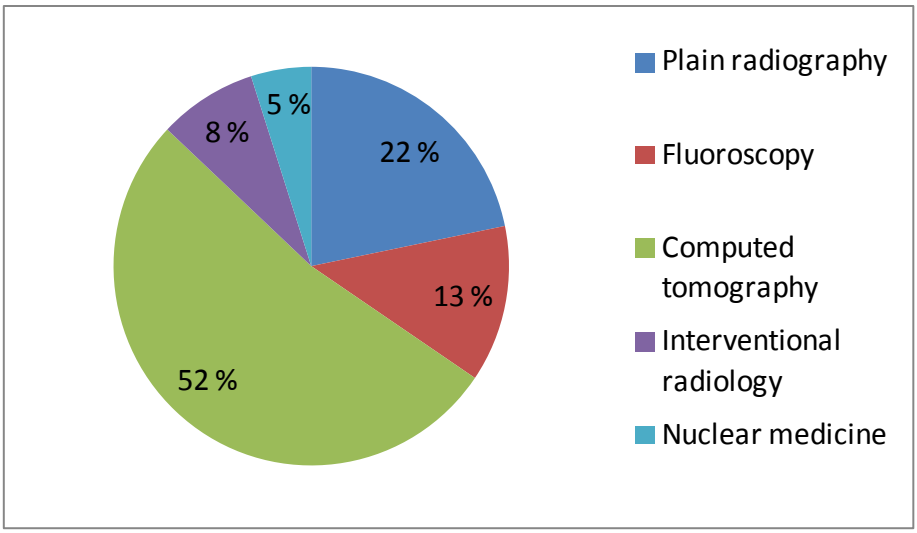


Figure 5.25. Contribution of the main groups of x-ray procedures and NM procedures to the total collective effective dose for Group 2 countries (All 36 countries).

6 ACCURACY OF EUROPEAN POPULATION DOSE ESTIMATION

6.1 X-ray procedures

6.1.1 Uncertainties in frequency estimations

Depending on the method of deriving frequency data there will be different algorithms used to estimate the total national frequencies of x-ray examinations, which will be prone to many potential sources of systematic and random (or statistical) error. These sources of error can lead to significant uncertainties in the frequency estimates and it is desirable, although often quite difficult, to identify and evaluate the major sources of uncertainty. The estimation of these uncertainties has been discussed in detail in RP 154, where important sources of uncertainty in the frequency estimates are identified as follows.

- Problems in relating the information stored in terms of examination codes into actual numbers of examinations (e.g. inadequate definition of an “examination”, problems of double-counting, particularly with examinations of double-sided organs).
- Insufficiently differentiated codes (“accumulative codes”).
- Bias in the sample and invalid assumptions made when scaling up sample data to derive frequencies for the whole country (i.e. problem of using data from an unrepresentative sample of hospitals or from incomplete central statistics).
- Lack of frequency data from some important providers of radiology services (e.g. interventional procedures performed outside x-ray departments or fluoroscopy performed in operating theatres and therefore not recorded by the RIS, or dentists in private practice not covered by central statistics).
- Mistakes in the data recorded or collected.

The range of uncertainties for the frequency data estimated by the member states, derived from the results of the project questionnaire, is between 0,03 % and 352 %. The high range suggests that the estimation of uncertainties is not very consistent. Most typically, the uncertainties range from 1 % to 25 %.

6.1.2 Uncertainties in estimating typical effective dose

Estimates of the typical effective dose for each type of examination in a country are usually based on measurements of practical dose quantities at a limited number of hospitals or clinics and conversion of these measurements to effective doses, for example using conversion factors recommended in RP 154. According to RP 154, the important sources of uncertainty in these estimates include:

- Uncertainties in the basic dose measurements
- Uncertainties due to variations in patient doses between hospitals and the limited sample size
- Uncertainties in the coefficients used to convert the measured dose quantities into typical effective doses

As discussed in detail in RP 154, the uncertainties in the basic dose measurements, ideally 7 % at a 95 % confidence level but in practice more likely about 10-20 %, are small compared to the variation in dose seen in a sample of patients undergoing the same x-ray examination in the same hospital and compared to the variation in mean doses for the same x-ray examination between all hospitals in a national survey. Consequently, the uncertainties in the individual basic dose measurements will not have a significant impact on the accuracy of the average dose estimates associated with each type of x-ray examination, and these uncertainties are essentially included in the uncertainties due to the variation in measured patient doses between hospitals.

Based on experiences from a UK practice, a method has been developed to roughly ascribe uncertainties in the estimated mean value due to the variation in patient doses between x-ray rooms and the limited number of rooms in any survey (Hart and Wall 2002). Random uncertainties from ±10 % to ± 50 % (at 95 % confidence level) have been estimated and tabulated as a function of sample size (patient doses from 5-19 to more than 100 radiology rooms; see RP 154). However, if no dose measurements are performed in the country for a particular examination and the mean effective dose is taken to be the same as that observed in another country, the uncertainties may be much larger: a general 95 % confidence limit of about a factor of about 2 is suggested (+100 %, -50 %) unless there are good reasons to believe that radiology practice in the foreign country is similar to that in the country in question and the foreign data are based on measurements in more than 20 radiology rooms.

Uncertainties in the conversion coefficients are difficult to quantify and depend on how closely the exposure conditions and the phantom for which the conversion coefficients were calculated match the average exposure conditions and the average patient for the x-ray examination in question. In RP 154, an estimate of ±10 % is given for the most common x-ray examinations and ±25 % for other less common examinations where the match might not be very good.

The uncertainties associated with limitations in the size of the patient dose survey and with the conversions coefficients (CC) can be combined to estimate the overall uncertainty in the mean effective dose estimate for a particular examination using the standard method of propagation of uncertainties (i.e. by totaling up the uncertainties in quadrature). Overall uncertainties estimated in this way for a number of different sample sizes and for good and poor matching of exposure conditions in the conversion coefficient calculations are tabulated in RP 154 and range from ±14 % (>100 rooms, good CC match) to +100%, -50 % (foreign data only).

The estimation of the uncertainty of the mean (or typical) effective dose has been further elaborated in the most recent population dose assessments in the UK (Hart et al. 2010) by introducing a reliability scale. This scale gives an approximate indication of the levels of uncertainty involved in the estimates of the typical effective dose for each examination. The scale comprises five levels of reliability (A to E), defined according to the quantity and quality of the data available for estimating typical effective doses. The reliability scale from Hart et al. (2010) has been reproduced here in Table 6.1, but modified for a more generic use.

The approximate ranges of uncertainty in the last column of Table 6.1 are based on the dose distributions observed in the UK National Patient Dose Database. Some allowance for systematic uncertainty associated with the conversion coefficients has been made by allocating a total uncertainty of about twice the average random uncertainty on the dose measurements, for reliability ratings A, B and C. The uncertainties for reliability levels D and E are likely to be higher, so for these levels the (somewhat arbitrary) uncertainty ranges of a factor of two or three, respectively, have been introduced. To justify a more generic use of this table, the uncertainties in last column should be based on the country's own dose distributions unless these can be assumed to be reasonably similar to that of the UK. In case of small countries, instead of the number (e.g. > 100), the criteria could better be based on a certain percentage of the hospitals (e.g. > 10 %).

In the UK, 69 % of the estimated total collective dose is due to examinations with reliability ratings A and B, thus a substantial part of the collective dose is known to a reasonable accuracy. In general, for a good accuracy of the overall collective effective dose, it would be important to aim at reliability ratings A, B and C, with decreasing order of importance, for the types of examination which have the highest contribution to it.

Table 6.1. Reliability scale for the typical effective dose estimates (modified from Hart et al. 2010)

Reliability rating	Criteria	Approximate uncertainty
A	>100 hospitals of the country providing dose data Conversion factors available directly from Monte Carlo calculations (e.g using PCXMC)	±10 %
B	>20 hospitals of the country providing dose data Conversion factors available directly from Monte Carlo calculations (e.g using PCXMC)	±25 %
C	1-19 hospitals of the country Conversion factors can be confidently derived from Monte Carlo calculations (e.g using PCXMC)	±50 %
D	1-19 hospitals of the country OR foreign data <20 patient measurements Conversion factors "guesstimated"	Factor of 2
E	No dose measurements; estimated from other examinations	Factor of 3

The range of uncertainties for the mean effective dose data estimated by the member states, usually based on the above principles of RP 154 and derived from the results of the project questionnaire, are shown in Figure 6.1. The range is from 10 to 100 %, while the average is about 20-40 %. The uncertainties for fluoroscopy procedures seem on average to be a little higher than for the other procedures. These ranges suggest that in many cases the effective dose is not estimated with high reliability but correspond to the reliability ratings from B to D.

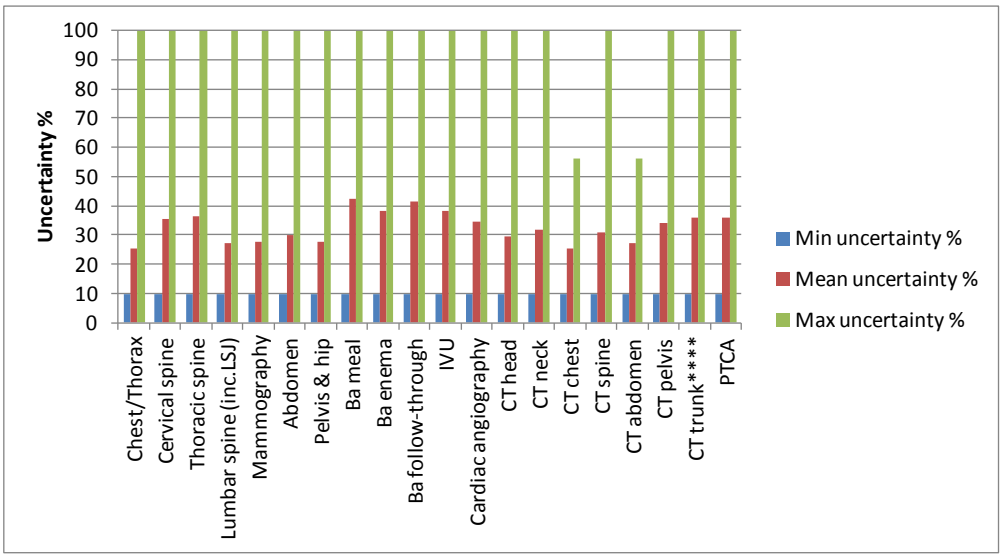


Figure 6.1. Range of uncertainties estimated for the mean effective dose.

6.1.3 Uncertainties of population dose estimations

Since the collective dose for each examination is the product of the frequency and the effective dose, the uncertainty on the collective dose for each examination can be calculated by combining in squares the *relative* (percentage) uncertainties for the frequency and for the effective dose. From the range of uncertainties for frequency data and effective dose data, as shown in Sections 6.1 and 6.2.1, it can be seen that the uncertainty of the collective dose is often dominated by the uncertainty of the typical effective dose, rather than uncertainty of the frequency.

Since the total, or overall collective effective dose (population dose), from all x-ray procedures carried out in the country, is the sum of the collective doses for each examination, the uncertainty of the overall collective effective dose can be calculated by combining in squares the *absolute* uncertainties for the collective doses for each examination (Hart et al. 2010, Taylor and Kuyatt 1994). The results of such calculations, for two European countries providing real data for all x-ray examinations, are ±12 % in UK (Hart et al 2010) and ± 9 % in Finland.

For the countries where the population dose estimate is based only on the Top 20 method, the uncertainty of the total collective effective dose from all Top 20 examinations can be estimated using the same principle as above for the overall collective effective dose from all x-ray examinations. In this estimation, due considerations should be made for:

- the effect of missing data on frequencies, e.g. by estimating the missing frequencies based on the comparison of the ratio of this unknown frequency to total Top 20 frequency with the corresponding average ratio for all Top 20 countries, and estimating the uncertainty of this estimation

- the effect of different interpretations of the examinations in a TOP 20 group and the accuracy/comprehensiveness of effective dose assignment for this group (how many different types of examinations have been considered to evaluate the mean dose for this group).

The uncertainties of the total collective effective dose from all Top 20 examinations, estimated in the above way, are typically 5-20 % but range from about 5 to 80 %; the mean value is 17 %.

However, the estimation of the uncertainty of the total collective effective dose from all Top 20 examinations is not of high value on its own, because the Top 20 method can only give a rough underestimate, between 58 and 96 %, or 78 % on the average (Section 6.1.2.2), of the overall collective effective dose (population dose), from all x-ray procedures carried out in the country. To obtain the real overall collective effective dose, a correction factor is needed as applied in the calculation of European population dose in this report. This correction factor has a standard uncertainty of 12-18 % (deviations 20-30 % from the mean value), based on the comparison of the data from the 6 countries providing both TOP 20 and overall data. Therefore, using the above mean value of 17 % for the uncertainty of the TOP 20 population dose, the uncertainty of the population dose in the TOP 20 countries becomes around 21-25%.

Since the overall European collective effective dose (population dose) is the sum of the overall collective doses for each country, the uncertainty of the overall European collective effective dose can be calculated by combining in squares the *absolute* uncertainties for the collective doses for each country (Taylor and Kuyatt 1994). Assuming 12 % for the estimated relative uncertainties of the population doses for the 6 countries with overall population dose estimations (corresponding to the value evaluated in the UK), and 25 % for the population dose uncertainty in all TOP 20 countries, the uncertainty of the overall European collective effective dose is about 6 %.

The above result is valid for the group of European countries providing either overall data or TOP 20 data; this includes all EU Member States (28 countries), the EFTA countries (CH, NO, IS) and 5 other countries (, MK, MD, ME, RS and UA).

6.2 Nuclear Medicine procedures

For nuclear medicine procedures, the estimation of the uncertainties can be based on similar considerations as above for x-ray procedures. As for frequencies, rather similar sources of uncertainty can be identified; in general, however, the frequencies seem to be better known than for x-ray procedures, probably because of much smaller number of health care units providing NM procedures. As for typical effective dose, the typical mean activities can be estimated from surveys with a reasonable accuracy, while the accuracy of conversion factors from activity to effective dose is very difficult to estimate. Finally, for the estimation of the uncertainty of population dose determination, exactly the same principles as for x-ray procedures can be applied, because the collective dose is the product of the frequency and the effective dose.

The DDM2 project questionnaires did not provide data on the uncertainties of population dose estimation for NM procedures. Therefore, a rough estimate of the uncertainty of European population dose for NM procedures has been performed on the following assumptions for all countries:

- mean uncertainty of frequencies: 5 %
- mean uncertainty of typical mean activities: 10 %
- mean uncertainty of conversion factors: 20 %

Using these assumptions and following the same principles as for x-ray procedures, the uncertainty of the overall European collective effective dose for NM procedures will be 5,6 %, i.e. about the same as for x-ray procedures.

7 ESTIMATIONS OF AGE AND SEX DISTRIBUTIONS

7.1 Age and sex distributions for X-rays examinations

The European Guidance on Estimating Population Dose from Medical X-ray Procedures (RP154, Annex 3; EC 2008) established typical European age/sex distributions for patients undergoing the Top 20 X-ray examinations.

EUROSTAT (http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home) data on age distribution from 2005 for five DDM1 countries (DK, LU, NL, CH and UK) and from 2010 for four DDM2 countries (HR, DK, FR and SK), that all provided information on age and sex distribution for X-rays examinations have been compared in Figure 7.1 and Figure 7.2. The typical age/sex distributions data used in this report are based on the average data from the four countries (HR, DK, FR and SK), weighted according to the sample size in each country as shown in Table 7.1.

Table 7.1. Sample size for age/sex data in four DDM2 countries

	Number of patients in sample (male & female)			
Top 20 Exam	Croatia	Denmark	France	Slovakia
1. Chest	186964	679597	11266836	791011
2. Cervical spine	6158	31324	1162529	111992
3. Thoracic spine	2961	43541	444842	15984
4. Lumbar spine	6437	92165	2847449	192001
5. Mammography	1325	409418	5076059	182288
6. Abdomen	18401	22918	2370254	73169
7. Pelvis and hips	19958	226713	5682951	93719
8. Barium meal	2526	5100	109919	4165
9. Barium enema	206	2664	0	2699
10. Barium follow	1949	4030	28388	4409
11. IVU	6869	632	129076	9525
12. Cardiac angiography	21023	962	0	12250
13. CT head	35535	134017	1926899	107410
14. CT neck	1331	30192	152231	6206
15. CT chest	7789	149075	1620603	27882
16. CT spine	2960	5485	852152	3356
17. CT abdomen	10530	178619	2177317	41755
18. CT pelvis	1280	36706	0	17126
19. CT entire trunk	10949	3215	63756	9792
20. PTCA	9420	9939	0	4750
Total	**354571**	**2066312**	**35911261**	**1711489**

The comparison shows a roughly similar distribution except a peak at ages of 15-29 years for the population in SK. The overall age distribution of the EU 27 countries shows no significant differences between the data from 2005 and 2010.

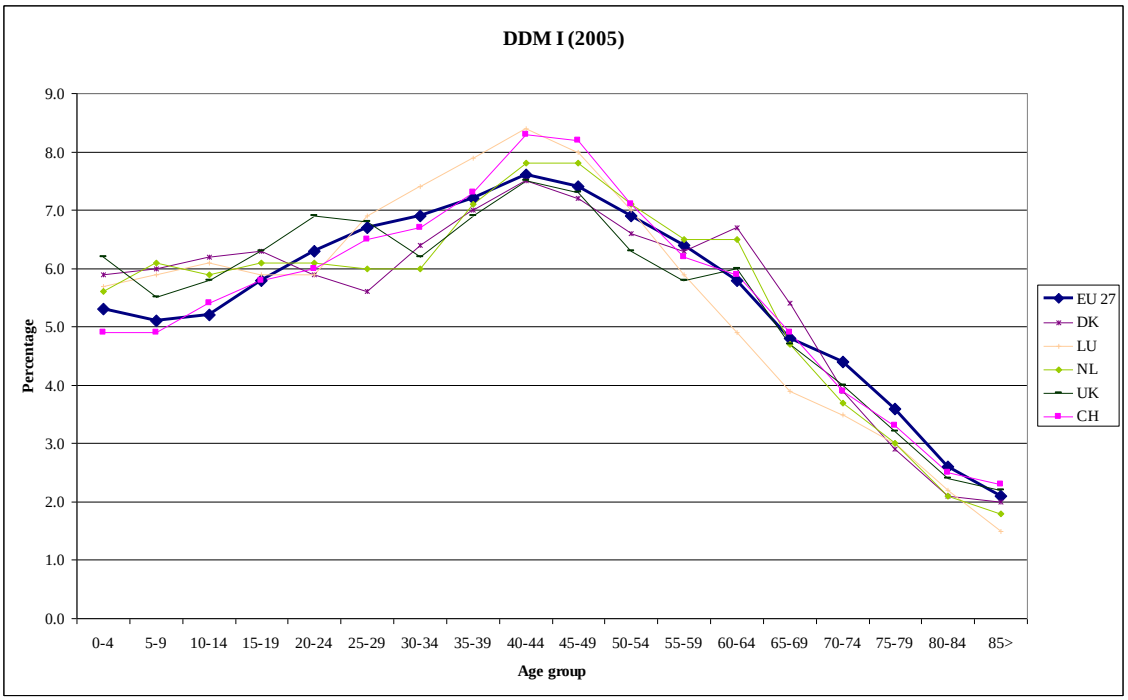


Figure 7.1. Population age distribution in five DDM1 countries (2005)

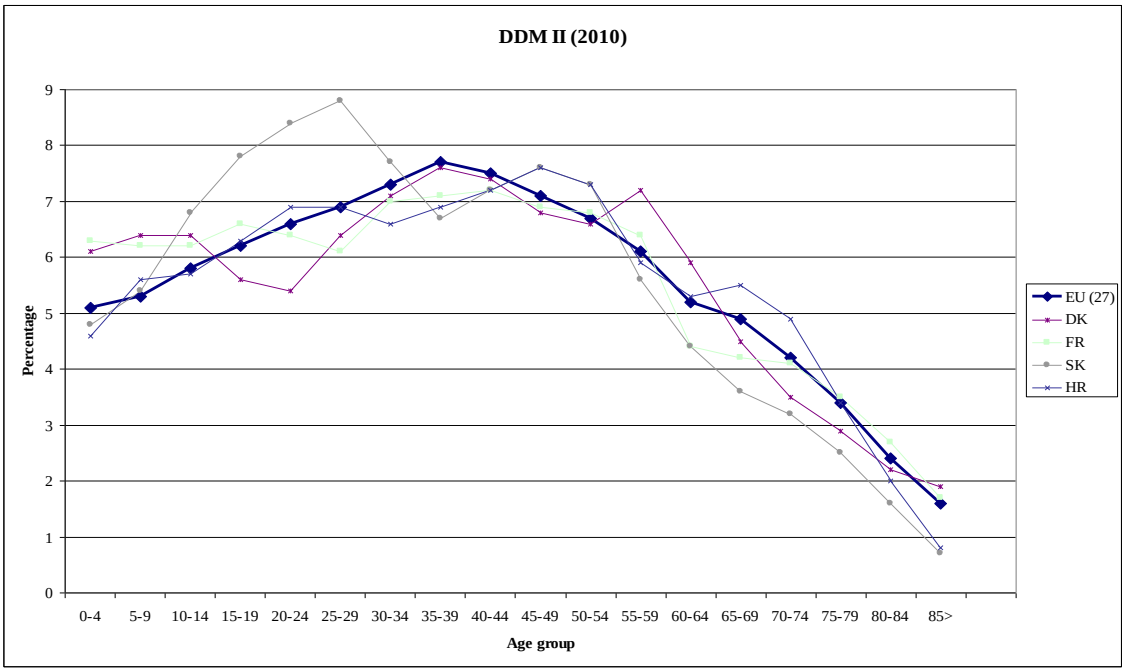


Figure 7.2. Population age distribution in four DDM2 countries (2010)

The average data on age/sex distribution for the five above-mentioned DDM1 countries and the four DDM2 countries for specific X-rays examinations were compared to see if they were sufficiently similar to confirm that there is no major change in the distribution of such data in Europe.

The age distributions (both sexes combined) were plotted in 5-year age bins. Example distributions are shown in Figure 7.3 to Figure 7.6 for male X-ray chest, PTCA and CT chest examinations and for female mammography examination respectively.

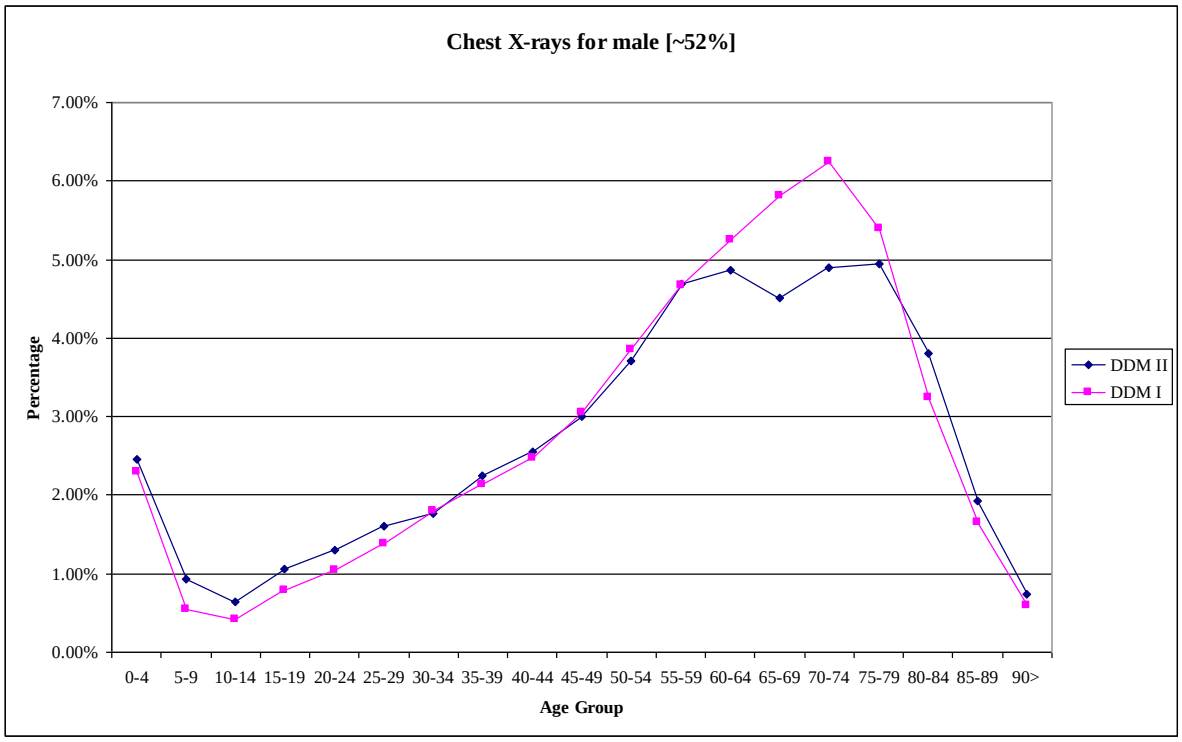


Figure 7.3. Comparison of age distribution for chest X-rays exams on males

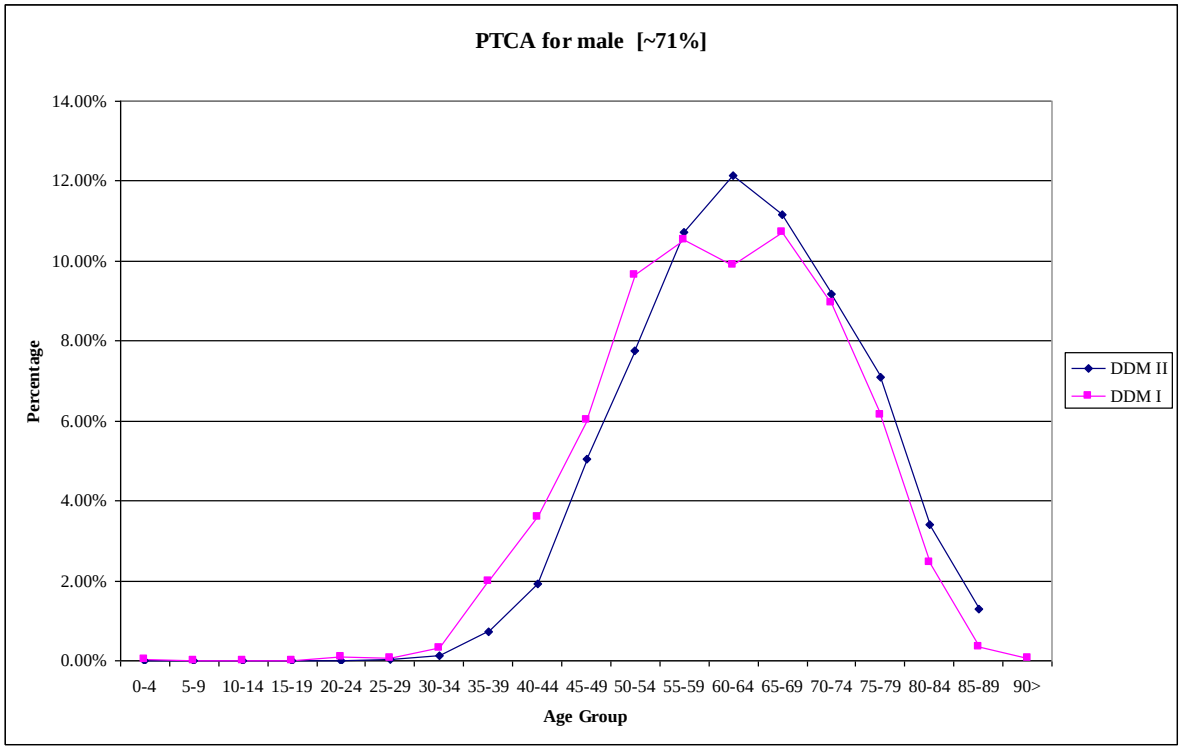


Figure 7.4. Comparison of age distribution for PTCA exams on males

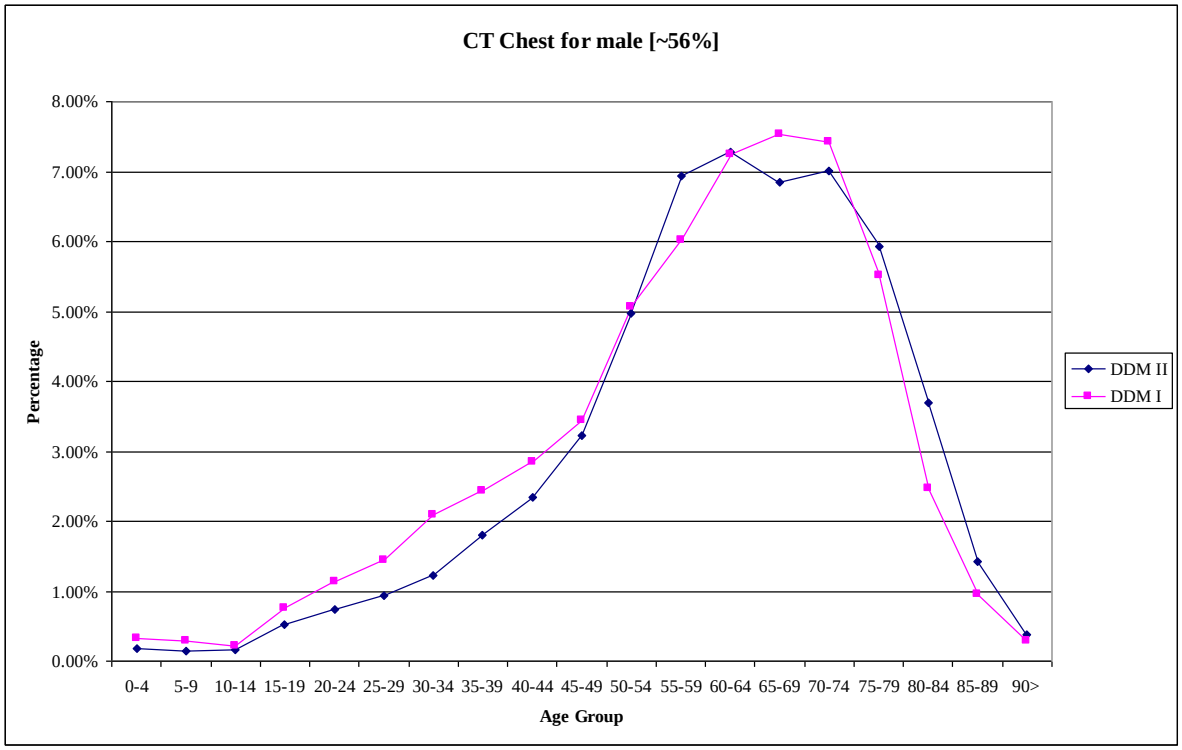


Figure. 7.5. Comparison of age distribution for CT chest exams on males

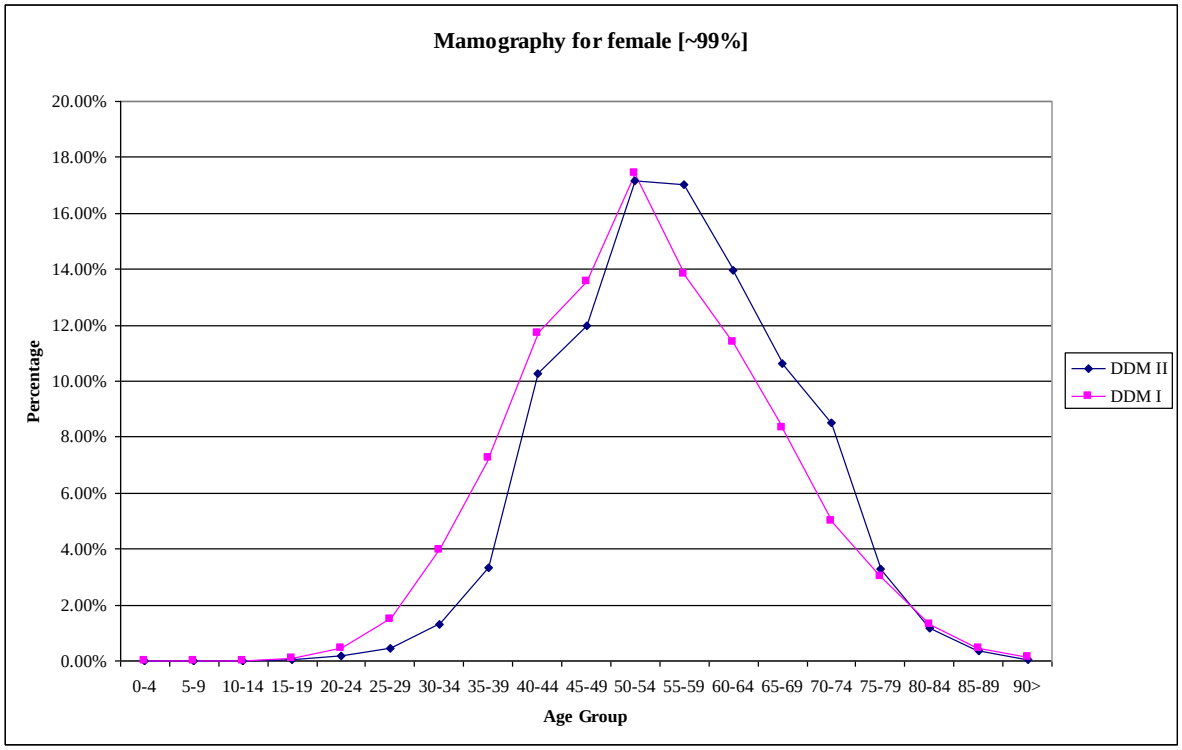


Figure 7.6. Comparison of age distribution for mammography exams on females only

It can be seen from these comparisons that the distributions are sufficiently similar between the DDM1 and DDM2 countries to conclude that the use of the European average is still a reasonable guide when specific national data on age and sex distribution per examination are not available. Annex 8 provides detailed data on age and sex distributions for the Top 20

examinations that can be used by any European country to relate collective doses to collective detriment, in the absence of more reliable national data. For further information see also annex 3 of the European Guidance on Estimating Population Dose from Medical X-ray Procedures (RP 154; EC 2008).

7.2 Age and sex distributions for nuclear medicine procedures

There are very few data in literature on age and sex distribution of patients undergoing nuclear medicine procedures. Nevertheless, there is no doubt that the percentage of various types of examination for children differs widely from those for adults. Most nuclear medicine procedures in adults are related to cardiac problems or cancer (both of which are rare in children). Renal examinations constitute the majority of nuclear medicine procedures done on children in some countries (UNSCEAR, 2010). Detailed data on age and sex distribution of patients undergoing nuclear medicine examinations were not available in this project.

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9 ANNEXES

(ONLY AVAILABLE ONLINE)

Annex 1. List of contact persons

Annex 2. General questionnaire (WP2)

Annex 3. Detailed questionnaire (WP3 and WP4)

Annex 4. General data

Annex 5. Variation of mean effective doses (x-ray exams) and mean activities (NM exams) between countries

Annex 6. Country specific data on the methods of population dose estimations

Annex 7. Summary of the results of the general questionnaire on the availability of frequency and population dose data

Annex 8. Age and sex distributions for the Top 20 examinations in European countries

Annex 9. Guidance on the interpretations of RP 154 in categorization of codes

Annex 10. Additional guidance for estimating population dose

Annex 11. Population dose database

Annex 12. Effect of tissue risk weighting factors on the estimation of effective dose for x-ray procedures

9.1 Annex 1 - LIST OF CONTACT PERSONS

Contacts from the EU member states

Nr	Country	Contact person	Address & Tel. & Contacts
1	Austria (AT)	Manfred Ditto	**Bundesministerium für Gesundheit, Familie und Jugend** Abteilung - Strahlenschutz Radetzkystraße 2 A-1030 Wien
2	Belgium (BE)	Michel Biernaux	**Federal Agency for Nuclear Control** Ravensteinstraat 36 B-1000 Brussels
3	Bulgaria (BG)	Jenia Vassileva	**National Center of Radiobiology and Radiation Protection** 3 Georgi Sofiiski str. BG-1606 Sofia
4	Czech Republic (CZ)	Leos Novak	**National Radiation Protection Institute** Bartoskova 28 CZ-140 00 Prague 4
5	Croatia	Ivana Kralik	**State Office for Radiological and Nuclear Safety** Zagreb
6	Cyprus (CY)	Panicos Demetriades	**Ministry of Labour and Social Insurance** Clementos 9 1061 Nicosia
7	Denmark (DK)	Hanne Waltenburg	**National Institute of Radiation Protection** Knapholm 7 DK-2730 Herlev
8	Estonia (EE)	Jelena Shubina	**Radiation Safety Department** Environmental Board Kopli 76 EE-10416 Tallinn
9	Finland (FI)	Hannu Jarvinen	**Radiation and Nuclear Safety Authority (STUK)** P.O.Box 14 FI-00881 Helsinki
10	France (FR)	Bernard Aubert	**Institut de Radioprotection et de Sûreté Nucléaire (IRSN)** Unité d'Expertise en radioprotection Médicale BP 17 FR- 92262 Fontenay-aux-Roses
11	Germany (DE)	Elke Nekolla	**Bundesamt für Strahlenschutz (BfS)** Fachbereich SG “Strahlenschutz und Gesundheit Ingolstädter Landstr. 1 DE-85764 Neuherberg
12	Greece (GR)	Stavroula Vogiatzi	**GAEC** P.O.Box 60092 Ag. Paraskevi 15310 Athens
13	Hungary (HU)	Sáfrány Géza	**National Research Institute for Radiobiology and Radiohygiene** Anna u. 5 HU-1221 Budapest
14	Ireland (IR)	Ciara Norton	**Medical Exposure Radiation Unit** Health Services Executive Mill Lane Palmerstown Dublin 20

15	Italy (IT)	Renato Padovani	**Az. Ospedaliero-Universitaria** S. Maria della Misericordia It-33100 Udine
16	Latvia (LV)	Signe Mahere	**Children's Clinical Hospital** Health technologies division manager
17	Lithuania	Julius Ziliukas	**Ministry of Health** Radiation Protection Centre Kalvariju 153 LT-08221 Vilnius
18	Luxembourg (LU)	Carlo Back	**Ministry of Health** Division de la Radioprotection Villa Louvigny L-2120 Luxembourg
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20	Netherlands (NL)	Ischa de Waard	**Laboratory for Radiation Research** RIVM, PB33 P.O.Box 1 NL-3720 BA Bilthoven
21	Poland (PL)	Dariusz Kluszczyński	**National Centre for Radiation Protection in Health Care (NCRPHC)**
22	Portugal (PT)	Pedro Manuel Peixoto Teles	**Instituto Superior Técnico, Universidade Técnica de Lisboa** Estrada Nacional 10 2686-953 Sacavém
23	Romania (RO)	Olga Girjoaba	**National Commission for Nuclear Activities Control** Libertatii Bvd. 14, sector 5 RO-Bucharest 050706
24	Slovenia (SI)	Dejan Zontar	**Slovenian Radiation Protection Administration** Ajdovščina 4 SI-1000 Ljubljana
25	Slovakia (SK)	Dusan Salat	**Radiation Protection Institute** Stanicna 1062/24SK-911 05 Trencin
26	Spain (ES)	Dr. Sergio Cañete Hidalgo	**University of Malaga** Head of Radiation Protection Malaga
27	Sweden (SE)	Anders Frank	**Swedish Radiation Safety Authority** Solna strandväg 96 SE-171 16 Stockholm
28	United Kingdom (UK)	Paul Shrimpton	**Medical Exposure Department** Health Protection Agency, Centre for Radiation, Chemical and Environmental Hazards Chilton, Didcot, Oxon, OX11 0RQ

Contacts from associate countries

Nr	Country	Contact person	Address & Tel. & contacts
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30	Switzerland (CH)	Philipp Trueb	**Federal Office of Public Health** Schwarzenburgstraße 165 CH-3097 Liebefeld
31	Bosnia and Herzegovina (HR)	Adnan Beganovic	**Clinical Centre of Sarajevo University** Bolnička 25 Sarajevo
32	Iceland (IS)	Guðlaugur Einarsson	**Icelandic Radiation Safety Authority** Raudararstigur 10150 Reykjavik
33	Moldova (MD)	Alexandru Hustuc	**Centrul National de Sanatate Publica (CNSP)** mun. Chisinau str. Gh. Asachi 67/a
34	Serbia (SP)	Olivera Ciraj Bjelac	**Vinca Institute of Nuclear Sciences** Radiation Protection Laboratory M. P. Alasa 12-14, Vinca, P.O.Box 522, 11001 Belgrade
35	Ukraine (UA)	Stadnyk Larysa	**Grigorev Institute for Medical Radiology** Radiation Hygiene of Medical Staff and Patients Kharkiv, vul. Pushkinska, 82, 61024 Ukraine
36	Frmr. Yug, Rep. Of Macedonia (MA)	Vesna Gersan	**MD Anderson Cancer Center** Faculty of Science and Mathematics

9.2 Annex 2 – GENERAL QUESTIONNAIRE (WP2)

The purpose of the general questionnaire to the European countries was to survey the national regulatory frameworks and the status of implementation of the requirements for medical dose surveys and population dose estimations.. The questionnaire was distributed to the national contact persons; the list of national contact persons was subsequently updated (Annex 1) through the implementation of WP2. In the following, a brief summary of the general questionnaire (with the original cover words) is presented.

Dose Datamed 2: General Questionnaire

Questionnaire on Population Dose Estimations

We would like to collect within the Dose Datamed 2 project information related to population dose estimates from x-ray examinations and nuclear medicine within the European Union. The data collection is organised in two levels: First the General Questionnaire will gather information about national regulations, national healthcare systems and basic data of national population dose estimates. In a second step, a more detailed questionnaire will gather the detailed information about national surveys and their results.

This General Questionnaire is composed of four parts:

1. General and contact information.
2. Regulatory framework: Existence of regulations (laws, decrees etc.), recommendations or established systems for population dose estimation.
3. Indicators of the national healthcare system.
4. Availability of basic data on national surveys of population doses.

Fill in the data carefully until {EXPIRY-DMY}, as the results of this review of national surveys on population doses will be used to prepare the second more detailed survey.

Usage instructions for this questionnaire:

In Dose Datamed 2, data collection is performed using this online questionnaire system. We have tried to make the questions as simple and clear as possible. If questions do not apply to the situation in your country, please give details about these specific topics in the comments. We often ask estimates. In this cases, we do not need exact number, but we would like to get an idea of the situation in your country.

There is no need to fill the questionnaire at once: At any time, you can stop and continue your work on the questionnaire by clicking on the “Resume Later” Button at the bottom of the page. At the first time you are asked to provide a name and a password for your survey to access it again later. If you provide an email address you will receive a message with a direct link to your saved survey. If not you can load a previously saved survey by clicking the “Load unfinished survey” button on this survey description page. This will show up a new input form where you can re-enter the name and password you used to save your survey. The final submission of the questionnaire is done with the Submit button at the end of the questionnaire. This has to be done within the time period of the questionnaire. Important: After the submission of the questionnaire you are not able to perform any changes to your answers!

If you have any questions regarding this questionnaire don't hesitate to contact the Dose Datamed 2 Team directly at contact@ddmed.eu

There are 49 questions in this survey.
General and contact information
Section 1/4
1 Name of the country: *
Please write your answer here:
2 Primary contact data of the person providing reply to this questionnaire: *

Please write your answer(s) here:
Organization(s)
Contact person(s)
Role in the organization
Address
Phone (e.g. +22 607 1234567)
E-mail
3 Additional contact data providing reply to this questionnaire:
Please write your answer(s) here:
Organization(s)
Contact person(s)
Role in the organization
Address
Phone (e.g. +22 607 1234567)
E-mail

Regulatory framework for population dose estimation

Section 2/4

This part of the questionnaire reviews the existence of regulations (laws, decrees etc.), recommendations or established systems with respect to population dose estimations.

4 Tick “x” in the relevant column; e.g., if regulations (law, statute, decree) for collection of frequencies exist, tick “x” in the column “Regulations (…) exist”

Check any that apply:	Recommendations or established systems exist.	No regulations, no recommendations, no established systems.	Regulations or recommendations are being prepared.
Regulations (Legal requirements: law, statute, decree,..) exist.			
Collection of frequencies (number of examinations)			
Population dose estimation			
Organization for collection of frequencies			
Organization for making population dose estimation			

9.3 Annex 3 - DETAILED QUSTIONNAIRE (WP3 AND WP4)

The results of the general questionnaire (Annex 2) were used to plan the more detailed surveys in WP3 and WP4, to collect data on national population doses and DRLs. The detailed questionnaire was a joint questionnaire, planned in a way that all countries were able to submit their available data, but also consider and be aware of the different options according to the existing guidance of RP 154. Questionnaires consisted of detailed electronic surveys and Excel-data sheets.

If you have any questions regarding this questionnaire don't hesitate to contact the Dose Datamed 2 Team directly at contact@ddmed.eu.

9.4 Annex 4 – General Data

Table 4.1. Organizations responsible for frequency collection and population dose estimation.

Country	Organization responsible for the collection of frequency data	Organization responsible for estimating the population dose	Organization responsible for providing data on medical exposures to UNSCEAR
AT	Federal Ministry of Health	Federal Ministry of Health	Federal Ministry of Health
BA	Medical physics departments or external technical services	National regulatory agency	National regulatory agency
BE	Institut national d'assurance maladie-invalidité (INAMI)	Federal Agency for Nuclear Control (FANC)	Federal Agency for Nuclear Control (FANC)
BG	National Centre of Radiobiology and Radiation Protection (NCRRP)	National Centre of Radiobiology and Radiation Protection (NCRRP)	National Centre of Radiobiology and Radiation Protection (NCRRP)
BY	State Dosimetric Registry, Republican Research and Practical Centre of Radiation Medicine and Human Ecology of the Ministry of Health	State Dosimetric Registry, Republican Research and Practical Centre of Radiation Medicine and Human Ecology of the Ministry of Health	—
CH	Institute of Radiation Physics (IRA)	Institute of Radiation Physics (IRA)	Federal Office of Public Health
CY	—	—	—
CZ	Institute of Health Information and Statistics	—	State Office for Nuclear Safety
DE	Bundesamt für Strahlenschutz (BfS)	Bundesamt für Strahlenschutz (BfS)	Bundesamt für Strahlenschutz (BfS)
DK	National Board of Health (Documentation Unit)	National Board of Health (National Institute of Health)	National Board of Health
EE	Ministry of Social Affair	Radiation Safety Department of the Environmental Board	—
EL	Greek Atomic Energy Commission	Greek Atomic Energy Commission	Greek Atomic Energy Commission
ES	Health Authorities	Health Authorities and Nuclear Safety Council	Health Authorities
FI	Radiation and Nuclear Safety Authority (STUK)	Radiation and Nuclear Safety Authority (STUK)	Radiation and Nuclear Safety Authority (STUK)
FR	Institut de Radioprotection et de Sûreté Nucléaire (IRSN)	Institut de Radioprotection et de Sûreté Nucléaire (IRSN)	Institut de Radioprotection et de Sûreté Nucléaire (IRSN)
HR	State office for radiological and nuclear safety	State office for radiological and nuclear safety	State office for radiological and nuclear safety
HU	National Center for Healthcare Audit and Improvement (X-rays), National Institute for Quality- and Organizational Development in Healthcare and Medicine (NM)	—	—
IE	Health Service Executive (HSE)	Health Service Executive (HSE)	Department of Health and Children
IS	Icelandic Radiation Safety Authority	Icelandic Radiation Safety Authority	Icelandic Radiation Safety Authority
IT	Regional Health Authorities	Regional Health Authorities	—
LT	Institute of Hygiene Health Information	Radiation Protection Centre	Radiation Protection Centre
LU	Division de la Radioprotection	Division de la Radioprotection	Division de la Radioprotection
LV	Radiation Safety Center	—	—
MD	—	—	—
ME	—	—	—
MK	—	Institute of Public Health	—
MT	Health Information Office	—	—
NL	National Institute for Public Health and the Environment (RIVM)	National Institute for Public Health and the Environment (RIVM)	National Institute for Public Health and the Environment (RIVM)
NO	Radiation Protection Authority (NRPA)	Radiation Protection Authority (NRPA)	Radiation Protection Authority (NRPA)
PL	National Centre for Radiation Protection in Health Care	National Centre for Radiation Protection in Health Care	National Centre for Radiation Protection in Health Care
PT	Directorate-General for Health / Division of Statistics for Health	Instituto Tecnológico e Nuclear Unit of Radiological Protection and Safety	—
RO	Ministry of Health, National Institute for Public Health	Ministry of Health, National Institute for Public Health	Ministry of Health, National Institute for Public Health
RS	Radiation Protection and Nuclear Safety Agency	Radiation Protection and Nuclear Safety Agency	Radiation Protection and Nuclear Safety Agency
SE	Radiation Safety Authority (SSM)	Radiation Safety Authority (SSM)	Radiation Safety Authority (SSM)
SI	—	—	Radiation Protection Administration
SK	Public Health Authority	Public Health Authority	Public Health Authority
UA	Ministry of Health (Information-analytical Center)	Grigorev Institute for Medical Radiology	Ministry of Health / Grigorev Institute for Medical Radiology
UK	Health Protection Agency (HPA)	Health Protection Agency (HPA)	Health Protection Agency (HPA)

Note: In NO and SI, the responsibility is not clearly stated but the given institution has performed the population dose surveys.

Table 4.2. Numbers of selected healthcare providers per million of population. Value 0,0: No information provided.

Country	University Hospitals	Other state hospitals	State hospitals TOTAL	Private hospitals	Private radiology institutes	General practicies	Chiro-practic Clinics	Dental practices	TB screening units	Mammo screening units
AT	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
BE	1,6	11,3	12,9	7,0	25,9	0,0	0,0	0,0	1,2	2,3
BG	2,9	27,7	30,7	2,0	0,0	0,0	0,0	45,3	3,7	0,0
CH	1,8	18,7	20,5	17,1	11,0	532,1	17,4	435,8	0,0	10,6
CY	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
CZ	1,0	5,1	6,2	11,5	0,0	58,3	0,0	49,4	0,0	6,5
DE	0,4	17,1	17,5	6,5	0,0	0,0	0,0	0,0	0,0	1,1
DK	0,5	7,2	7,7	7,2	2,2	0,0	34,2	287,8	0,0	0,9
EE	0,8	25,0	25,8	0,0	0,0	9,1	0,0	300,0	0,0	0,8
EL	0,5	13,6	14,0	0,8	48,8	0,0	0,0	0,0	0,0	0,0
ES	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
FI	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
FR	0,5	13,9	14,4	25,3	40,8	0,0	0,0	322,3	0,0	39,4
HR	1,9	5,4	7,2	1,2	6,5	0,0	0,0	121,7	0,0	0,2
HU	0,4	14,6	15,0	1,0	0,0	0,0	0,0	30,0	17,0	5,0
IE	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
IS	3,1	0,0	3,1	0,0	6,3	68,9	9,4	1296,3	0,0	3,1
IT	0,6	13,0	13,6	8,3	22,2	0,0	0,0	0,0	0,0	0,0
LT	3,4	19,1	22,5	0,3	0,0	25,9	0,0	61,6	0,0	8,0
LU	0,0	6,4	6,4	4,3	0,0	0,0	0,0	851,1	6,4	12,8
LV	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
MD	1,7	19,1	20,8	0,8	2,0	12,1	0,0	21,0	0,0	0,0
ME	0,0	11,9	11,9	4,5	0,0	31,3	0,0	597,0	0,0	0,0
MK	5,9	1,5	7,4	1,0	18,7	24,1	0,0	0,0	0,0	18,2
MT	2,5	14,8	17,3	14,8	19,8	14,8	0,0	0,0	0,0	42,0
NL	0,5	5,2	5,6	0,3	0,0	0,0	1,2	0,0	0,1	0,5
NO	1,3	13,9	15,2	1,9	5,1	0,0	10,6	612,2	0,2	3,4
PL	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
PT	0,1	8,0	8,1	2,8	0,0	0,0	0,0	0,0	0,0	0,0
RO	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
RS	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
SE	0,9	7,9	8,8	0,1	2,7	0,0	0,0	0,0	0,0	6,6
SI	1,0	7,8	8,8	0,0	2,0	22,4	0,0	160,5	0,0	17,6
SK	0,7	10,5	11,2	4,6	19,1	0,0	0,0	230,6	0,0	19,5
UA	0,0	20,9	20,9	0,0	0,0	15,5	0,0	6,3	25,5	7,6
UK	0,0	19,2	19,2	3,1	0,0	0,0	11,4	179,2	0,0	1,3

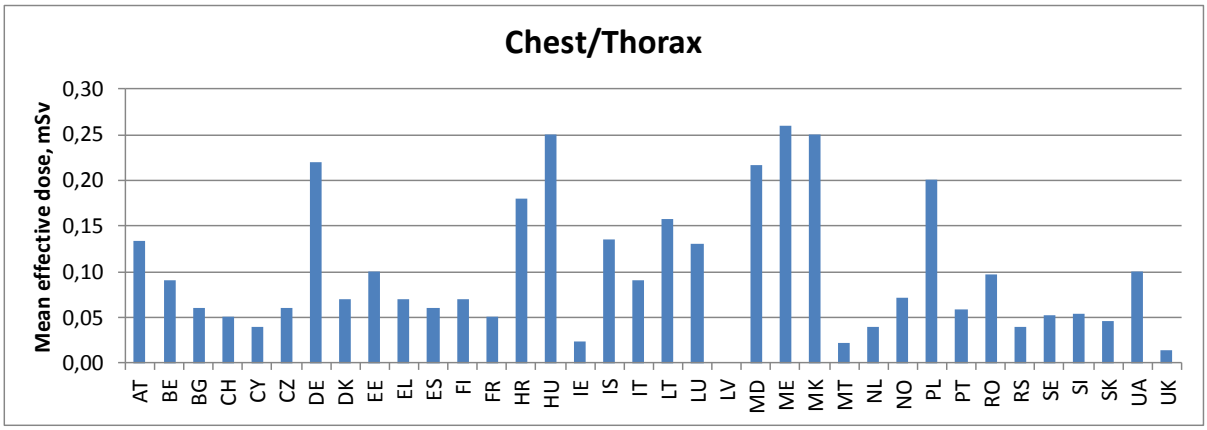
Table 4.3. Numbers of selected professional groups of physicians, per million of population. Value 0,0: No information provided.

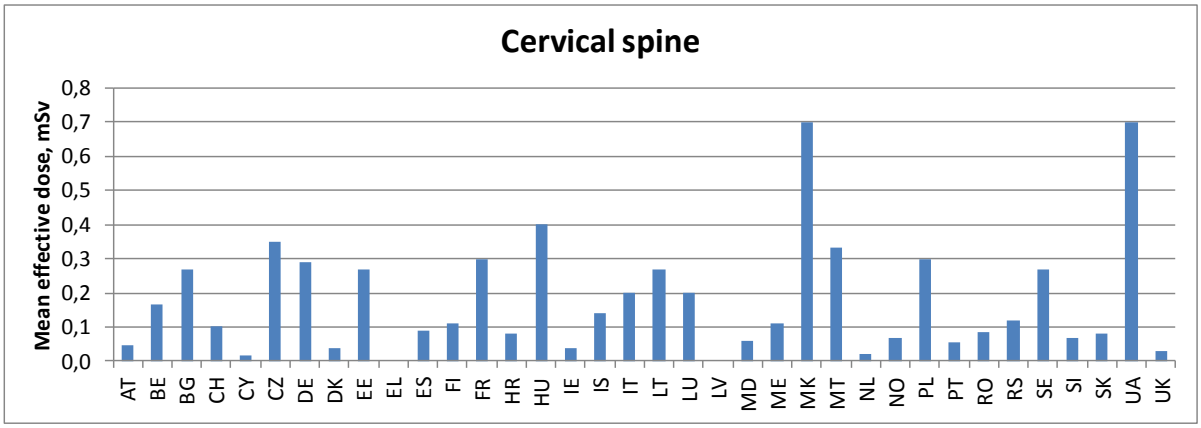
Country	General Practitioners	Radiologists	Nuclear medicine physicians	Cardiologists	Vascular surgeons
AT	0,0	119,0	20,2	0,0	0,0
BE	273,4	134,8	23,5	47,4	90,3
BG	0,0	114,8	6,2	26,5	0,0
CH	649,4	84,0	7,4	69,9	9,1
CY	0,0	0,0	0,0	0,0	0,0
CZ	0,0	138,5	14,9	27,6	3,1
DE	0,0	80,7	12,2	55,0	0,9
DK	649,0	121,4	11,7	48,0	0,0
EE	0,0	122,0	5,3	8,3	11,4
EL	0,0	166,0	31,0	29,6	29,6
ES	0,0	0,0	0,0	0,0	0,0
FI	1032,7	111,7	15,2	40,4	6,9
FR	0,0	93,4	8,2	17,3	6,7
HR	0,0	62,2	8,2	5,8	0,0
HU	0,0	129,8	8,3	49,9	10,0
IE	0,0	0,0	0,0	0,0	0,0
IS	682,6	119,0	12,5	68,9	0,0
IT	0,0	159,7	15,7	0,0	0,0
LT	250,5	106,8	5,8	12,9	6,5
LU	638,3	95,7	21,3	63,8	10,6
LV	0,0	0,0	0,0	0,0	0,0
MD	104,0	108,3	5,0	2,8	2,2
ME	31,3	67,2	3,0	0,0	10,4
MK	937,9	56,7	9,9	37,9	9,9
MT	0,0	0,0	0,0	0,0	0,0
NL	599,7	51,8	6,4	43,1	0,0
NO	572,5	125,6	7,4	0,0	19,2
PL	0,0	0,0	0,0	0,0	0,0
PT	490,2	79,3	5,9	81,2	13,7
RO	571,9	50,3	2,0	13,1	0,0
RS	1191,5	80,4	6,3	0,0	0,0
SE	0,0	108,7	0,0	0,0	0,0
SI	0,0	109,8	14,6	7,3	2,4
SK	4133,5	94,9	7,2	5,0	4,2
UA	93,7	87,1	3,1	1,7	1,3
UK	0,0	45,9	0,0	0,0	0,0

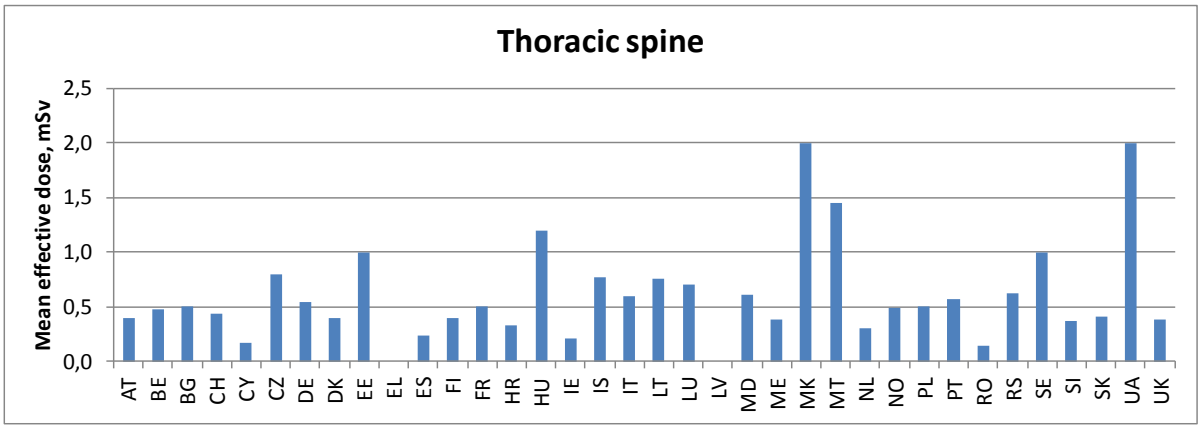
9.5 Annex 5 - VARIATION OF MEAN EFFECTIVE DOSES (X-RAY EXAMS) AND MEAN ACTIVITIES (NM EXAMS) BETWEEN COUNTRIES

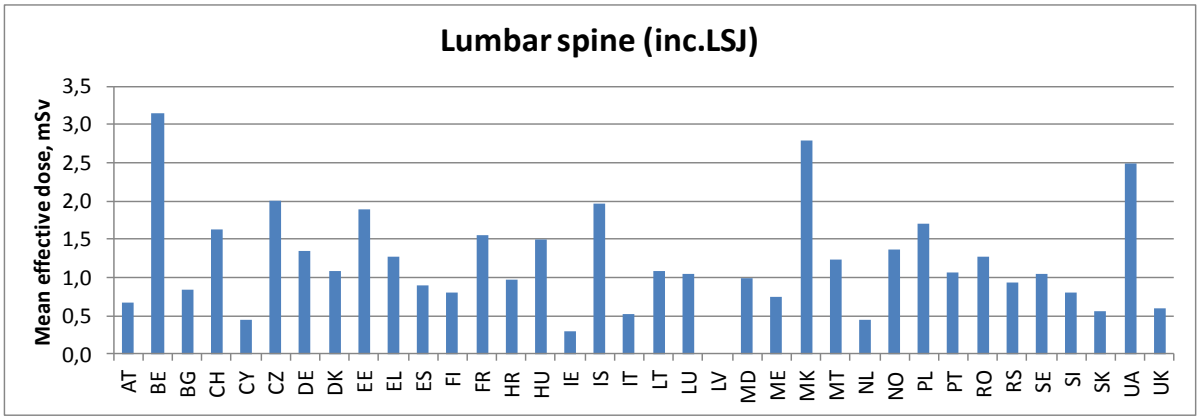
In this Annex, the variation of mean (typical) effective doses for each Top 20 group of x-ray procedures and the variation of administered mean activities for selected NM procedures, as reported by the European countries, is shown by graphs.

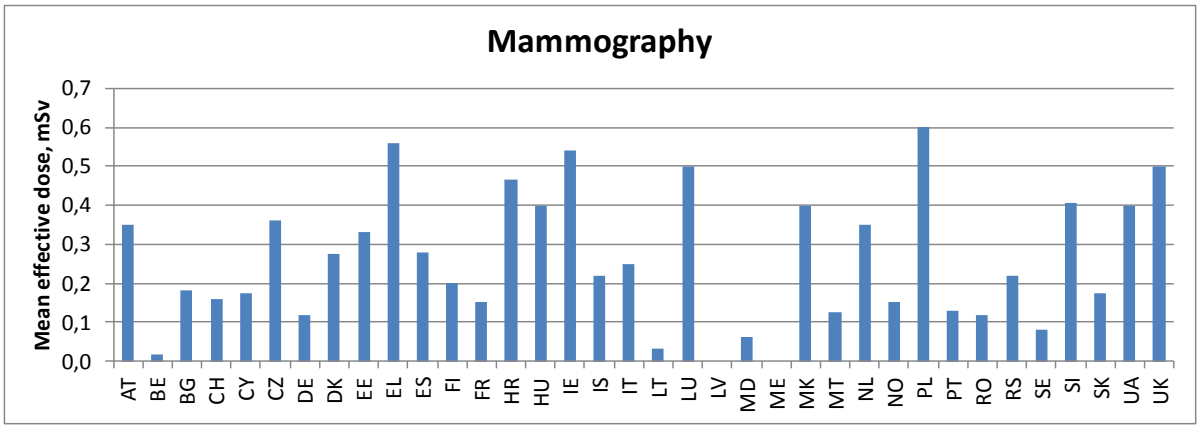
Mean effective doses for x-ray procedures

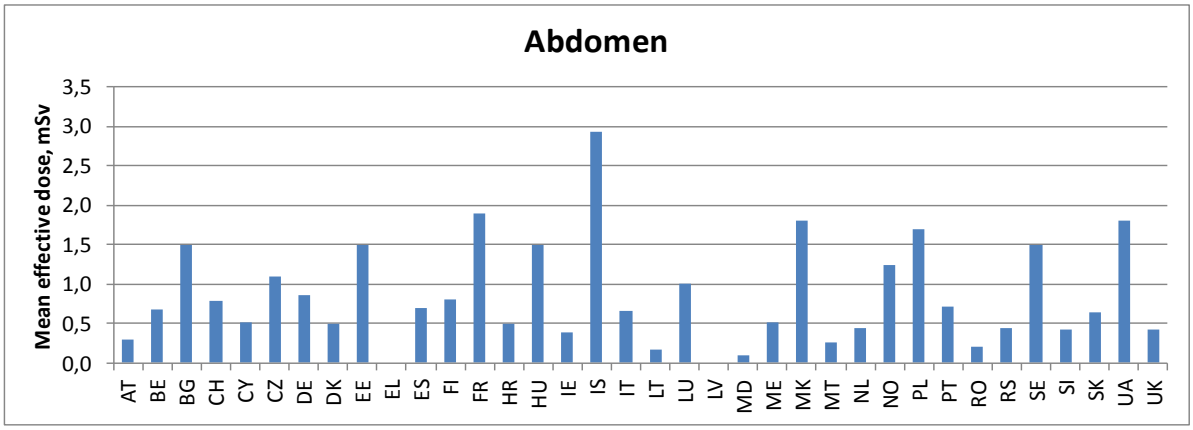


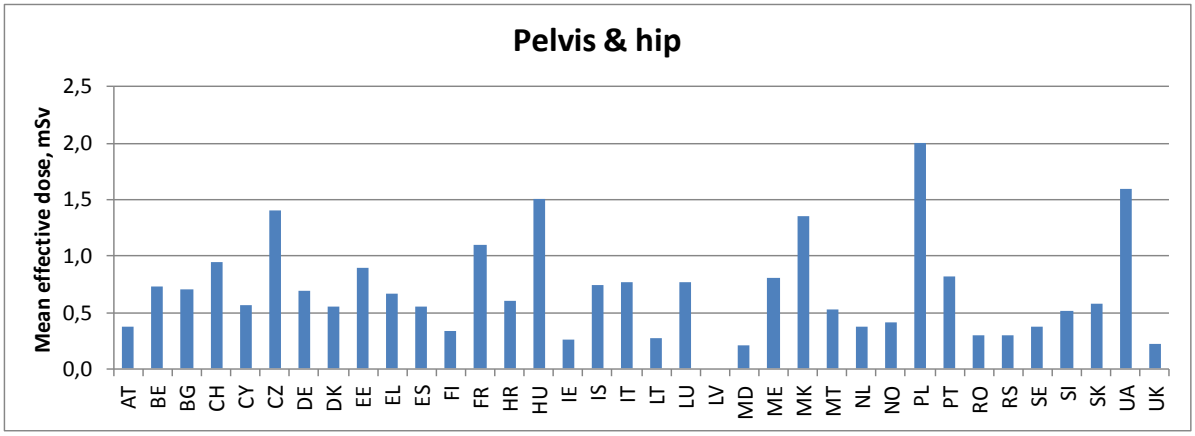


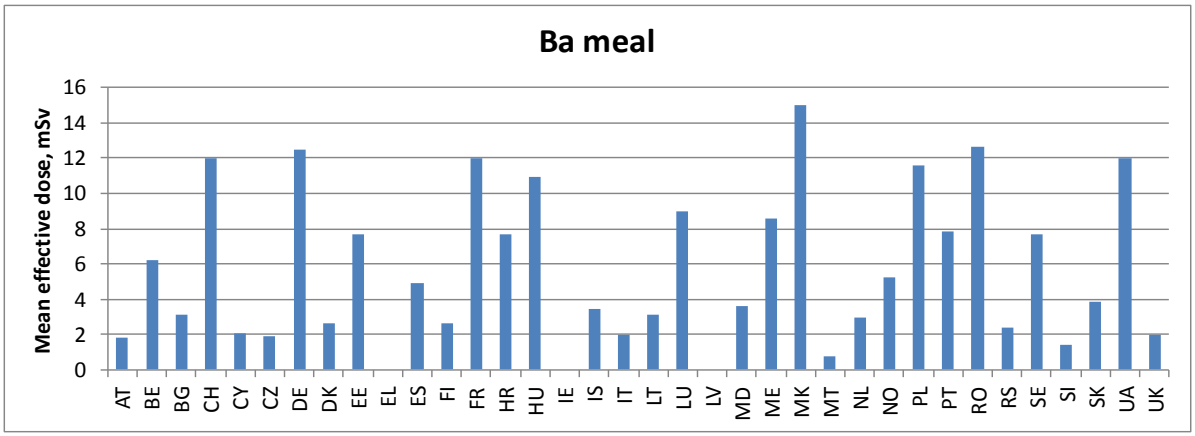


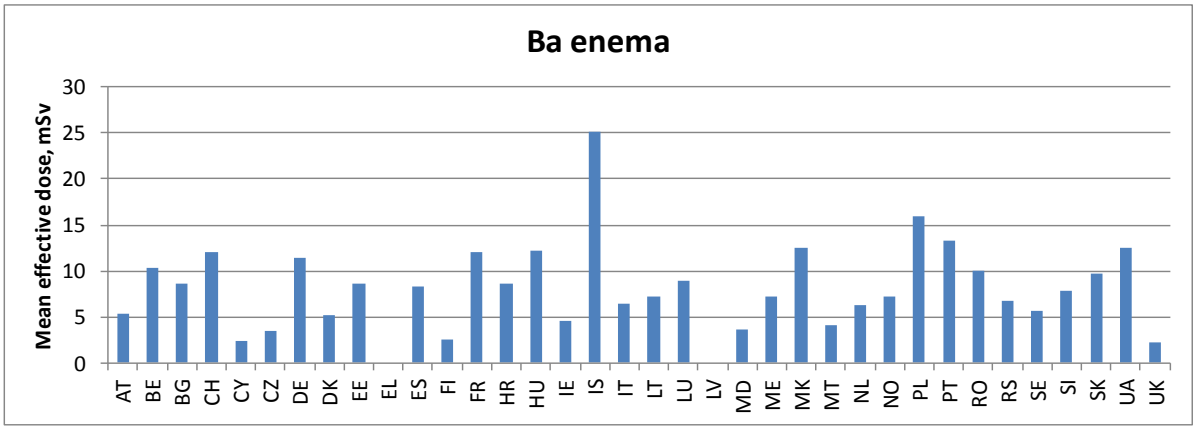

Lumbar spine (inc.LSJ)
Mean effective dose, mSv
3,5
3,0
2,5
2,0
1,5
1,0
0,5
0,0
AT BE BG CH CY CZ DE DK EE EL ES FI FR HR HU IE IS IT LT LU LV MD ME MK MT NL NO PL PT RO RS SE SI SK UA UK

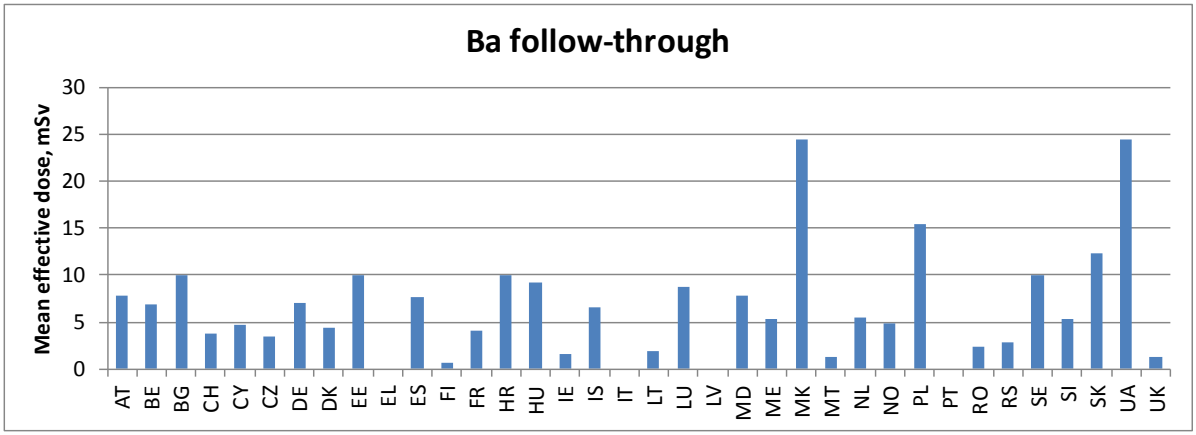

Mammography
Mean effective dose, mSv
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0,0
AT BE BG CH CY CZ DE DK EE EL ES FI FR HR HU IE IS IT LT LU LV MD ME MK MT NL NO PL PT RO RS SE SI SK UA UK


Abdomen
Mean effective dose, mSv
3,5
3,0
2,5
2,0
1,5
1,0
0,5
0,0
AT BE BG CH CY CZ DE DK EE EL ES FI FR HR HU IE IS IT LT LU LV MD ME MK MT NL NO PL PT RO RS SE SI SK UA UK


Pelvis & hip
Mean effective dose, mSv
2,5
2,0
1,5
1,0
0,5
0,0
AT BE BG CH CY CZ DE DK EE EL ES FI FR HR HU IE IS IT LT LU LV MD ME MK MT NL NO PL PT RO RS SE SI SK UA UK


Ba meal
Mean effective dose, mSv
0
2
4
6
8
10
12
14
16
AT BE BG CH CY CZ DE DK EE EL ES FI FR HR HU IE IS IT LT LU LV MD ME MK MT NL NO PL PT RO RS SE SI SK UA UK


Ba enema
Mean effective dose, mSv
0
5
10
15
20
25
30
AT BE BG CH CY CZ DE DK EE EL ES FI FR HR HU IE IS IT LT LU LV MD ME MK MT NL NO PL PT RO RS SE SI SK UA UK


Ba follow-through
Mean effective dose, mSv
0
5
10
15
20
25
30
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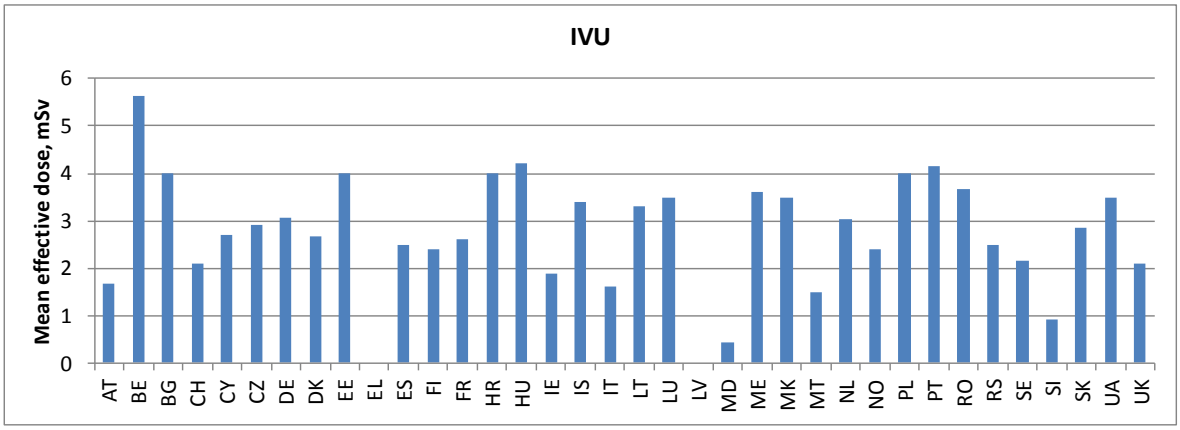
IVU
Mean effective dose, mSv
0
1
2
3
4
5
6
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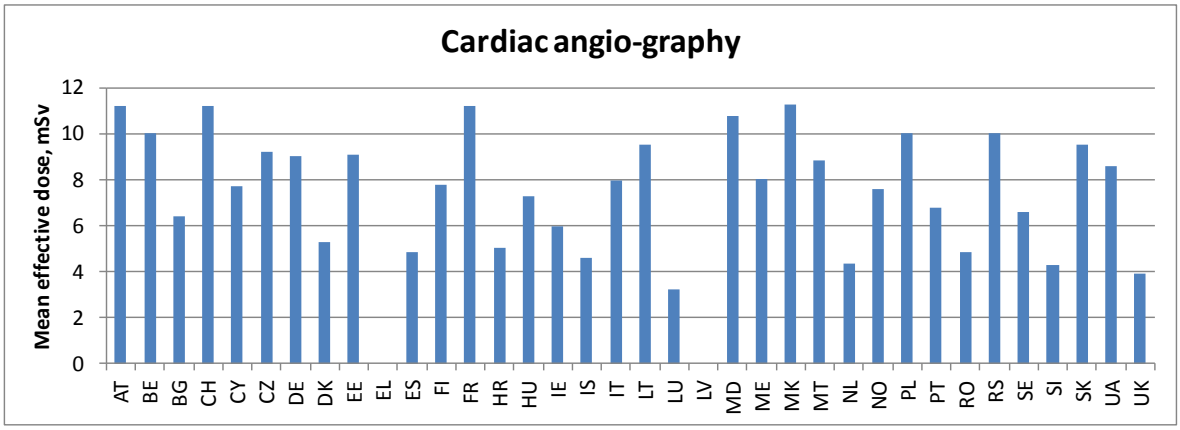
Cardiac angio-graphy
Mean effective dose, mSv
0
2
4
6
8
10
12
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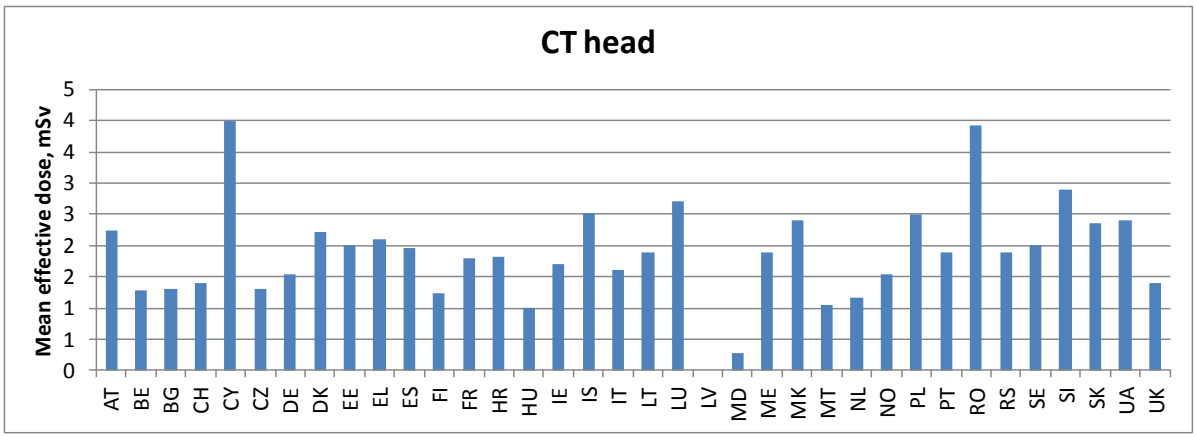
CT head
Mean effective dose, mSv
0
1
1
2
2
3
3
4
4
5
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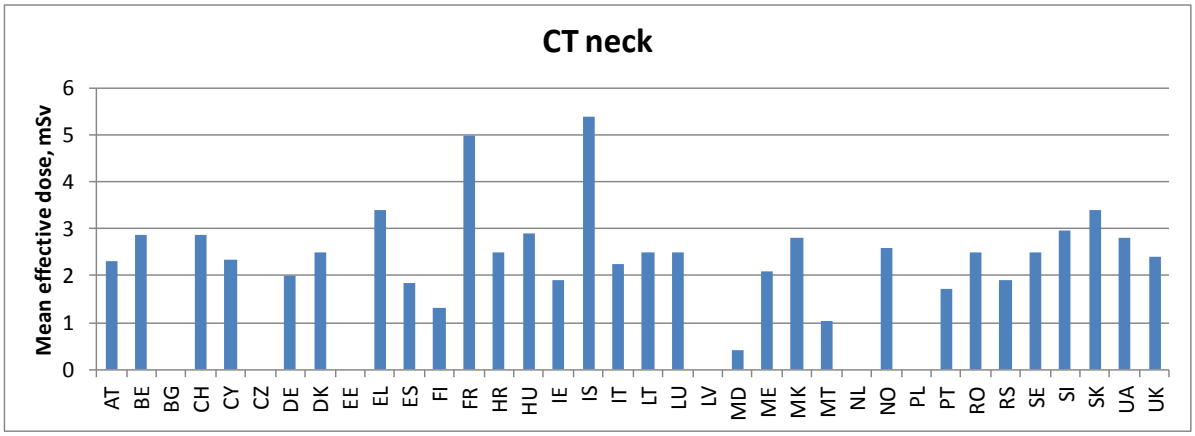
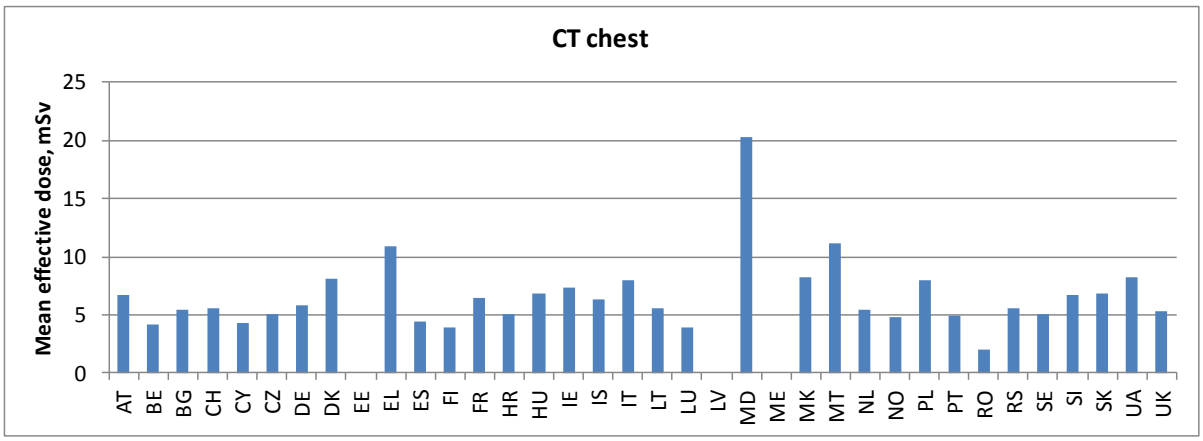
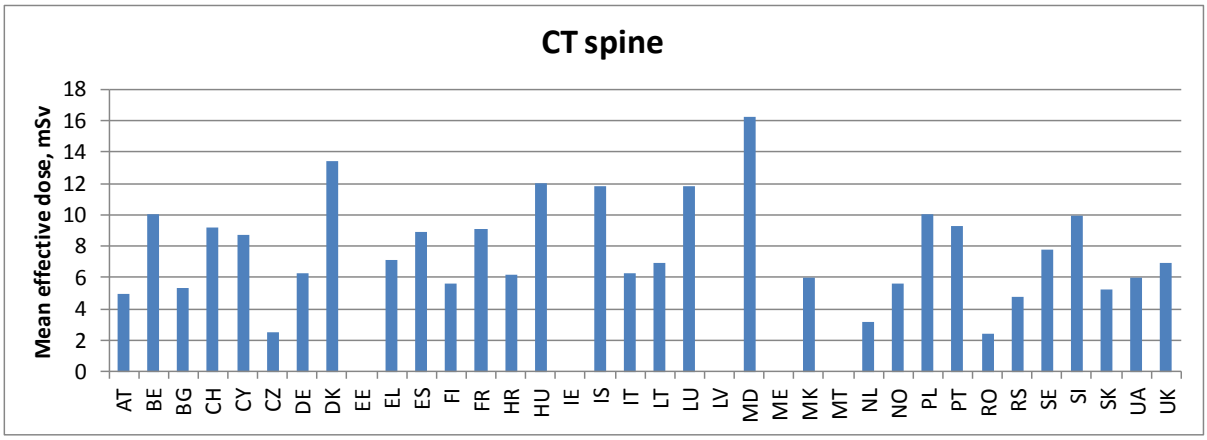

CT neck
Mean effective dose, mSv
0
1
2
3
4
5
6
AT BE BG CH CY CZ DE DK EE EL ES FI FR HR HU IE IS IT LT LU LV MD ME MK MT NL NO PL PT RO RS SE SI SK UA UK


CT chest
Mean effective dose, mSv
0
5
10
15
20
25
AT BE BG CH CY CZ DE DK EE EL ES FI FR HR HU IE IS IT LT LU LV MD ME MK MT NL NO PL PT RO RS SE SI SK UA UK


CT spine
Mean effective dose, mSv
0
2
4
6
8
10
12
14
16
18
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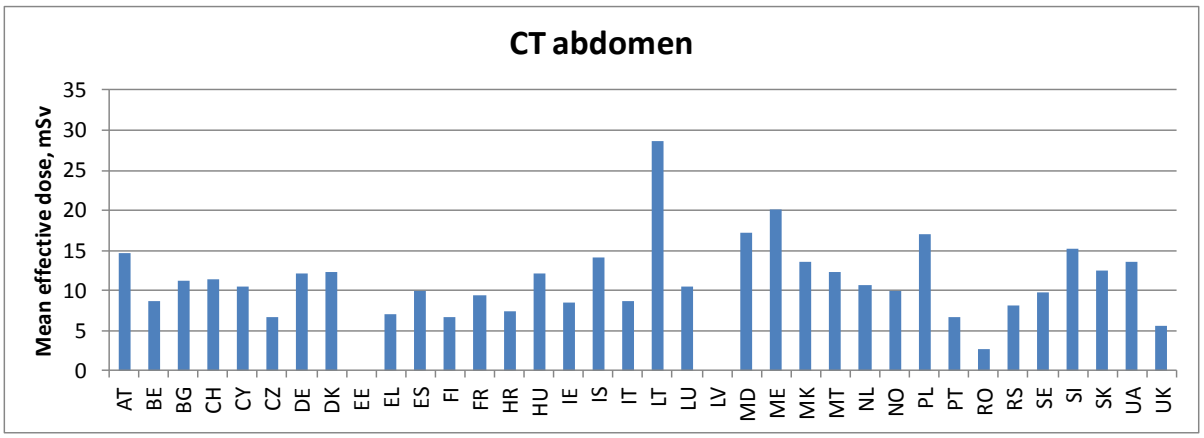
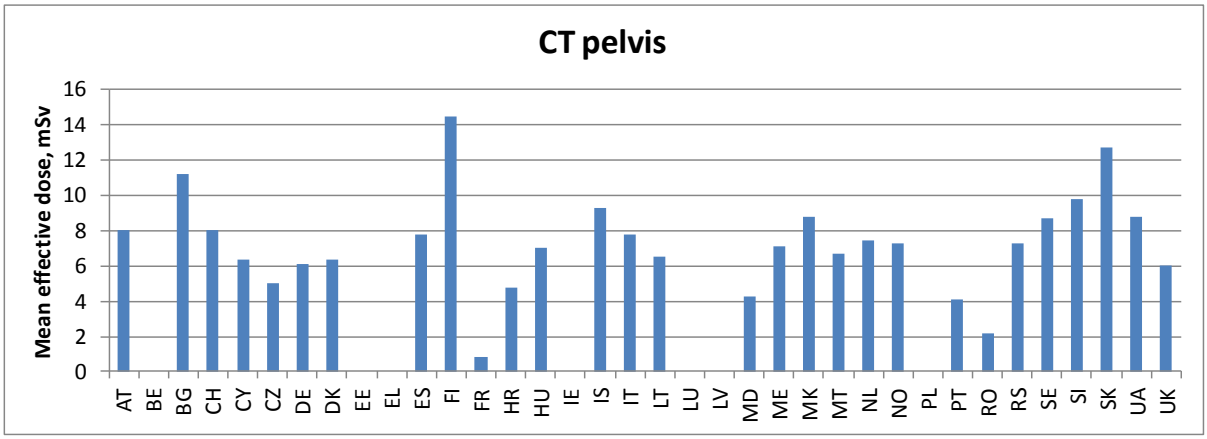
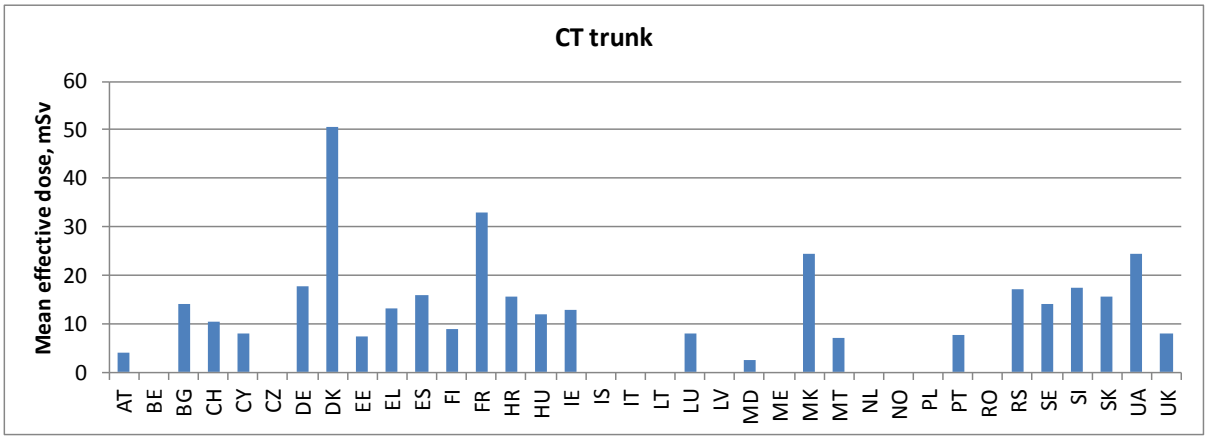
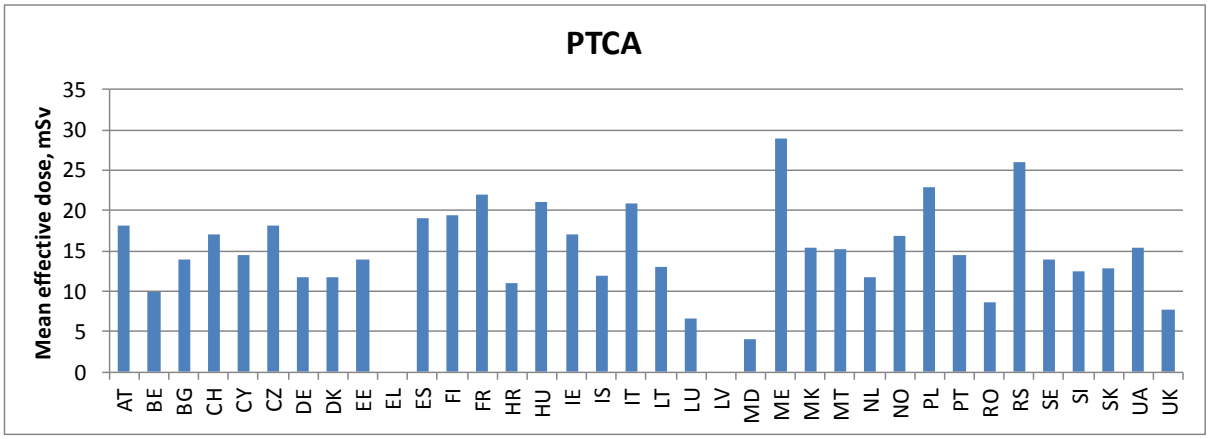

CT abdomen
Mean effective dose, mSv
0
5
10
15
20
25
30
35
AT BE BG CH CY CZ DE DK EE EL ES FI FR HR HU IE IS IT LT LU LV MD ME MK MT NL NO PL PT RO RS SE SI SK UA UK

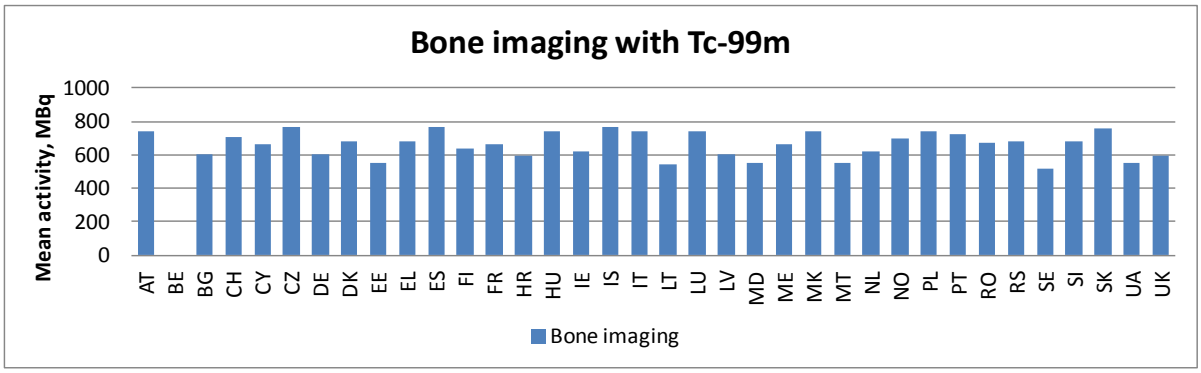

CT pelvis
Mean effective dose, mSv
0
2
4
6
8
10
12
14
16
AT BE BG CH CY CZ DE DK EE EL ES FI FR HR HU IE IS IT LT LU LV MD ME MK MT NL NO PL PT RO RS SE SI SK UA UK

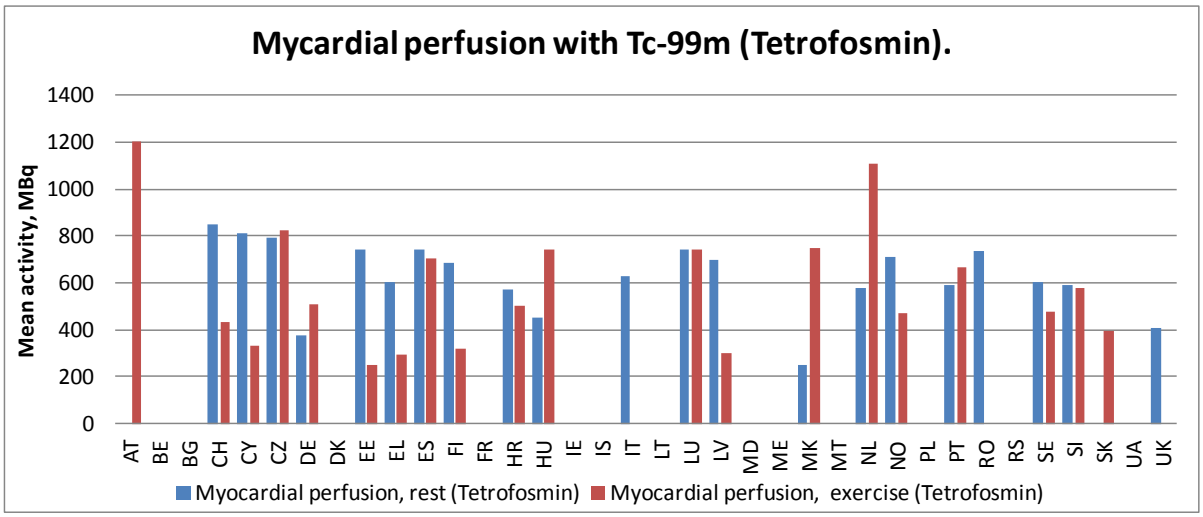

CT trunk
Mean effective dose, mSv
0
10
20
30
40
50
60
AT BE BG CH CY CZ DE DK EE EL ES FI FR HR HU IE IS IT LT LU LV MD ME MK MT NL NO PL PT RO RS SE SI SK UA UK

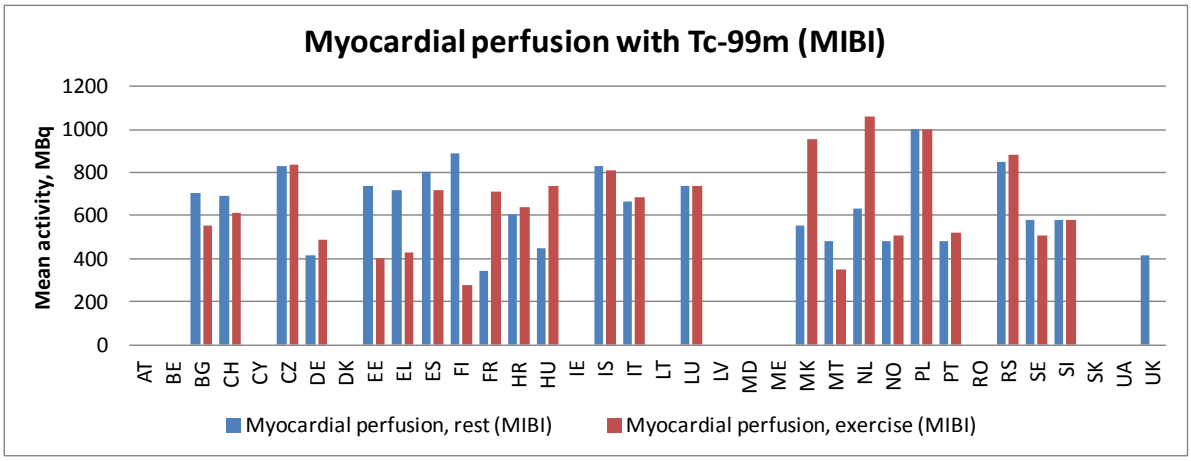


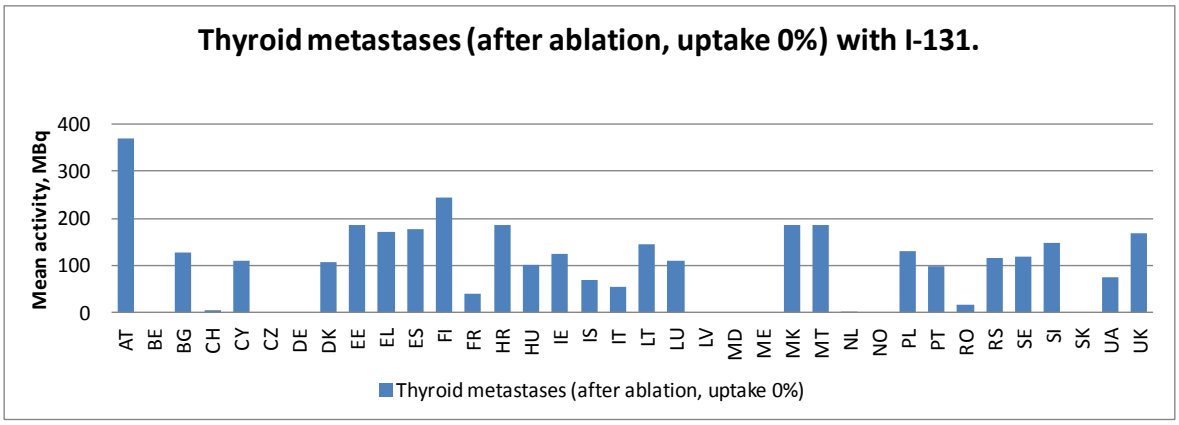
Note: The exceptionally high doses for PTCA in Serbia are due to the fact that common practice in Serbia is that PCI is performed after CA, so the dose reported for PTCA is for combined CA and PCI.

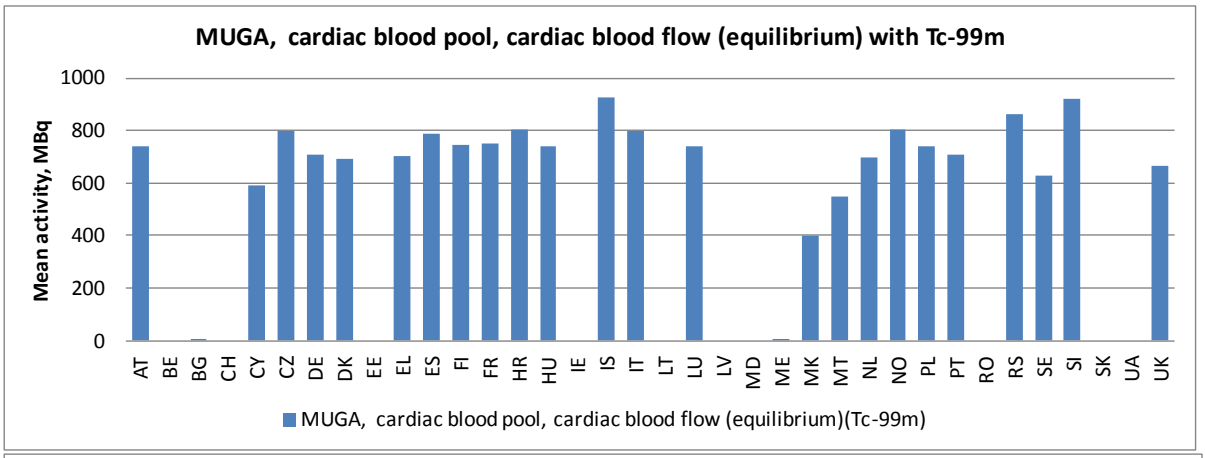
Mean activities for NM procedures

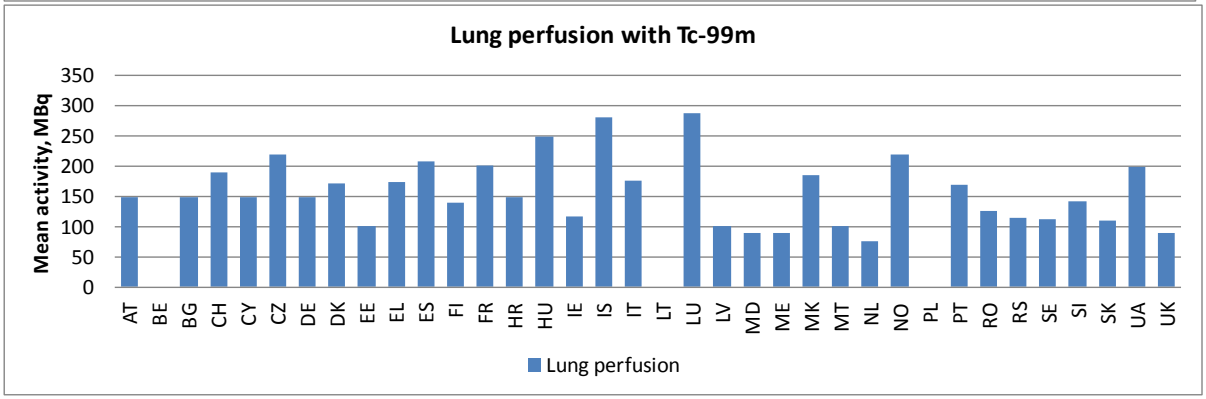


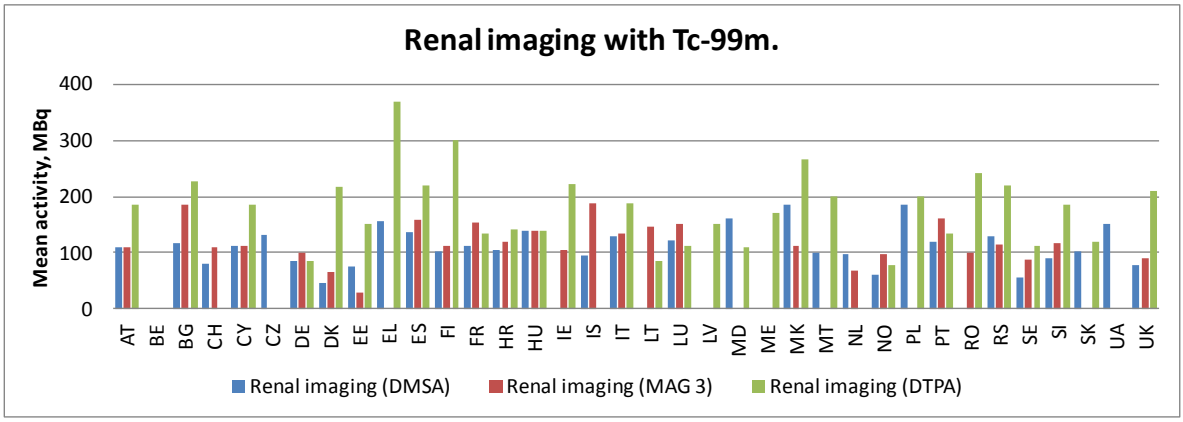


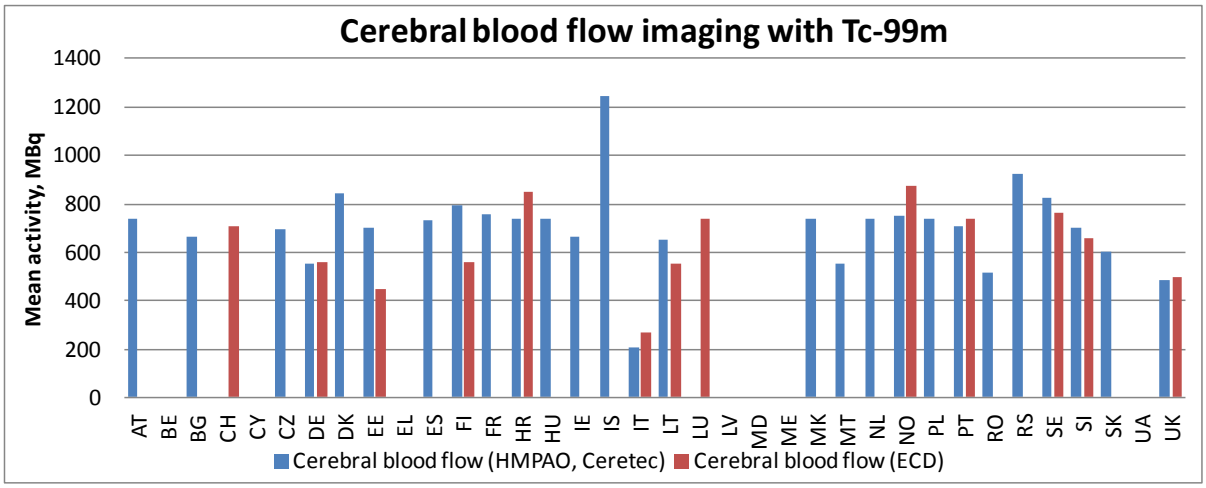

Myocardial perfusion with Tc-99m (MIBI)
Mean activity, MBq
1200
1000
800
600
400
200
0
AT BE BG CH CY CZ DE DK EE EL ES FI FR HR HU IE IS IT LT LU LV MD ME MK MT NL NO PL PT RO RS SE SI SK UA UK
Myocardial perfusion, rest (MIBI)
Myocardial perfusion, exercise (MIBI)

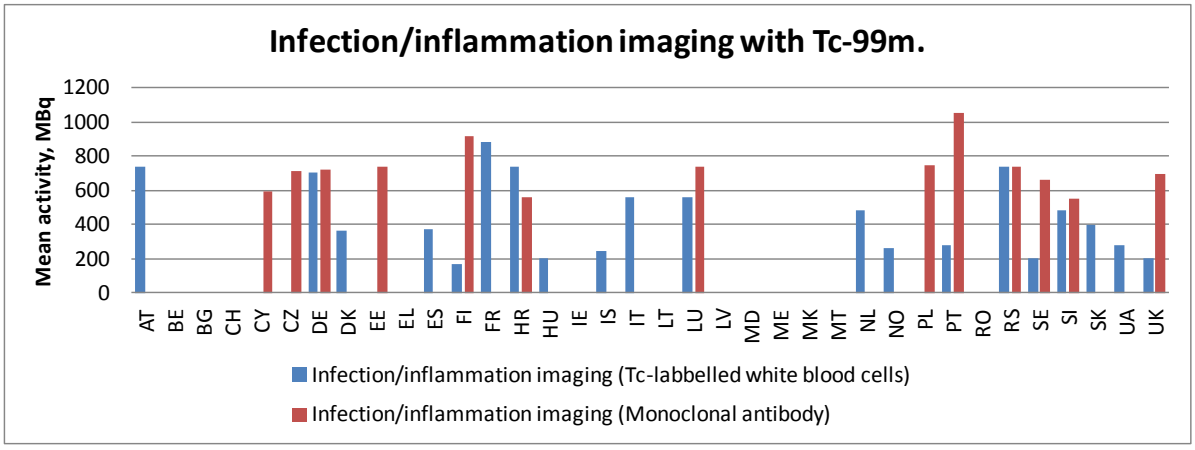

Thyroid metastases (after ablation, uptake 0%) with I-131.
Mean activity, MBq
400
300
200
100
0
AT BE BG CH CY CZ DE DK EE EL ES FI FR HR HU IE IS IT LT LU LV MD ME MK MT NL NO PL PT RO RS SE SI SK UA UK
Thyroid metastases (after ablation, uptake 0%)


MUGA, cardiac blood pool, cardiac blood flow (equilibrium) with Tc-99m
Mean activity, MBq
1000
800
600
400
200
0
AT BE BG CH CY CZ DE DK EE EL ES FI FR HR HU IE IS IT LT LU LV MD ME MK MT NL NO PL PT RO RS SE SI SK UA UK
MUGA, cardiac blood pool, cardiac blood flow (equilibrium)(Tc-99m)


Lung perfusion with Tc-99m
Mean activity, MBq
350
300
250
200
150
100
50
0
AT BE BG CH CY CZ DE DK EE EL ES FI FR HR HU IE IS IT LT LU LV MD ME MK MT NL NO PL PT RO RS SE SI SK UA UK
Lung perfusion


Renal imaging with Tc-99m.
Mean activity, MBq
400
300
200
100
0
AT BE BG CH CY CZ DE DK EE EL ES FI FR HR HU IE IS IT LT LU LV MD ME MK MT NL NO PL PT RO RS SE SI SK UA UK
Renal imaging (DMSA)
Renal imaging (MAG 3)
Renal imaging (DTPA)


Cerebral blood flow imaging with Tc-99m
Mean activity, MBq
1400
1200
1000
800
600
400
200
0
AT BE BG CH CY CZ DE DK EE EL ES FI FR HR HU IE IS IT LT LU LV MD ME MK MT NL NO PL PT RO RS SE SI SK UA UK
Cerebral blood flow (HMPAO, Ceretec)
Cerebral blood flow (ECD)


Infection/inflammation imaging with Tc-99m.
Mean activity, MBq
1200
1000
800
600
400
200
0
AT BE BG CH CY CZ DE DK EE EL ES FI FR HR HU IE IS IT LT LU LV MD ME MK MT NL NO PL PT RO RS SE SI SK UA UK
Infection/inflammation imaging (Tc-labbelled white blood cells)
Infection/inflammation imaging (Monoclonal antibody)

9.6 Annex 6 - COUNTRY SPECIFIC DATA ON THE METHODS OF POPULATION DOSE ESTIMATIONS

In this Annex, brief descriptions of the methods of the latest population dose estimations in various European countries are given. The major features of the population dose estimations are further summarized in Table 6. (x-ray procedures) and Table (nuclear medicine).

9.6.1 BELGIUM

The last population dose survey in Belgium was conducted in 2010 for X-ray procedures. The frequency data was given by the National Health Insurance for RX procedures from a national coding system. Following the RP154 Report, more than 70 examinations were included in the survey except for cardiac angiography and PTCA for which the codes were restricted. The average effective dose was assessed by patient dose survey and calculations using conversion factors published by the ICRP for radiography and CT examinations and recent bibliographic data for all other X-ray modalities.

For NM procedures the national coding system does not allow to classify the various examinations. From a survey launched in the end of 2011 in the nuclear medicine departments, administered activities (minimum and maximum) were defined for more or less 70 NM examinations with a response rate of 66%.

9.6.2 BULGARIA

The national Medical exposure regulation requires the healthcare providers to report every year the number of X-ray and Nuclear medicine procedures to the Ministry of Health, using a standardized questionnaires and classification of 50 codes for X-rays and 34 codes for NM.

The frequency data for X-rays are collected by the National Centre of Public Health and Analysis and the summarized data are provided to the National Centre of Radiobiology and Radiation Protection (NCRRP). Using these data, NCRRP estimates annually the collective dose of the Bulgarian population. The latest X-ray frequency data are based on the information for the procedures performed in 2010. The latest patient dose survey in X-ray procedures was performed by NCRRP in 2007-2008, and the mean effective dose for each examination was assessed by calculations using appropriate software (PCXMC, CT expo, etc) or conversion coefficients, or data were taken from the literature for those examinations for which own measurements were not available.

For NM procedures the healthcare providers are reporting information directly to the NCRRP every year. 100% of the NM centres reported their data on number of NM procedures and typical administered activities in 2010. The mean effective dose was calculated from mean administered activities, using conversion factors published by the ICRP.

9.6.3 CROATIA

The population dose survey in Croatia was conducted for 2010 for X-ray procedures and NM procedures. The frequencies of different examinations were extracted from Croatian Institute for Health Insurance (CIHI) database that covers over 99% of Croatian population. Two different types of coding exists: in-hospital patients are coded according ACHI (Australian classification of health interventions) codes, and out-of-hospital patients are coded using national coding system. The first coding system can be used for 225 examinations approach, but the second one has its limitations even for TOP20 examinations approach. Mammography screening data were also given by CIHI. We decided to use TOP20 approach. To minimize uncertainties and to investigate usability of database, a direct survey in 7 out of 9 major Croatian nuclear medicine departments, 5 interventional cardiology departments and one University hospital was done. The results showed that the CIHI database results must be used with caution.

The average effective dose for each examination was assessed by typical practice survey, output measurements and calculations (by NRPB) for radiography, typical practice and phantom dose measurement survey in mammography (Faj et all, 2008, RPD), by patient dose survey and phantom measurements for CT examinations, by patient dose survey in 5 out of 12

interventional cardiology departments (Faj et al, 2008, RPD; Brnić et al, 2010, RPD), and using average exposure group values from RP154 for other examinations (Ba enema, follow and meal and IVU). Survey of mean administered activities was conducted for NM procedures and calculation, using conversion factors published by the ICRP, was done.

9.6.4 CZECH REPUBLIC

In last years, no whole scale population dose survey was conducted in the Czech Republic. Within years 2003-2010 several dose surveys in particular imaging modalities (general radiography, CT, mammography, dental, paediatric chest X-rays, interventional cardiology) were performed, but population dose was never assessed. For the purpose of Dose Datamed project, frequency data (2009) were obtained from largest health insurance company in CZ, covering 60 % of population and also from Institute of Health Information and Statistics (IHIS) of the Czech Republic annual report 2009, covering 100 % of procedures. In the database of the health insurance company information about frequencies for particular coded exams were obtained. Data from the health insurance company allows to assess sex and age distributions for the coded exams. From the IHIS total numbers of performed exams in the whole population for different imaging modalities (e.g. CT in general) were obtained. Codes of exams in the CZ do not correspond to codes in EC RP 154, main difference is in CT exams. In CZ, CT exams are sorted according to use of contrast agent and number of scans, not according to a region of the body. Frequency of CT exams of different body regions were estimated on a basis of a practice in a large faculty hospital and total number of all CT exams. Typical effective doses of X-ray exams were computed from typical ESD, DAP, DLP using PCXMC or conversion coefficients given in EC RP 154. For NM procedures, E was computed from administered activity.

9.6.5 DENMARK

The last population dose survey in Denmark was conducted in 2009/2010 for X-ray procedures. Frequency data is available from the National Patient Registry for all examinations carried out in hospitals, and data from 2008 was used. Additionally, frequency data for examinations carried out in chiropractic clinics (2006) was obtained. Only examinations carried out at public hospitals and in chiropractic clinics were included in the survey, and a scaling factor of 1.05 was used to account for examinations carried out in private hospitals and clinics. However, later assessment has shown that public hospitals account for 99 % of examinations. Frequency data is available for the 195 examinations types included in the Danish national coding system, but only the Top-20 examinations were included in this survey. Patient doses have been reported from the hospitals for some types of examinations and these were used together with conversion factors to assess average effective doses for these examinations. For the remaining types of examinations, literature values were used.

Population dose surveys have been conducted nearly every year for nuclear medicine procedures, and the values reported here are from survey of 2010 data. Frequency data as well as average administered doses are reported from the hospitals and the coverage is 100 %. Examinations are grouped in around 70 examination types for which frequencies are determined. The average effective dose for each type of examination is determined from the average administered doses using conversion factors.

9.6.6 ESTONIA

In Estonia systematic data collection of patient doses has not been nationally regulated yet. Patient doses have been studied at random since 1999 in some typical examinations in paediatric and adult radiology. For the frequency data collection the both DDM2 questionnaires were sent to the health care providers: the response rate was 53 % (x-rays), therefore data was extrapolated to cover the whole country, and 100% (NM). In 2010, there were 948 X-Ray units (most of them, approximately 74 %, is dental X-Ray) in use by 486 health care providers (hospital departments, medical and dental practices, the latter is approximately 85 % from all users). “TOP20” examinations type and 29 NM examinations were included in the survey. In accordance with the Estonian national coding system, the description for the conditions of the

X-Ray examination depends on the body anatomic region and the number of X-ray exposures. CT examinations in Estonia are categorized in CT head and CT trunk only. The use mean value for CT trunk dose to mean effective dose for all CT neck &c hest & spine & abdomen & pelvis has resulted in a collective dose.

The average effective dose for each examination was reassessed based on EC RP154 Report and calculation from mean administered activities, using conversion factors published by the ICRP, for NM procedures.

9.6.7 FINLAND

The last population dose survey in Finland was conducted in 2008 for X-ray procedures and 2009 for NM procedures. The frequency data was collected by questionnaires carried out by the Radiation and Nuclear Safety Authority (STUK) to the healthcare providers; the response rate was 98 % (x-rays) and 100 % (NM). All 799 type of x-ray examinations and about 80 NM examinations, in accordance with the Finnish national coding system, were included in the survey. The average effective dose for each examination was assessed by patient dose surveys and calculations (by PCXMC) for radiography, by patient dose surveys and phantom measurements for CT examinations, by patient dose surveys and recent bibliographic data for all other x-ray modalities and by calculation from mean administered activities, using conversion factors published by the ICRP, for NM procedures.

9.6.8 FRANCE

The last population dose survey in France was conducted in 2007 by the Institute for radiation protection and nuclear safety (IRSN) and the National institute for public health surveillance (InVS). The frequency data was obtained from two sources:

for private practice : date was provided by the national health insurance data for a representative sample of 1% of the population (about 500 000 persons),

for public practice, 2 surveys in public hospitals; in radiology the survey included 50 hospitals (about 12% of the public hospitals). In NM, a questionnaire has been sent to the 127 public NM departments (response rate 72%).

All 269 types of x-ray examinations and 108 types of NM examinations, in accordance with the French national coding system, were included in the survey.

The average effective dose for each examination was assessed:

for conventional radiology and CT: by patient dose surveys and annual DRL study carried out by IRSN, and calculated using PCXMC, CTExpo or conversion factors from DAP or DLP to effective dose for radiology and CT,

for all other x-ray modalities (dental and interventional): by patient dose surveys and recent bibliographic data,

for NM procedures: by calculation from mean administered activities assessed through the survey described above, using conversion factors published by the ICRP.

9.6.9 GERMANY

In Germany, surveys on frequency of diagnostic procedures are conducted annually, data being available for 1996 to 2009. The survey of 2011 refers to 2009. Estimates on frequencies are mainly based on German health insurance data, namely on specific codes used for the reimbursement of radiological procedures. These codes are well suited to estimate the frequency of X-ray and NM examinations, since in Germany almost 98% of the population has full-cover health insurance (statutory or non-statutory, i.e. full-cover private). There are about 100 / 40 codes referring to X-ray / NM diagnostics (in each case, i.e. different codes for statutory and non-statutory health insurance). The out-patient sector is completely covered by estimates from health insurance data where about 80% of all radio-diagnostics are performed in out-patients. For in-patients, representative data come from surveys of German hospitals. In 2009, about 85 Mio. X-ray exams (+ 33 Mio. dental) and 3 Mio. NM exams were performed. The

effective doses per X-ray exam type were calculated using measured quantities, e.g. KAP, and conversion factors which were either obtained from literature or by using the software X-RAY DOSIMET-RG which is based on the results of Monte Carlo calculations with anthropomorphic phantoms. For NM procedures, effective doses were estimated from mean administered activities using conversion factors published by the ICRP.

9.6.10 GREECE

The last population dose survey in Greece was conducted in 2005 for X-ray procedures and 2009 for NM procedures. The frequency data was collected by questionnaires carried out by the Greek Atomic Energy Commission (GAEC) to the healthcare providers; the response rate was 20 % (x-rays) and more than 86% (NM). 45 types of x-ray examinations and 14 types of NM examinations were included in the survey. The average effective dose for each examination was assessed by patient dose surveys and calculations (by PCXMC) for general radiography and mammography, by Greek bibliographic data for CT examinations and by calculation from mean administered activities, using conversion factors published by the ICRP, for NM procedures.

9.6.11 ICELAND

The last population dose survey in Iceland was conducted in 2008 for X-ray procedures and in 2009 for NM procedures. The frequency data was collected by questionnaires carried out by the Icelandic Radiation Safety Authority (IRSA) to the healthcare providers; the response rate was over 90 % for both x-rays and NM.

The survey extends to just over 1000 different examination codes in use for all x-ray and NM examinations, as they are also used for reimbursement purposes.

The average effective dose for each examination is based on patient dose surveys, conducted over a period 5 years (2004-2009), were Dose Area Product (DAP) was measured patient examinations in radiography, fluoroscopy, interventional and angiography examinations. For mammography the effective dose is based on measured Mean Glandular Dose (MGD) during patient examinations. For CT examinations the effective dose is based on collected data on Dose Length Product (DLP) for CT examinations. For NM procedures the effective dose is based on calculations from mean administered activities in patient examinations, using conversion factors published by the ICRP.

9.6.12 ITALY

The survey included 5 Italian regions (Emilia-Romagna, Friuli Venezia Giulia, Lombardia, Toscana, Umbria) accounting for approximately 30% of the population.

The included radiology procedures in 2006 (reference year) covered several broad categories: projection radiography (Chest/Thorax; Cervical, Thoracic and Lumbar spine; Mammography; Abdomen; Pelvis and hip); radiography and fluoroscopy (Ba meal and Ba enema; Intravenous urography); interventional radiology (Cardiac angiography; Percutaneous Transluminal Coronary Angioplasty); computed tomography (CT head; CT neck; CT chest; CT spine; CT abdomen; CT pelvis).

In nuclear medicine many examinations and radiopharmaceuticals were considered: Adrenal cortical scintigraphy (I-131); Bone imaging (Tc-99m); Bone marrow scintigraphy (Tc-99m); Cerebral blood flow (Tc-99m); Dopamine transporter imaging (I-123); Esophageal-gastric-duodenal transit (Tc-99m); Evaluation of heterotropic gastric mucosa (Tc-99m); Infection/inflammation imaging (Tc-99m, Ga-67); Lung perfusion (Tc-99m); Lymphatic and lymph nodes scintigraphy (Tc-99m); Multiple Gated Acquisition scan (Tc-99m); Myocardial perfusion (Tc-99m, Tl-201, F-18); Neuroendocrine tumours (In-111); Parathyroid imaging (Tc-99m); Renal imaging (Tc-99m); Scintigraphic study of cancer (Ga-67, I-123, I-131); Tumor imaging (F-18); Thyroid imaging (Tc-99m, I-123) and metastases (I-131); Ventilation lung scan (Tc-99m).

For each procedure were requested to each region both the frequency and the dose: the metric of the latter was selected depending on the type of examination (Entrance Skin Dose in projection radiography, Kerma Area Product in interventional radiology, Entrance Skin Air Kerma and Average Glandular Dose in mammography, Dose Length Product in computed tomography, Administered Activity in nuclear medicine). Where a region was not able to provide data for a specific examination, the results were interpolated on the basis of the other regions data. Using appropriate conversion coefficients effective dose per examination were estimated and, finally, data extrapolated to the entire Italian population, to assess collective effective dose and per caput effective dose.

The uncertainties at 95% confidence level were calculated according to the Dose DataMed2 criteria: in radiology procedures, the total relative uncertainties were 9.3% and 11.4% for frequency and collective dose, respectively.

9.6.13 LATVIA

The estimation was performed in 2010. The frequency data for NM was collected by data provided by the healthcare providers. We got response from all hospitals delivering NM procedures. In NM questionnaire were included more than 99% of all NM procedures. The mean administered activities for each examination was calculated from patient examination data.

The frequency data for different X-ray examinations was not collected because of late involvement in DDM2 project and lack of national database of patient dosimetry. However, the total number of X-ray procedures for 2010 was obtained from the national statistics for the following groups of exams: radiography, fluoroscopy (including diagnostic angiography), CT (with and without contrast), and interventional (endovascular). Since frequency data for Latvia were close to the average values for Europe and dose data were not available, the collective dose was estimated using the average values from the DDM2 survey.

9.6.14 LITHUANIA

The last general dose survey in Lithuania was conducted in 2008 for X-ray procedures (except interventional procedures) and 2011 for interventional procedures (IR) and for NM procedures. For computer tomography (CT) procedures dose data was updated in 2009 and for plain film radiography in 2011. Because the frequency data is available only for total number of x-ray and NM procedures, the frequency of procedures (except CT, IR and NM) was calculated by taking average frequency % from RP 154. The frequency data of CT, IR and NM was collected in 2010 by questionnaires carried out by the Radiation Protection Centre to the healthcare providers; the response rate was 95 % (CT), 100 % (IR) and 100 % (NM). ALL TOP 20 (except CT trunk) and 11 the most popular in Lithuania NM examinations were included in the survey. The average effective dose for each examination was assessed by patient dose surveys, measurements with TLD and calculations (by PCXMC) for plain film radiography, by patient dose surveys and phantom measurements for CT examinations, by patient dose surveys and recent bibliographic data for all other x-ray modalities and by calculation from mean administered activities, using conversion factors published by the ICRP, for NM procedures.

9.6.15 LUXEMBOURG

Article 12 of the European Directive 97/43EURATOM [1] obliges the Member States to determine the population dose from medical exposures. In 2005, the Radiation Protection Department of the Ministry of Health in Luxembourg implemented these requirements of this European Directive and conducted the first national evaluation on radiation doses from diagnostic procedures in Luxembourg [2]. The evaluation was based on frequency information of more than 250 types/codes of diagnostic radiation examinations, covering conventional radiology, computed tomography, interventional radiology and nuclear medicine.

Although the relatively high radiation exposure associated with computed tomography has been known for a long time the first evaluation in 2005 has provided valuable information on the situation of diagnostic radiology in Luxembourg and it showed that over 50% of the received dose comes from computed tomography.

The examination frequency data provided to the Dose Datamed II project were abstracted from electronic records of the National Health Insurance which covers about 99% of Luxembourg's population. Concerning the dosimetric data some measured patient doses of examinations were available from national DLR surveys [3,4]. Most of the information regarding the effective dose per examination was taken from the published literature.

The Radiation Protection Department of the Ministry of Health has initiate and carried out in cooperation with the Public Research Centre Henri Tudor (Tudor), the Luxembourgian Society of Radiology, the Federation of Hospitals (FHL) and CT experts for medical dose optimisation several studies to optimize the radiation exposure of patients due to CT. To publish the results of the actions taken , national CT conferences were organised in 2008, 2010 and 2011. Further actions have been announced on the last conference in 2012 with a special focus on paediatric examinations.

The planned electronic "Radiology Passport" will have an important role to play and might help to decrease medical radiation exposures in Luxembourg [5].

European Council: Directive 97/43/EURATOM Health protection of individuals against the dangers of ionising radiation in relation to medical exposure; Memorial of the European Union Nr. L 180 from 9th July 1997, p. 22-27

Medical exposure of the population from diagnostic use of ionizing radiation in Luxembourg between 1994 and 2002, Shannoun F, Zeeb H, Back C, Blettner M. Health Phys. 2006, 91: 154-162

Réglement grand-ducal du 16 mars 2001 relatif à la protection sanitaire des personnes contre les dangers des rayonnements ionisants lors d'expositions à des fins médicales. Memorial A no 66 du 6 juin 2001. Service central de legislation – 2001 – Luxembourg.

Dose optimisation in computed radiography. A. Schreiner-Karoussou. Radiation Protection Dosimetry (2005). Vol. 117, No 1-3, pp-139-142. Nuclear Publishing Technology.

Benefits of a National Electronic Radiological Record, Jahnen A, Pruski C, Bouzid H, Jerusalem N, Krippes R, Roth U, Benzschawel S, Back B, Med-e-Tel 2010, 14-16.04.2010 Luxembourg, Luxexpo, Published in: Global Telemedicine and eHealth Updates: Knowledge Resources", Vol. 3, 2010

9.6.16 FORMER YUGOSLAV REPUBLIC OF MACEDONIA

This is the first survey ever performed for frequency of examination and assessment of effective dose in Macedonia. A questionnaire about frequency of TOP20 examinations was sent to all 85 X-ray departments in the country and 57 of them (67%) provided data. A questionnaire for Nuclear medicine was sent to all three NM departments and all of them (100%) provided data. Since there is no a national coding system and the coverage of national codes, an additional letter for type examination categorization was accompanied to the questionnaire. It was used a calculation method of estimating the mean (typical) effective dose for plain radiography, CT and interventional radiology by using of mean effective doses for TOP20 exams according to the RP154 European Guidance. For effective and collective effective dose in NM examinations it were used conversion factors from the ICTP 80 report.

9.6.17 MOLDOVA

The population dose survey in the Republic of Moldova was conducted for the first time (until now there are no responsible central authority for data collection and evaluation). Following the recommendations of the EC RP154 Report for the study 9 persons was included in the team to carry out the tasks: Coordination (and contact person), experts in areas: Radiology (Nuclear Medicine), Dosimetry, Public Health, Statistics, and Project Management. The frequency data was collected for the period y.y.2000-2010(only y.2010 was presented for DDM2) by questionnaires carried out by the Centre of Radiation Protection (CRP) of the National Centre of Public Health (NCPH) of the Ministry of Health RM as follow: - for the NM the questionnaires were distributed to 5(100%) healthcare providers; - for X-Ray the CRP collected the data about the number of investigations from so-called Radiological Centre and the doses were

investigated and evaluated by CRP during the QC control procedures. The collected data rate was 49% (from 225 institutions for X-Rays) and 80 % (from 5 institutions for NM). Top 20 type of X-Ray and NM examinations was selected for the first evaluation. In the Republic of Moldova the obsolete (not actual) code (statistical) system is in use (Radiological Centre - data manager). The average effective dose was assessed for audits only: - for X-Ray examination by patient dose surveys, calculations, and phantom measurements, and - for NM by calculation from mean administered activities, using conversion factors published by the ICRP.

9.6.18 MONTENEGRO

Montenegro is a small, developing country with the population of 670 000 inhabitants. There are approximately 80 large X-ray units for radiological diagnostics, 250–300 dental ones, 12 CTs (Computed Tomography), 15 mammography devices, 3 densitometers, two angiography units and one NM. Most X-ray generators (50 %) work in high frequency mode, 19 % in three phase/six pulse, 6 % in twelve pulse rectifications and 25 % have monophase/two pulse unit.

A quality control (QC) system was started five years ago. The first survey in Montenegro of patient doses in diagnostic radiology was conducted in 2010 as part of the results for my PhD thesis. Part of results of patient dose surveys for CT has been collected by a colleague Ms. Sonja Ivanovic for the project RER/9/093. Results for mammography have missed because I do not have appropriate equipment in order to determine the main glandular dose (MGD) or effective dose. Following the recommendations EC RP154 I have gathered all the frequencies within your questionnaire for all TOP 20 groups (DOSE DATAMED 2). The response rate was 100 % (x-rays) and 100 % (NM). It should be emphasized that patient dose monitoring has no tradition in radiological practice in Montenegro. There are no established national diagnostic reference levels (DRL). Another poor practice reflects the lack of patient dose records in radiological practice per year and population.

Exposure analysis covered 6 most frequent diagnostic centres in 6 different medical institutions, in 3 towns (Podgorica, Niksic, Bar). The X-ray tube output (or ESAK) and uncertainty was measured according to the IAEA Code of Practice (Technical Reports Series No. 457- IAEA). With applying proper conversion coefficients, ESAK represent the basis for dose estimations for total effective dose for an individual patient, by using various software packages, like NRPB-SR62 and PCXMC.

9.6.19 NORWAY

The Norwegian Radiation Protection Authority (NRPA) has the authorization to request information about examination frequency, administered activity and patient doses, and has made regular assessments of the use of diagnostic radiology and nuclear medicine since the 80thies in order to explore trends in the use of different imaging modalities and impact on population doses. The two last frequency studies relate to the years 2002 and 2008, both have been based on the main principles in the European guideline RP154 with annexes. We collect frequency information for magnetic resonance- and ultrasound imaging as well.

X-ray based radiology (Radiography, fluoroscopy, angio/intervension, CT), MR and Ultrasound

Annual numbers of examinations was obtained directly by questionnaires sent to all Norwegian hospitals, clinics and practices. The Norwegian College of Radiology had through more than twenty years developed a code system that has been used both for activity analysis and reimbursement [1]. The number of codes was gathered from the radiological information systems (RIS) in all departments, from which actual numbers of examinations were estimated. Some problems of double-counting, particularly with examinations of double-sided organs had to be adjusted for, and likewise examinations which consisted of several contrast series that would create more than one radiological code in the system.

For radiographic and fluoroscopic X-ray examinations the dosimetry in Norway has been based on the dose-area product, PKA. In older days, the data were collected by site visits to all hospitals by the NRPA. For CT examinations the CT dose index for the actual scanners, CK, were either measured or looked up in the literature, while the technique parameters for standard protocols and for certain clinical indications were collected by questionnaires to all CT rooms.

The Monte Carlo based conversion coefficients published by the former NRPB in the UK (now part of the Health Protection Agency) were used to calculate the effective dose. Since 2004, the dose values are based on collected information from the hospitals and X-ray institutes by asking for their local diagnostic reference levels (DRL's) or "representative dose values"; these are the mean values for 20 representative patients in each X-ray or CT room.

23% of the examinations were done in private sector, the rest in public hospitals. In the time period from 2002 to 2008 the number of planar X-ray is reduced; ultrasound is about the same, while both CT and MR have doubled in frequency. As a result, the part of the total dose caused by CT has increased from 59% (2002) to 80% (2008) even though the collective effective dose has not changed since 2002. Simple radiographs involve lower doses to the patient today compared with the situation before the millennium, while fluoroscopic examinations show examples of both higher and lower doses. It is worth noticing that CT examinations generally gives lower doses today compared with the 90s, except for CT of the spine.

Nuclear Medicine

A questionnaire was sent to all 25 hospitals in Norway with nuclear medicine to collect information about the practice of examinations. The collective effective dose to the Norwegian population from nuclear medicine (NM) was calculated using information on the number of NM procedures and the average effective dose per procedure. In the calculations of average effective dose per procedure, information on the average administered activity per procedure and the effective dose per activity was required. This information was derived from the questionnaires and the ICRP Publication 80, respectively.

Conclusion

The average effective dose in Norway has not changed since 2002. This is partly explained by technological advances in CT, but also the implementation of new radiation protection regulations since 2004, with increased focus on quality assurance and optimisation/diagnostic reference levels (DRL's). Nuclear medicine contributes about 5% to this total dose.

References:

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StrålevernInfo 1012:2 Nukleærmedisinske undersøkingar og behandlingar. http://www.nrpa.no/dav/42aeb29342.pdf (Text Norwegian)

9.6.20 POLAND

Estimation of medical exposure for Polish population was based on few sources of data. The annual frequency and dose for the plain film radiography and fluoroscopy examinations estimated by National Centre for Radiation Protection in Health Care (NCRPHC) were based on data collected in 2006 for UNSCEAR. The frequency data for computed tomography was assessed using the number of procedures reimbursed by National Health Fund (NHF) in 2010. As the NHF coding system is based on the international classification system for surgical, diagnostic and therapeutic procedures ICD-9 the modalities that don't have its counterpart in ICD-9 (i.e. CT pelvis, spine and trunk) were approximated using data obtained by NCRPHC from private health care providers and recent bibliographic data. For all X-ray modalities the average effective dose for each examination was assessed by patient dose surveys and bibliographic data. The average effective dose for NM procedures were calculated on the basis of mean administered activities using conversion factors published by ICRP.

9.6.21 PORTUGAL

Radiology exams:

In order to determine the frequency of the TOP 20 exams for the year 2010, and obtain robust data we have proceeded to:

compile the frequency data from the Civil Servants' reimbursement system (10% of exams)

compile the frequency data from the reimbursements of the exams performed under the "conventioned" regime (roughly 20% of exams);

perform a hospital survey in order to obtain the annual frequency of the exams performed in the "general regime" i.e. reimbursed on a hospital basis), by sending out a questionnaire. Out of 122 Hospitals in Portugal, 28 responded to the questionnaire, which gives a 23% representation.

For the Angiography and PTCA exams we asked the APIC (Portuguese Association of Cardiovascular Intervention) which compiles data to give us their annual number of exams for the year 2010.

In order to obtain the final results, we summed the values obtained from the ADSE, the 5 ARSs and an extrapolation of the data of the values obtained from the Hospital survey. Rhe PTCA and the Angiography exam values were obtained directly from the APIC. The remainder of the exams (from the other subsystems - military, judicial, etc.) account for only approximately 5% of the total exams and we thus not considered in this study.

In order to estimate the typical patient dose for the TOP20 x-ray examinations, we have proceeded to:

Compile the existing academic and published studies (total of 31 studies) and analyse their relevance in the scope of this project (10 relevant studies);

Additional measurements/dose data gathered with a pilot study conducted in 7 public hospitals (3 in the north region, 3 in the centre and 1 in the south), 2 private hospitals in the centre region and 7 Health Centres in the south region of Portugal.

Nuclear Medicine exams:

A survey, based on the one designed by the Dose Datamed II consortium, consisting of an excel sheet with a set of 28 nuclear medicine exams, were sent to all nuclear medicine healthcare providers in Portugal with a request to fill a form with the annual frequency data, together with the average administered activity per procedure. For a universe of 26 centers with significant statistics, 19 centres replied to the survey, which corresponds to a 73% response rate to the survey. We used a linear extrapolation to obtain the values for the entire country.

9.6.22 SERBIA

The systematic population dose survey in Serbia has never been performed. For the purpose of Dose Datamed II project frequency data collection trough questionnaire was performed by Radiation and Environmental Protection Department of Vinca Institute of Nuclear Sciences, which is a licensed technical service for radiation protection and medical physic support to hospital. Data were collected from approximately 40 % x-rays units and 71% nuclear medicine departments. For x-ray procedures, hospitals were classified according size and number of x-ray units to Clinical centres, Clinical hospitals, General hospitals and Small health centres. The fraction of institutions participated in the survey was 50% (2/4) for clinical centres, 75% (3/4) for Clinical hospitals, 48% (19/40) for General hospitals and 8% (12/157) for small health centres with only a few x-ray units. Data collection was performed in 100% (2/2) departments with more than one gamma camera and 62% (8/13) departments with one gamma camera. National coding system suitable for population dose assessment is not available in Serbia, as multiple radiological examinations are pooled in the single code. Trough questionnaire, data was collected for 20 x-ray and 18 nuclear medicine examination types. The average effective dose for each examination was assessed by patient dose surveys and calculations (using conversion factors available from literature of NRPB software packages) for radiography, fluoroscopy

including interventional procedures and CT. The patient dose surveys in terms of suitable dosimetric quantities have been performed in the recent years and published in the peer reviewed journals or presented on the international conferences. Patient dose in NM procedures was calculated from mean administered activities, using conversion factors published by the ICRP.

9.6.23 SLOVAKIA

The last survey of population exposure from medical application of ionizing radiation was conducted in the common work of Slovak and Czech public health professional bodies, published by Kodl and Šnobr in Čsl. Radiologie 42,1988,54.

In Slovakia, the survey conducted in the framework of DDM project is the first one conducted on the basis of the EC Report No.154/2008 and started by the Institute of Radiation Protection, together with the Slovak Medical University.

In 2009 there were 3500 healthcare providers in Slovakia having the licenses to run an X-ray unit, covering the hospital departments and medical practices (incl.dentists).

Slovakia has a national radiological procedures code system for categorization of procedures (x-ray and NM procedures), which is applied in our survey.

The frequency data were collected by two sources of information:

the National Health Information Centre and

the main Slovak Health Insurance Companies, covering about 80% of all diagnostic examinations, as well as the examinations of nuclear medicine.

For the dose assessment, the DQC module have been installed in the 15% of the Slovak hospitals and departments of radiology, covering in the total about 1 Mil selected examinations per year.

In Dose Datamed II study, 67 142 selected examinations are presented, divided into the following X-ray modalities:

9 374 CT examinations (mean Eff.dose 16,7 mSv for abdomen examinations)

23 785 conventional examinations (plain film screen and digital radiography)

31 914 mammographies (film and digital with mean AGD=1,44 mGy)

389 examinations of intervention radiology

1 023 PET-CT procedures (Eff. dose 14 mSv) and 657 gamma scanner examinations of NM

For the above monitored procedures, all exposition parameters were collected and the individual as well as the average effective doses were assessed by using the new conversion coefficients and the methods recommended by the ICRP.

For all monitored examinations, included in the DDM report, also the radiation outputs were available for the x-ray units involved, as well as the results of the last Acceptance tests and the protocols of the Tests of long term stability.

9.6.24 SLOVENIA

The frequency data was collected by the Slovenian Radiation Protection Administration in 2011 via questionnaires to the healthcare providers. The response rate was 100% for NM and about 2/3 (representing approximately 90% of the total workload in Slovenia) for X-ray. The missing frequencies for X-ray were estimated from data collected during licensing procedures and/or from insurance database. Data were gathered for TOP20 X-ray procedures and for over 40 NM procedures. The average effective dose for all examination was determined from measurements of the relevant quantities on a number of patients during regular practice. Data were collected in the past few years and are available for approximately 2/3 of institutions performing plain film radiography (DAP per projection), all mammography units (MGD from phantom measurements) and all units performing PTCA, for about 80% of CT units (DLP per

phase) but is scarce for fluoroscopy, except for cardiac angiography (known for all units). Measured quantities were converted to the effective dose using conversion factors available from the literature. For nuclear medicine effective doses were calculated from mean administered activities using conversion factors provided by DDMED2 project or from the literature.

9.6.25 SPAIN

An intensive population dose and frequency survey for x-ray procedures (plain radiography, fluoroscopy, CT and interventional radiology) and NM procedures have been developed (DOPOES and DOMNES projects supported by the Nuclear Safety Council (CSN) and the Ministry of Health of Spain).

X-Ray Procedures

The data provided included 5 Spanish regions (Andalucia, Murcia, Extremadura, Castilla La Mancha y Aragón) accounting for approximately 40% of the Spain population. The number of codes was obtained from the RIS-PACS systems; in each hospital selected and grouped in TOP_20 according to the RP154 European Guidance. We used several dose quantities like entrance surface dose (ESD) or the dose-area product (DAP) for simple radiography, the total dose-area product for fluoroscopy examinations, and the dose-length product (DLP) for CT examinations, and MGD (mean glandular dose) in Mammography. For all X-ray procedures the effective dose were estimated following the recommendations of the RP 154 report.

Nuclear Medicine

The frequency data from NM was collected for year 2011 by questionnaires carried out by the DOMNES consortium and the questionnaires were distributed to all NM departments (167) and 70% of them provide data. Effective doses were estimated from mean administered activities using conversion factors published by the ICRP.

9.6.26 SWEDEN

The last population dose survey in Sweden was conducted in 2008 for x-ray procedures (plain radiography, fluoroscopy, CT and interventional radiology) and 2010 for NM procedures. Frequency data from all x-ray procedures during 2008 were collected from a sample of hospitals in Sweden. From each hospital, data was retrieved from the local radiological information systems (RIS) comprising local RIS codes, examination description and number of examinations. Most, but not all local RIS codes corresponded to the national coding system. Non-matching codes could be identified by checking the description of examination given together with the code. By this time consuming procedure a rather complete estimate of the frequencies for the TOP 20 examinations could be performed. Frequency data from the sample was scaled up to represent the whole country by using information from a national survey from 2005. Data for all NM procedures are collected each year and contains for each procedure; frequency, used isotope and administrated mean activity.

In 2008 all Swedish hospitals reported the patient doses for 12 x-ray examinations, as the average for approximately 20 normal sized patients for every examination room. These examinations correspond to 11 of the TOP 20 categories and hence the average of the radiation doses reported was taken as the national dose value for the respective examination. For the remaining 9 categories, tabulated dose values from the RP154 were used. Patient dose for NM procedures was calculated using reported mean activities and conversion factors published by ICRP.

9.6.27 SWITZERLAND

The last survey in Switzerland was conducted in 1998 and the annual effective dose from medical radiology was estimated to be 1 mSv/capita. For the national survey performed in the country for collecting the 2008 data, an online database (www.raddose.ch) was developed. All healthcare providers who hold a license to run an X-ray unit in the country were invited to participate in the survey by sending their annual frequency data. In 2008, there were 17,391 X-ray units in use by 8,247 healthcare providers (hospital departments, medical and dental

practices). Following the recommendations of the EC RP154 Report, more than 225 examinations, covering eight radiological modalities, were included in the survey. The average effective dose for each examination was reassessed by audits and surveys for radiography and CT examinations and recent bibliographic data for all other modalities. Data from about 3,500 users were collected (42% response rate; 45% in terms of X-ray units) and extrapolated to cover the whole country according to the number of X-ray units, taking also into account the type of healthcare provider.

9.6.28 UKRAINE

The last population dose survey in Ukraine was conducted in 2009-2011 for X-ray procedures and in 2009 - for nuclear medicine (NM) procedures.

Method of frequency collection

The frequency data for X-ray and NM procedures was collected using method of questionnaire survey carried out by Grigoriev Institute of Medical Radiology in 2009-2011 and in according to data of the Medical Statistic Centre of MoH of Ukraine for 2009. The questionnaires about annual frequency data of diagnostic procedures were sent to the Regional Body of MoH for regional radiology department that are responsible for statistical data of survey. Participation in questioning was accepted by 24 from 27 Regions of Ukraine that covered the information about 85 % procedures in Diagnostic Radiology. All Ukrainian laboratories and departments of NM have been covered by survey. In the review of DDM2 Ukraine presented the data about the 22 types of X-ray and 15 types of NM procedures.

At present in Ukraine there is not national coding system of diagnostic researches.

Method of estimating the mean (typical) effective dose (for plain radiography, fluoroscopy, CT and interventional radiology)

The average effective dose for all type of radiographic procedures has been estimated by a calculation method with the Program ODS-60 (Finland) using the data of ionization dosimetry. The average effective dose for fluorography has been estimated by phantom modeling and using the average values of ESDs from measurements in different hospitals.

For all other X-ray procedures: fluoroscopy, CT, angiography, interventional procedures, the effective doses were estimated following the recommendations and data of the EC RP154 Report. The estimation of effective doses in NM was spent by calculation from mean administered activities (data from questionnaire), using conversion factors published by the ICRP (data from EC RP154 Report).

9.6.29 UNITED KINGDOM

The latest population dose surveys in the UK were conducted in 2008 for X-ray procedures and 2004 for nuclear medicine procedures. In 2008 the Health Protection Agency collected X-ray frequency data for 231 examinations and interventional procedures from a sample of National Health Service hospitals in England. The total number of X-ray examinations and procedures in the UK, in both the state and private sectors, was estimated to be 46 million. The average effective dose for most of the X-ray examinations was calculated from measurements of entrance surface dose or dose-area product contained in the National Patient Dose Database. Doses for CT were provided by a national survey for 2003. Where no data on an examination was available, a dose was estimated either from a similar type of examination, or taken from the literature.

In 2004 a questionnaire was sent to every known nuclear medicine centre in the UK, and a 66% response rate was achieved.

Table A6.1. Basic data for national surveys of population dose for x-ray procedures

	Country	Survey Date (year)	Population millions	Source of frequency data (CA, HP, HI, OT)*	Sample covered	Scaled up to whole country based on	Number of exam types	Dental included (yes/no)	Age/sex data (yes/no)	Method to determine effective dose per exam	Uncertainty estimate provided (yes/no)
1	Austria		8,7								
2	Belgium	2010	10,8	CA	100%	-	70	yes	no	Meas+calc +literature	no
3	Bosnia and Herzegovina		4,6								
4	Bulgaria	2010 Frequency; 2007 – 2008 Dose	7,535	CA	>95% of the health centers	no	50	yes	Partially (3 age groups: (0-15); (16-40); (>40 y)	Calc+meas +literature	yes
5	Croatia	2010 Frequency; 2008 – 2010 Dose	4,4	HP, HI	100,00%	-	20	No	Partially	Calc+meas +literature	Y
6	Czech Republic	2006-2011	10,5	HI, OT	HI 60 % of population OT 100 % of performed exams	linear extrapolation to whole population	Top 20	yes	yes	Conv. Coeff. EC RP 154, calculations	no
7	Denmark	2008 Frequency ; 2010 Dose	5,7								
8	Estonia	2010	1,3	HP	53%		20	No	No	literature	rough estimate, foreign data only
9	Finland	2008	5,4	CA	100 %	-	225+	Partially	Partially	Calc+meas +literature	yes
10	France	2007	65,6	CA	12 % of X rays dept	Examination number	269	yes	yes	Calc+meas +literature	yes
11	Germany	2009	81,8	HI (out-pat.), HP (in-pat.)	100% (op), 25% (ip)	Number of in-patients	About 70	Yes	Only for in-patients	Calc+meas +literature	yes
12	Greece	2003-2005	10,96	HP	20%	Weighted extrapolation	45	No	No	Calc+meas +literature	rough estimate
13	Hungary	2010	9,9								

	Country	Survey Date (year)	Population millions	Source of frequency data (CA, HP, HI, OT)*	Sample covered	Scaled up to whole country based on	Number of exam types	Dental included (yes/no)	Age/sex data (yes/no)	Method to determine effective dose per exam	Uncertainty estimate provided (yes/no)
14	Iceland	2008	0,32	CA	100 %		TOP20	yes	no	Calc+literature	Yes
15	Ireland	2010	5,4								
16	Italy	2006	60,6	HP	100%**	Linear extrapolation to whole population	From 18 to 45	no	Some regions	Calc + meas+ literature	yes
17	Latvia	2010	2,2	-	0%	-	-	no	no		no
18	Lithuania	2010	3,2	CA	20.9 % of X-ray units	Number of x-ray units	19	No	No	Calculations + measurements + literature	Yes (rough estimate)
19	Luxembourg	2009	0,6								
20	Former Yugoslav Republic of Macedonia	2010	2,0	CA	67% X-Ray; 100% NM	Number of X-ray units	20	No	No	Calc+meas +literature	Yes (DDM2 team)
21	Malta	2011	0,4								
29	Republic of Moldova	2010	3,57	CA	49% of x-ray institutions	Number of x-ray institutions	Top 20	Yes	No	x-ray: Calc+meas	Yes
22	Montenegro	2010	0,67	HP	100%	-	-	no	partialy	Meas+calc +literature	yes
23	Netherlands	2009	16,9								
24	Norway	2008	4,7								
25	Poland	2010	38								
26	Portugal	2010	10,6	CA, HP	45%		20	no	no	Meas+literature+calc	yes
27	Republic of Belarus		9,65								
28	Republic of Cyprus	2011	1,0								
29	Romania	2010	20,8								
30	Serbia	2009/2010	7,123	OT	Clinical Centers (50%), Clinical hospitals (75%), General hospitals (48%), and Small health	Number of hospitals which were distributed in 5 categories according to	20	No	No	Literature, calculations and measurements	Yes

	Country	Survey Date (year)	Population millions	Source of frequency data (CA, HP, HI, OT)*	Sample covered	Scaled up to whole country based on	Number of exam types	Dental included (yes/no)	Age/sex data (yes/no)	Method to determine effective dose per exam	Uncertainty estimate provided (yes/no)
					centers(8%), Average: 18% in terms of health institutions, it terms of x-ray units rough assessment would be 40%	their size (Clinical Centers, Clinical hospitals, General hospital, and Small health centers)					
31	Slovakia	2010	5,4	HP,HI	15% of Radiology Departments	yes	Top 20	No	Yes	Calc+meas +literature	No
32	Slovenia	2011	2,1	CA, HP	100%	/	20	No	No	Measurements + conversion factors	Yes (estimate)
33	Spain	2010	51,1								
34	Sweden	2008	9,2	HP	20% of examinations	Information from a complete survey from 2005	20	no	no	Meas+ litterature	Yes (rough estimate
35	Switzerland	2008	7,7	HP	45% of x-ray units	Number of x-ray units	225+	Yes	No	Calculations + literature	Yes (rough estimate)
36	Turkey		70,6								
37	Ukraine	2011	45,1								
38	United Kingdom	2008	61	HP	8% of x-ray exams	Total number of x-ray exams	231	Yes	No	Calc + Measure + Literature	Yes

*CA: Central authority (ministry of public health, radiation protection agency, etc.); HP: Healthcare providers (hospitals, practices, etc.); HI: Health insurance companies; OT: Others
** for the 5 Italian regions (out of 21) representing 32% of the Country population

Table A6.2. Basic data for national surveys of population dose for NM procedures

	Country	Survey Date (year)	Population millions	Source of frequency data (CA, HP, HI, OT)*	Sample covered	Scaled up to whole country based on	Number of exam types	Age/sex data (yes/no)
1	Austria	2009	8,7					
2	Belgium	2010	10,8	CA /HP	66%	no	70	no
3	Bosnia and Herzegovina		4,6					
4	Bulgaria	2010	7,535	CA	100%	-	34	2 categories of reporting: Adults/ children
5	Croatia	2010	4,4	HP, HI	100,00%	-	28	Partially
6	Czech Republic	2009	10,5	HI	60 % of population	linear extrapolation to whole population	86 without PET	yes
7	Denmark	2010	5,7					
8	Estonia	2010	1,3	HP	100%	-		No
9	Finland	2009	5,4	CA	100 %	-		No
10	France	2007	65,6	CA	72 %	Examination number	108	No
11	Germany	2009 Frequendies; 2007 – 2008 Activities	81,8	HI	100%	-	25	Yes
12	Greece	2009 Frequencies; 2006 – 2009 Activities	10,96	HP	>86%	Weighted extrapolation	14	No
13	Hungary	2010	9,9					
14	Iceland	2009	0,32	CA	100 %	-	20	No
15	Ireland	2010	5,4					
16	Italy	2006	60,6	HP	100%**	Linear extrapolation to whole population	From 18 to 45	no
17	Latvia	2010	2,2	HP	>99%	-	13	no
18	Lithuania	2010 Frequencies ; 2011 Activities	3,2					
19	Luxembourg	2009 Frequencies ; 2011 Activities	0,6					

	Country	Survey Date (year)	Population millions	Source of frequency data (CA, HP, HI, OT)*	Sample covered	Scaled up to whole country based on	Number of exam types	Age/sex data (yes/no)
20	Macedonia	2010	2,0	CA	67% X-Ray; 100% NM	Number of X-ray units	20	No
21	Malta	2010	0,4					
22	Republic of Moldova	2010	3.57	CA	80% of NM institutions	Number of NM institutions	Top 20	No, but possible
23	Montenegro	2010	0,62					
24	Netherlands	2009 Freqencies ; 2008 Activities	16,9					
25	Norway	2008	4,7					
26	Poland	2010	38					
27	Portugal	2010	11,1					
28	Republic of Belarus		9,65					
29	Republic of Cyprus	2011	1,0					
2930	Romania	2009	20,8					
30	Serbia	2010	7,123	OT	67%	Number of NM departments according to number of gamma cameras	18	No
32	Slovakia	2010	5,4	HP,HI	15%	No		Yes
33	Slovenia	2010	2,1	CA, HP	100%	/	36	No
34	Spain	2010	51,1					
35	Sweden	2010	9,3	HP	100%	-	90	no
36	Switzerland		7,7					
37	Turkey		70,6					
38	Ukraine		45,1					
39	United Kingdom	2004	60	HP	66%	Gamma cameras	151	No

*CA: Central authority (ministry of public health, radiation protection agency, etc.); HP: Healthcare providers (hospitals, practices, etc.); HI: Health insurance companies; OT: Others
** for the 5 Italian regions (out of 21) representing 32% of the Country population.

9.7 Annex 7 - SUMMARY OF THE RESULTS OF THE GENERAL QUESTIONNAIRE ON THE AVAILABILITY OF FREQUENCY AND POPULATION DOSE DATA

For completeness of reporting, the results of the first general questionnaire of the DDM2 project, on the availability of frequency and population dose data, have been summarized in this Annex. However, conducting the questionnaires, organizing the training course and all other actions within this project have had a tremendous impact on the development of population dose estimations also in those European countries which had little or no previous experiences on this topic (see Section 4.4). In consequence, the data in this Annex has become partly out of date. The present status of population dose estimations (organization, methods) in several countries has been summarized in Annex 6, while the results of the latest estimation for the European population dose have been presented and discussed in Section 5.

9.7.1 Availability of data on x-ray procedures

9.7.1.1 Availability of the frequencies of x-ray procedures

Figure 7.1 shows that in 27 countries (69%) the frequencies of x-ray procedures were available.

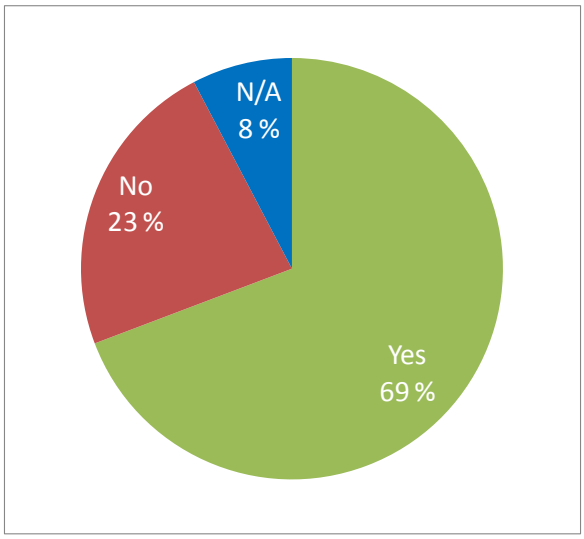


Figure 7.1. Percentage of countries where the frequency of X-ray examination were available or not

9.7.1.2 Types / categories of x-ray procedures

Figure 7.2 shows the number of types / categories of x-ray procedures for which frequency data were available in each country. The number is higher than 200 in 8 countries. In 10 countries it is between 20 and 200 and in 8 countries it is less than 20.

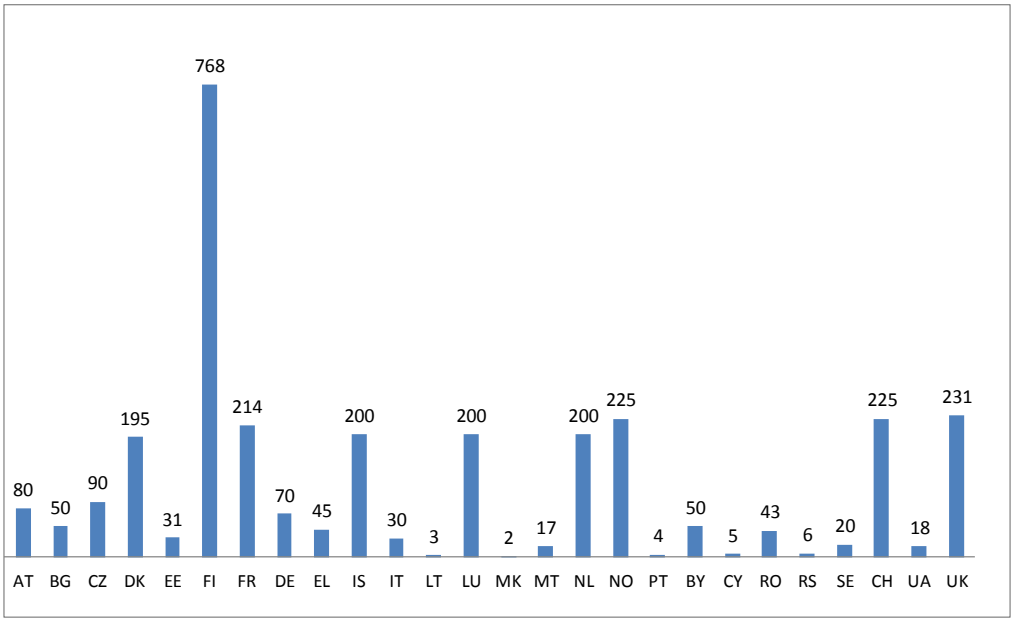


Figure 7.2. Number of types / categories of x-ray procedures for which frequency data were available

9.7.1.3 Years of collections

Among the 26 countries who gave information on the years of collections of the frequency data, 23 have collected data in 2008 or onwards. At least 8 countries could have provided frequencies for 2009-2010.

9.7.1.4 Coverage of total data

Figure 7.3 shows the coverage of the total data, i.e. how many x-ray facilities (in percent of the total number) were covered by the frequency survey. Among the countries that provided information 18 assure coverage higher than 50%, 9 of them have a full coverage (100%).

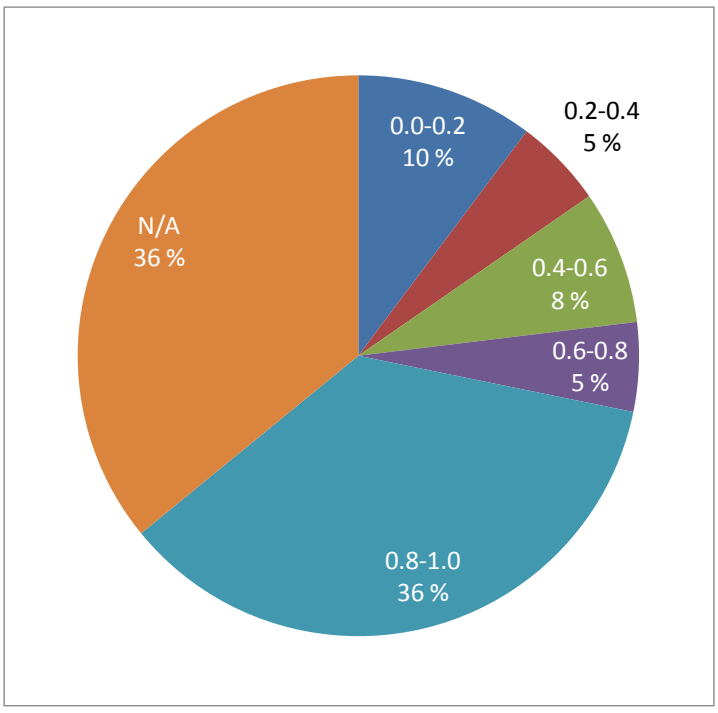


Figure 7.3. Percentage of countries with a coverage of the total data amounting to 0%-20%, 20%-40%,40%-60%, 60%-80% and 80%-100%.

9.7.1.5 *Sources of data*

Among the countries that provided information on the source of the frequency data for X-ray modalities, surveys using questionnaires seemed to be the most commonly used source, followed by RIS/PACS systems, then health authorities and insurance companies (Figure 7.4). In some cases two methods were used: questionnaire and RIS/PACS or insurance company and RIS/PACS. A couple of countries used their legislative tools to get the data that is either collected during the testing of the equipment or are fed into a national registry.

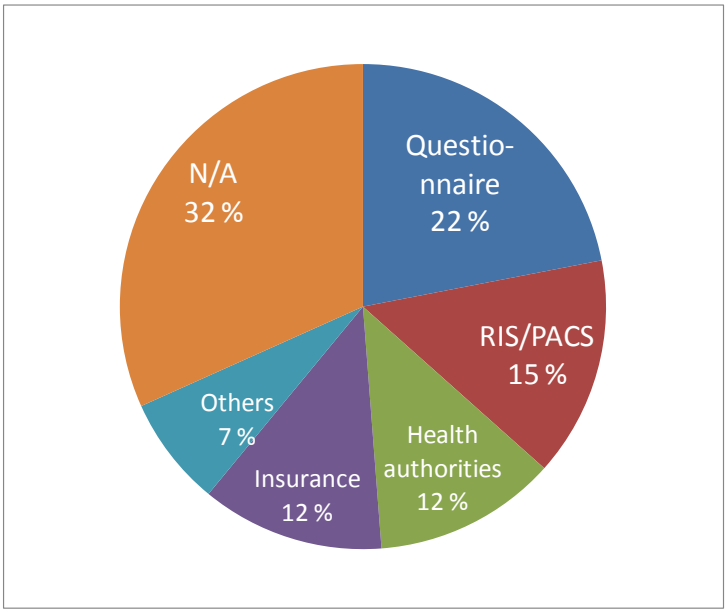


Figure 7.4. Percentage of the various sources of frequency data

9.7.2 Availability of patient dose data for x-ray procedures

9.7.2.1 *Availability*

Half of the countries (19) had patient effective doses for each type of x-ray procedure, as shown in Figure 7.5.

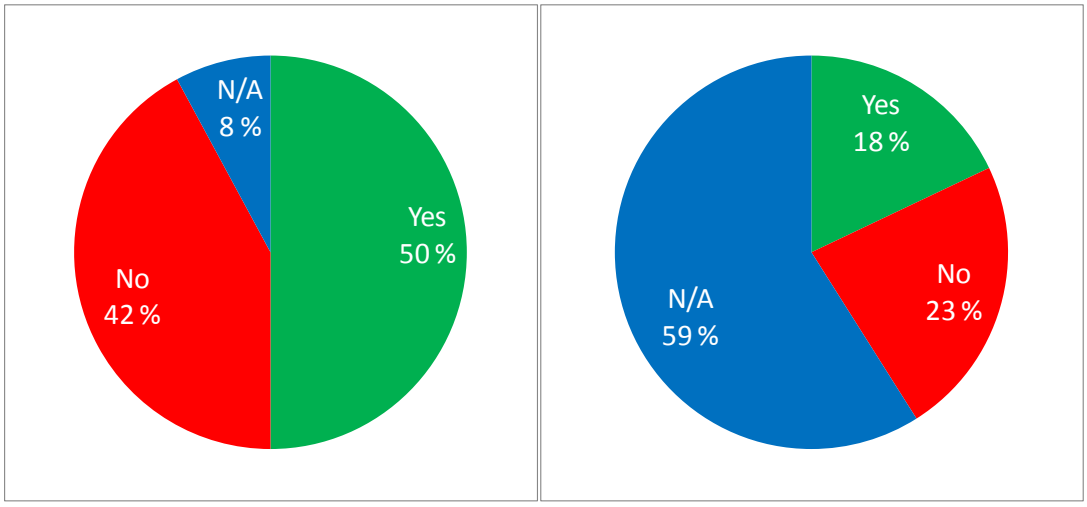


Figure 7.5. Percentage of countries with typical patient effective doses determined for each type of x-ray procedure (left) and for a limited number of types of x-ray procedures, formed by suitable grouping of all types of x-ray procedures (right)

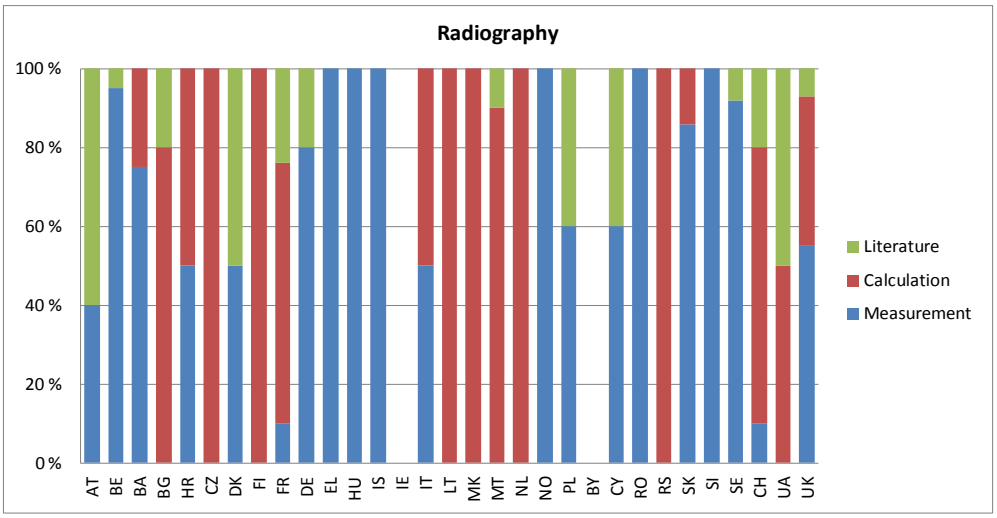
7 countries (almost 1 out of 5) had patient effective doses for a limited number of types of x-ray procedures, formed by suitable grouping of all types of x-ray procedures. The number of these limited types was 150 in BE, 50 in BY, 30 in IT, 18 in RS, 12 in SE, 3 in EL and 1 in IE.

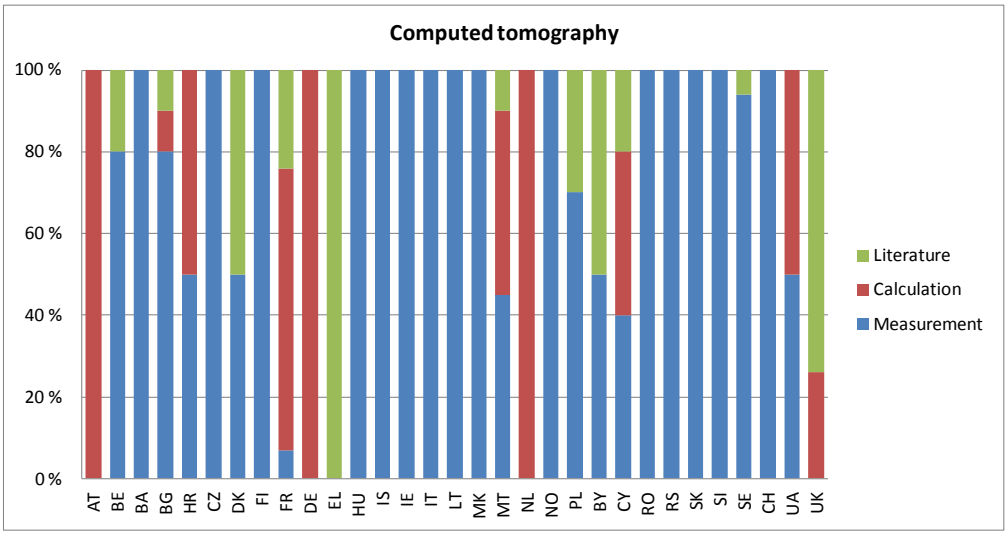
9.7.2.2 Methods of dose determination

Figure 7.6 shows the relative proportion of the three possible methods for dose determination: (1) measurement, i.e. measurement of a practical quantity (KAP, DLP etc) and conversion to effective dose by published conversion factors, (2) calculation, i.e. calculation of effective dose by Monte Carlo (e.g. using a commercial software PCXMC, CTEXPO) or other software, and (3) literature, i.e. taking the effective dose from published literature. The relative proportion of methods is shown separately for general radiography (plain film or projection radiography), computed tomography, and fluoroscopy and interventional radiology. Nine countries did not provide information on the method of dose determination: CZ, EE, LV, LU, ME, PT, MD, ES and TR.

For radiography, 10 countries relied either exclusively or mainly on measurements, 7 countries relied either exclusively or mainly on calculations. The others used a combination of methods.

Concerning computed tomography 17 countries (60%) relied mainly on measurements; 4 relied mainly on calculations and 3 mainly on literature. The remaining countries used a combination of these methods.





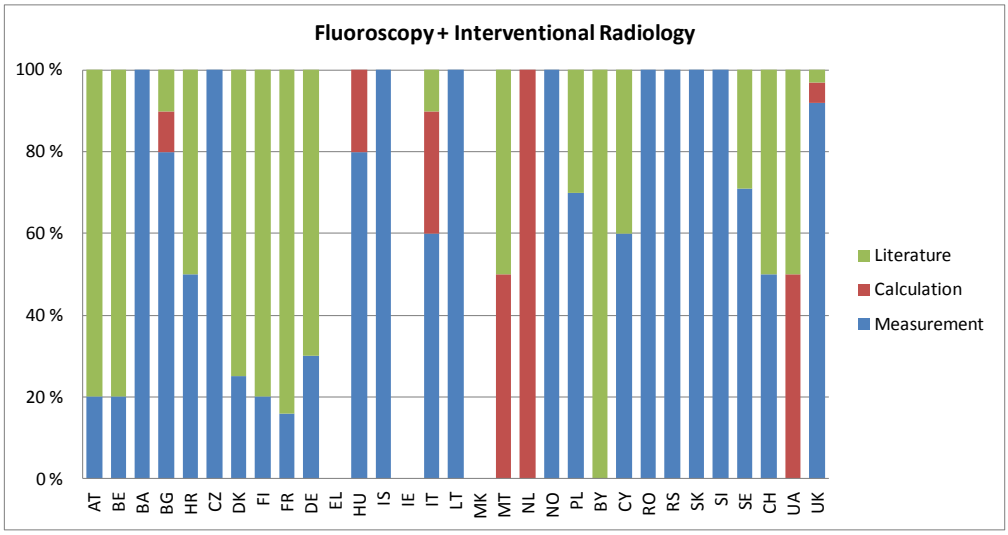


Figure 7.6. Percentage of countries using measurement, calculation or literature for dose determination in the case of radiography, computed tomography, fluoroscopy and interventional radiology.

Regarding fluoroscopy and interventional radiology, most countries relied mainly on measurements (15) or on literature (7). Only one country relied on calculations. The rest used a combination of methods.

9.7.3 Availability of data for nuclear medicine procedures

9.7.3.1 Availability of the frequencies of NM procedures

Fig.7.7 shows that in 29 countries (74%) the frequencies of nuclear medicine procedures were available.

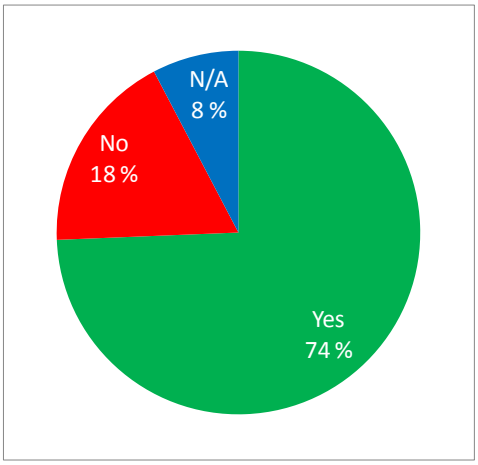


Figure 7.7. Percentage of countries where the frequency of NM examination is available or not.

9.7.3.2 Types / categories of NM procedures

Figure 7.8 shows the number of types/categories of nuclear medicine procedures for which frequency data was available. The number of categories was higher than 50 in 8 countries. In 7 countries it was between 20 and 50 and in 13 countries it was less than 20.

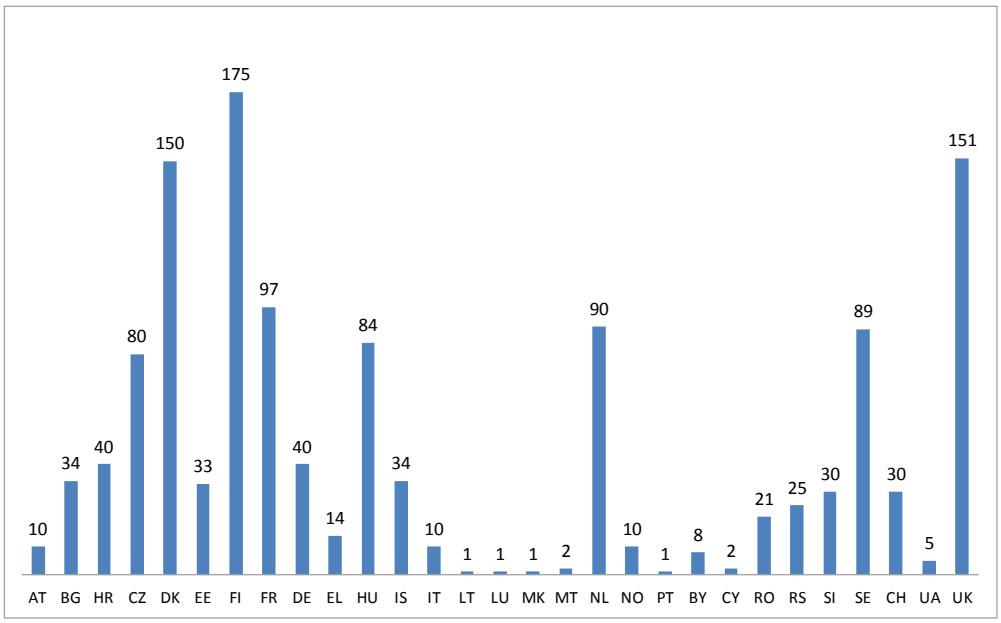


Figure 7.8. Number of types / categories of nuclear medicine procedures

9.7.3.3 Availability of the administered activities

Figure 7.9 shows that in 28 countries (72%) typical data of administrated activities were collected for each type of nuclear medicine diagnostic procedure.

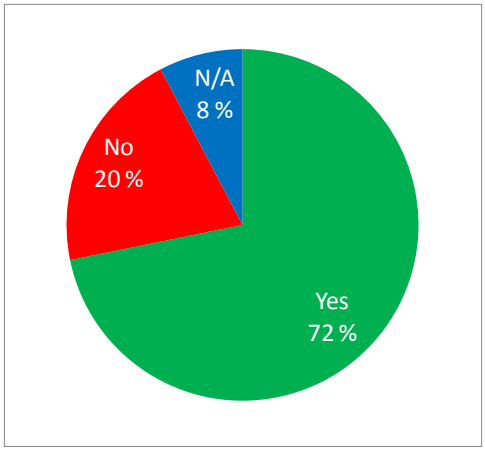


Figure 7.9. Percentage of countries where the data of administrated activity for each type of NM procedure were available.

9.7.3.4 Years of collections

Among the 28 countries who gave information on the years of collections of the frequencies of nuclear procedures, 23 had collected data for 2008 onwards and 10 countries could provide frequencies for 2010.

9.7.3.5 Coverage of total data

Figure 7.10 shows the coverage of total data, i.e. how many NM facilities (in percent of the total number) were covered by the frequency survey. Among the countries that provided information, 24 assured coverage higher than 50%; 18 of them had a full coverage (100%).

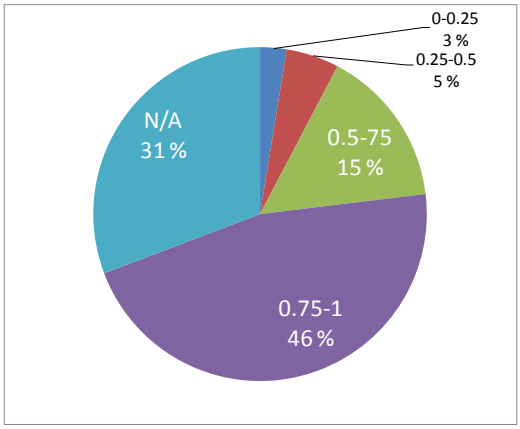


Figure 7.10. Percentage of countries with a coverage of the total data amounting to 0%-25%, 25%-50%, 50%-75% and 75%-100%.

9.7.3.6 Sources of data

Among the countries that provided information about the source of the frequency data for nuclear medicine, the most frequently used source of information was surveys using questionnaires, followed by RIS/PACS systems, then health authorities and insurance companies (Figure 7.11). In some cases two methods were used: questionnaire and RIS/PACS or insurance company and RIS/PACS. A couple of countries used their legislative tools to get the data that was either collected during the testing of the equipment or was fed into a national registry.

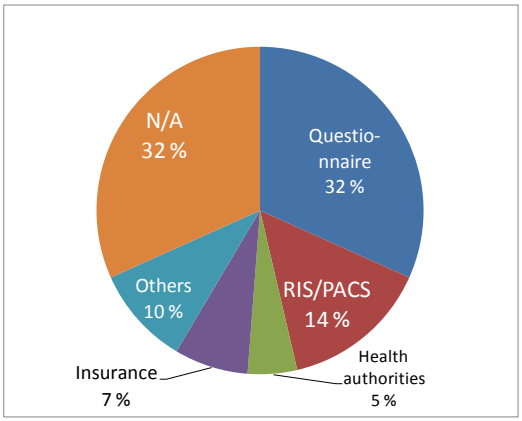


Figure 7.11. Percentage of the various sources of frequency data

9.7.3.7 Conversion factors for effective dose calculation

Figure 7.12 shows that in 21 countries (54%) the effective dose was calculated for each nuclear medicine procedure with a given radionuclide, using published conversion factors (effective dose/activity).

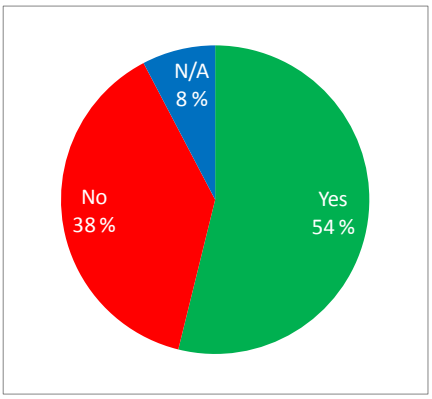


Figure 7.12. Percentage of countries where the effective dose was calculated or not for each NM examination.

9.7.4 Availability of population dose estimations

9.7.4.1 Diagnostic and interventional x-ray procedures

Figure 7.13 shows that in 24 countries (61%) population dose estimation was performed for x-ray procedures, in 21 countries on a national basis and in 3 countries on a regional basis.

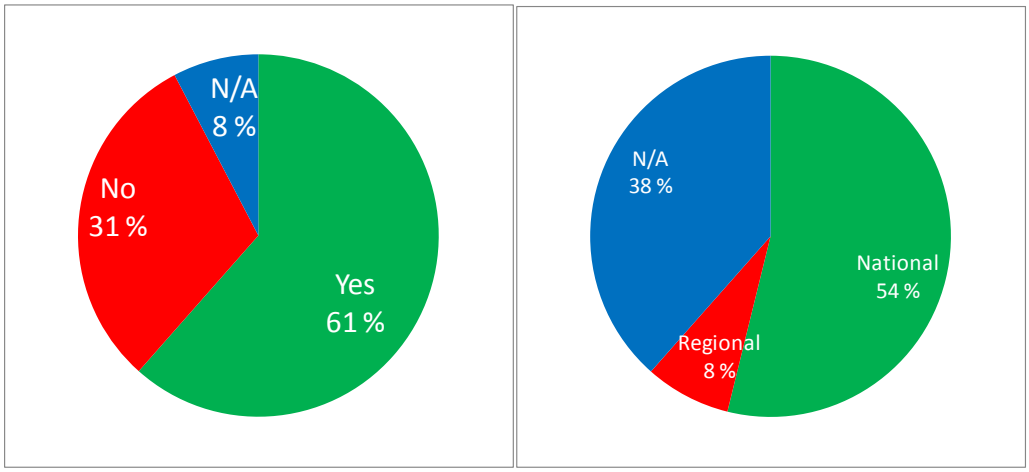


Figure 7.13. Percentage of countries where population dose estimation was performed for x-ray procedures (left) and percentage of countries that performed population dose estimation on a national or regional basis (right).

9.7.4.2 Nuclear medicine procedures

Figure 7.14 shows that in 17 countries (43%) population dose estimation was performed for nuclear medicine procedures, in 16 countries on a national basis and in 1 country on a regional basis.

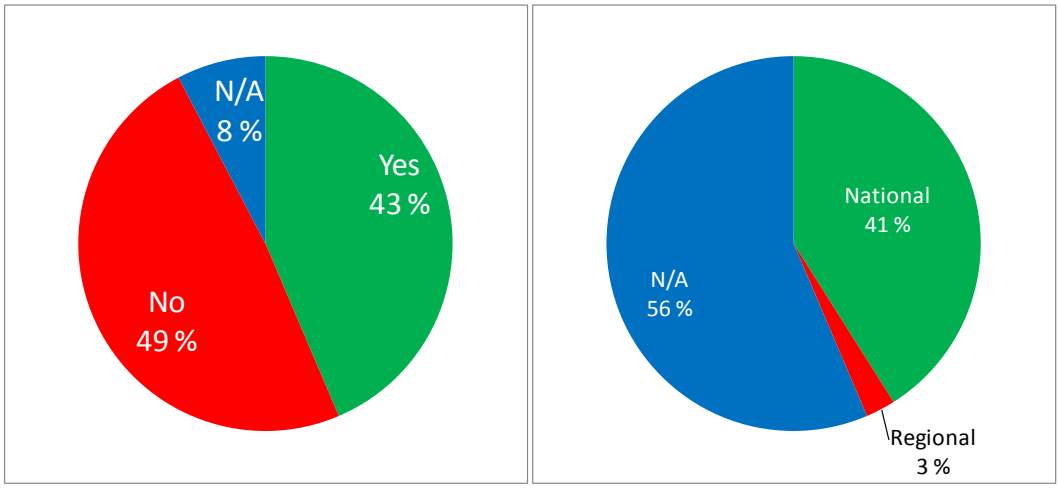


Figure 7.14. Percentage of countries where population dose estimation was performed for nuclear medicine procedures (left) and percentage of countries that performed population dose estimation on a national or regional basis (right).

9.7.4.3 Years of estimations

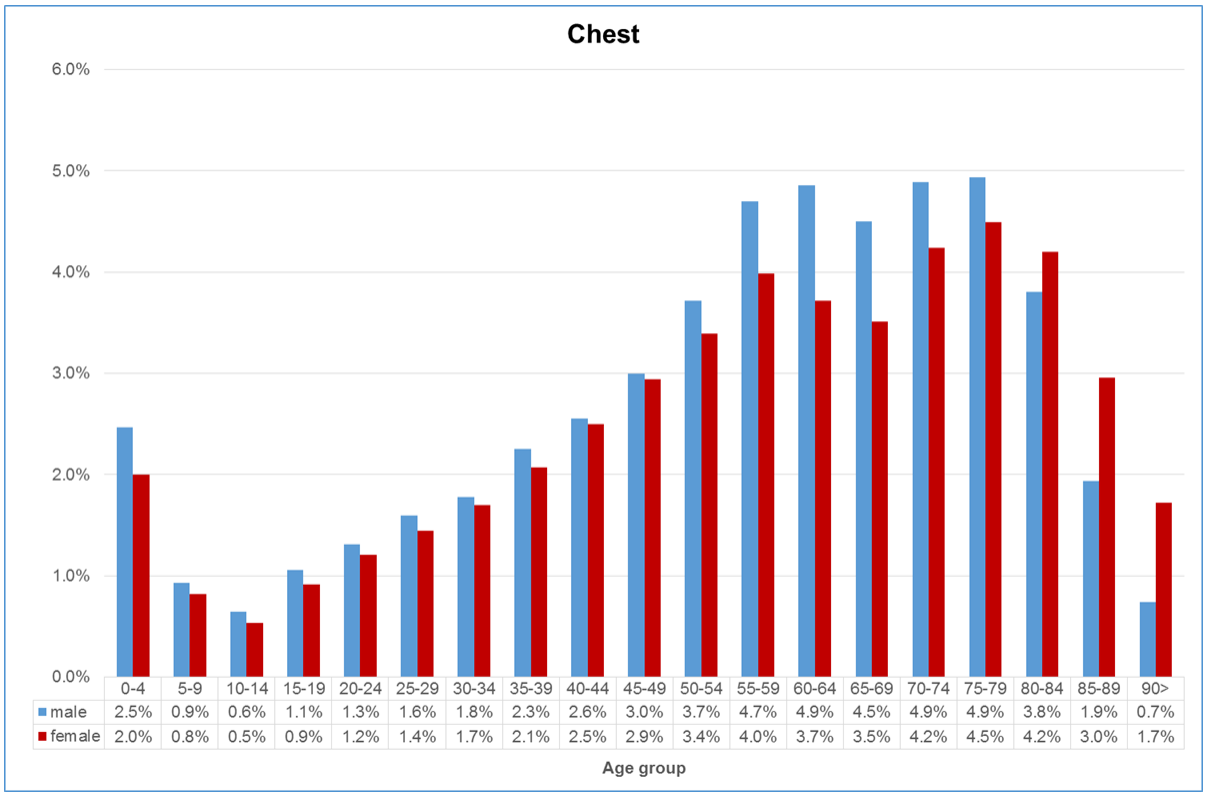
For both x-ray and nuclear medicine procedures, among the 23 countries that provided information on the years of population dose estimations all had recent estimations (last five years).

15 countries did provide information on the years of population dose estimations: BE, HR, CZ, HU, LV, LU, ME, PL, PT, CY, MD, SK, SI, ES and TR.

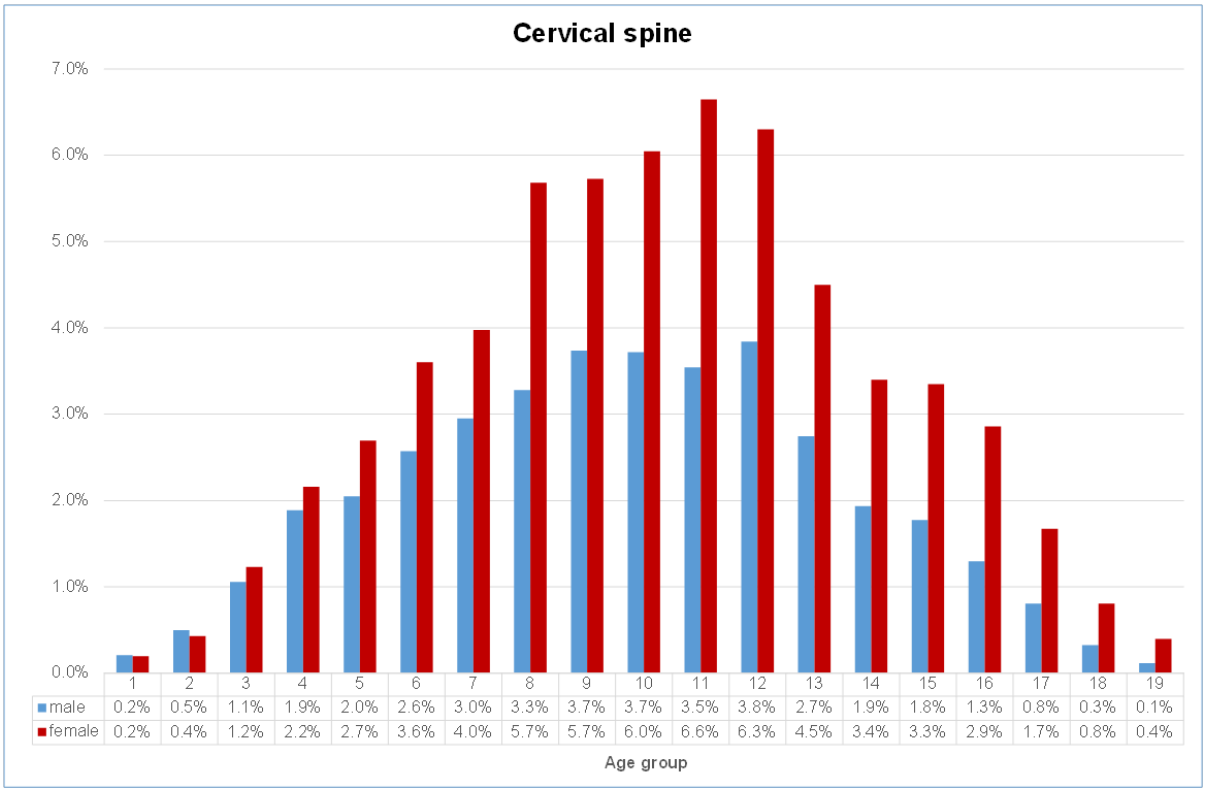
9.8 Annex 8 - TYPICAL EUROPEAN AGE/SEX DISTRIBUTIONS FOR TOP 20 X-RAY EXAMINATIONS OF PATIENTS

The figures shown in this annex (Fig. 8.1) are typical age/sex distributions data for the 'Top 20 Exams' from four countries namely HR, DK, FR and SK. The distributions are based on the average data from these four countries, weighted according to the sample size in each country as shown in Table 7.1 (Section 7.1). The data are divided into five-year age bands and the percentage that is indicated for each band and each gender is taken with respect to the total number of examinations carried out on both male and female patients in these four countries. These percentages are also presented numerically in the legend of each figure.

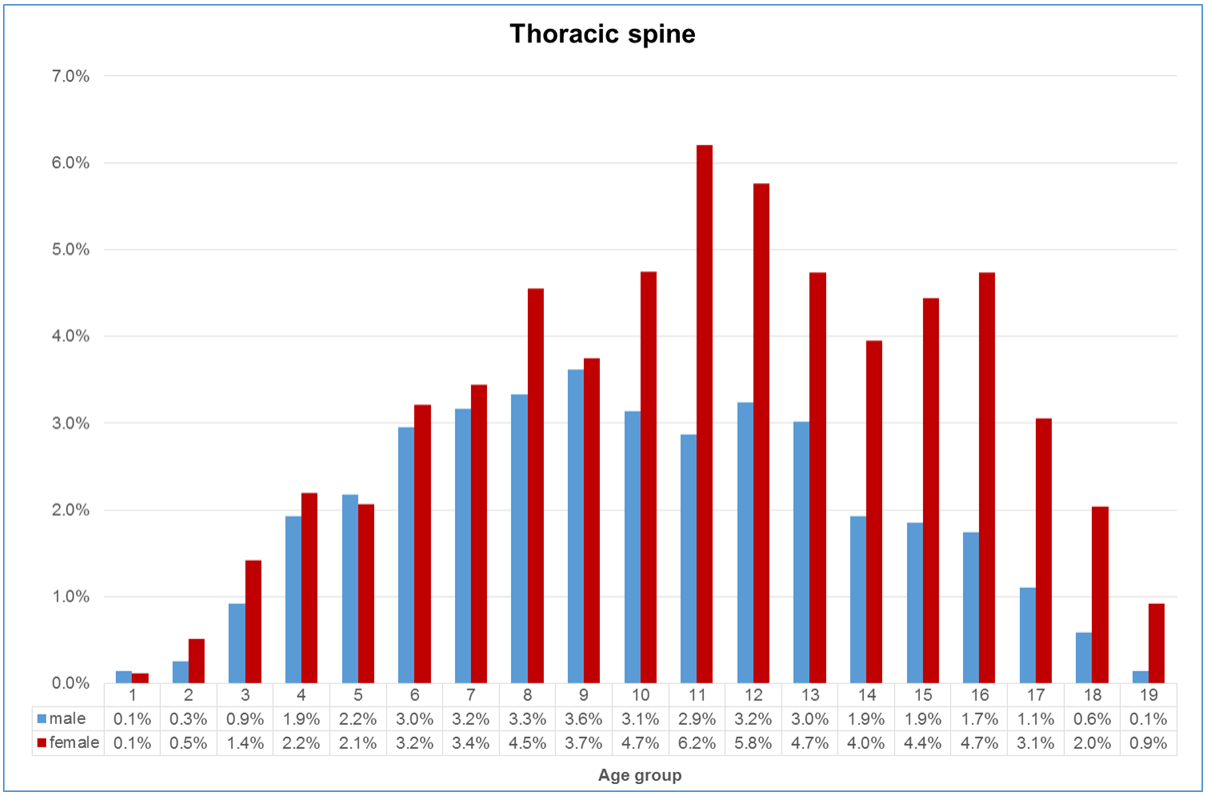
It is suggested that these typical European data can provide a useful guide to the age and sex distributions for these important types and categories of examination that can be used by any European country to relate collective doses to collective detriment, in the absence of more reliable national data. For further information see also annex 3 of the European Guidance on Estimating Population Dose from Medical X-ray Procedures (RP154; EC 2008).



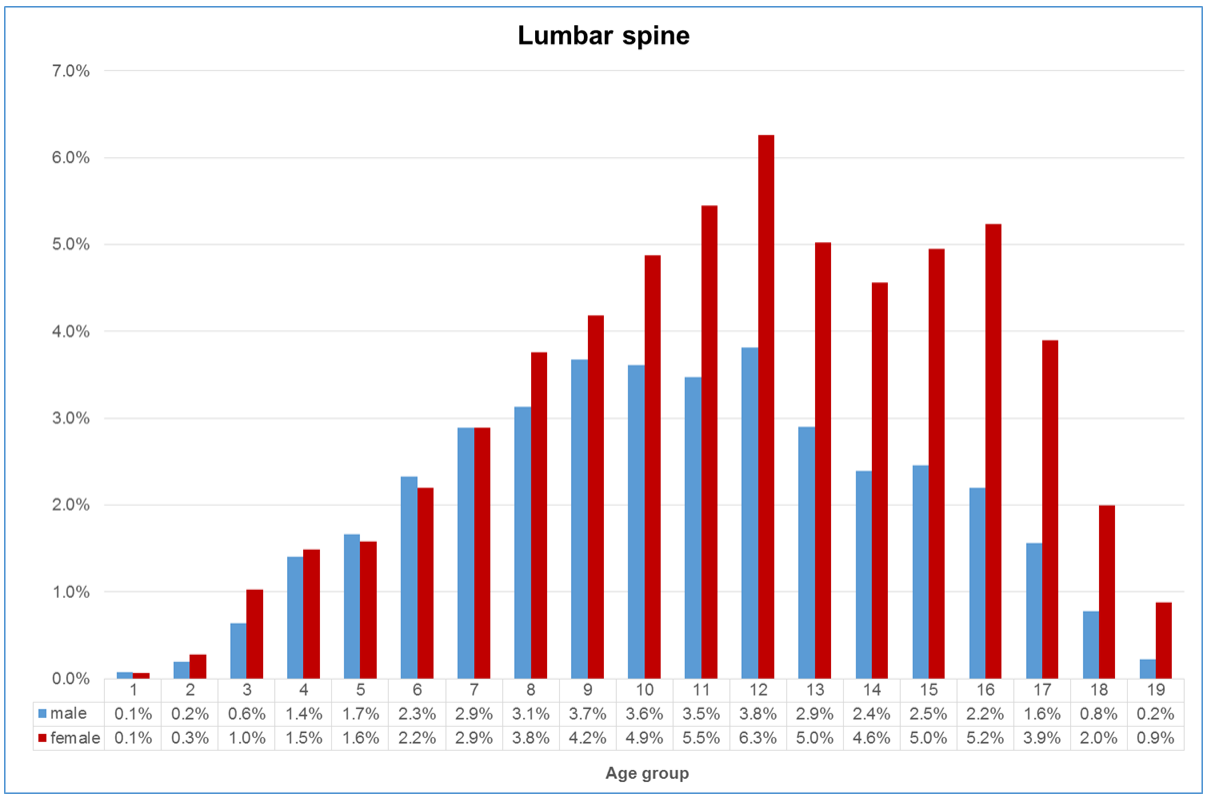
	0-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90>
male	2.5%	0.9%	0.6%	1.1%	1.3%	1.6%	1.8%	2.3%	2.6%	3.0%	3.7%	4.7%	4.9%	4.5%	4.9%	4.9%	3.8%	1.9%	0.7%
female	2.0%	0.8%	0.5%	0.9%	1.2%	1.4%	1.7%	2.1%	2.5%	2.9%	3.4%	4.0%	3.7%	3.5%	4.2%	4.5%	4.2%	3.0%	1.7%



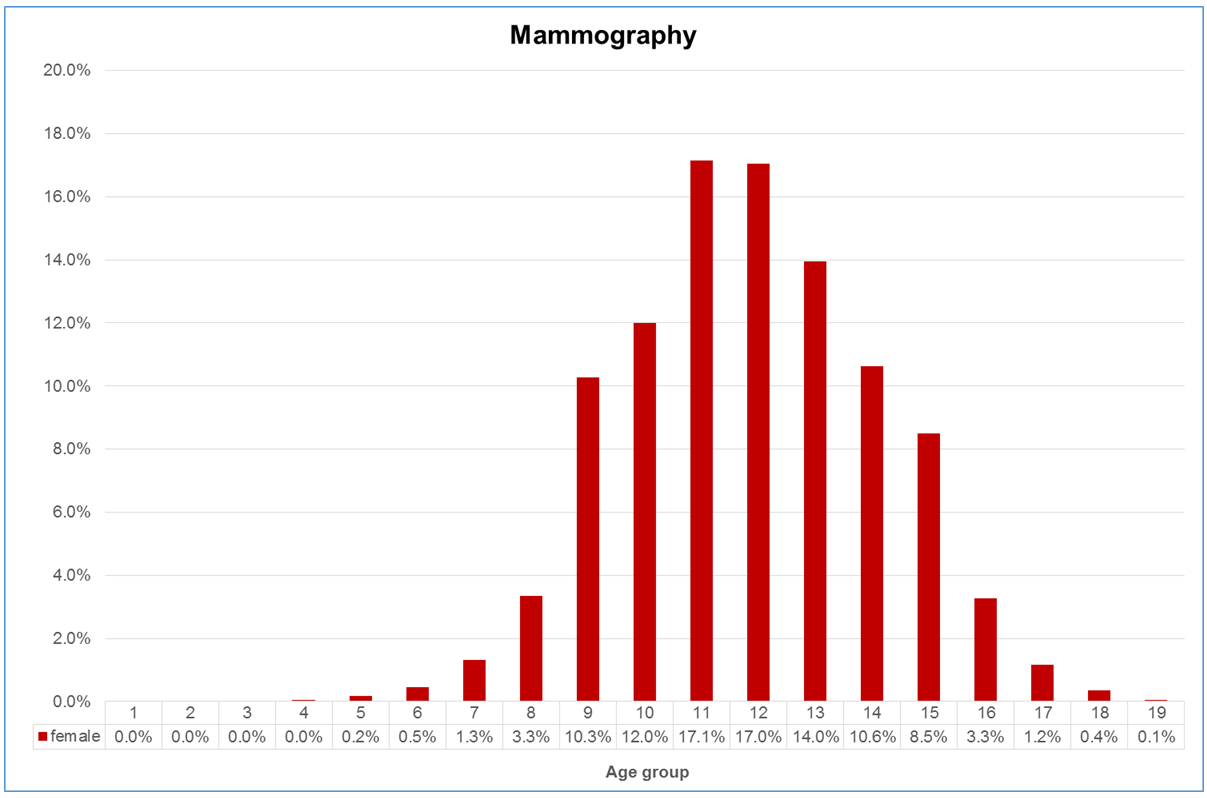
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
male	0.2%	0.5%	1.1%	1.9%	2.0%	2.6%	3.0%	3.3%	3.7%	3.7%	3.5%	3.8%	2.7%	1.9%	1.8%	1.3%	0.8%	0.3%	0.1%
female	0.2%	0.4%	1.2%	2.2%	2.7%	3.6%	4.0%	5.7%	5.7%	6.0%	6.6%	6.3%	4.5%	3.4%	3.3%	2.9%	1.7%	0.8%	0.4%



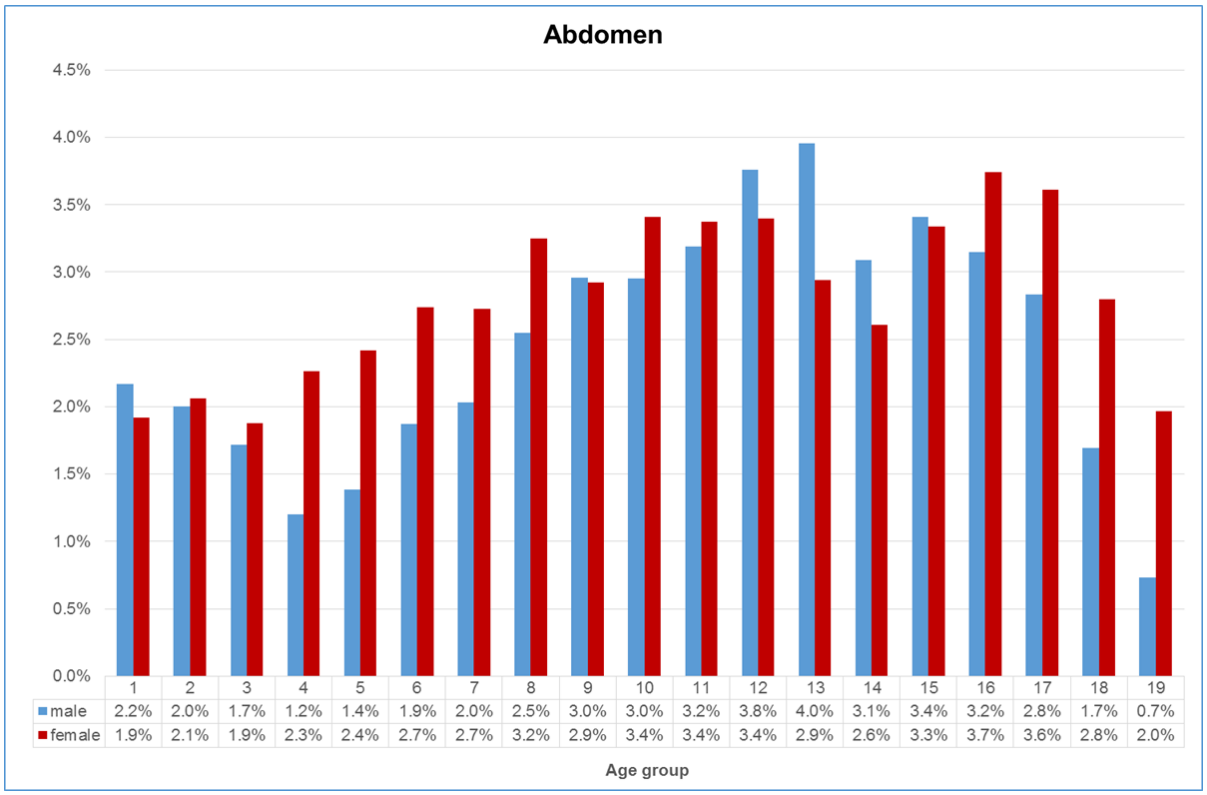
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
male	0.1%	0.3%	0.9%	1.9%	2.2%	3.0%	3.2%	3.3%	3.6%	3.1%	2.9%	3.2%	3.0%	1.9%	1.9%	1.7%	1.1%	0.6%	0.1%
female	0.1%	0.5%	1.4%	2.2%	2.1%	3.2%	3.4%	4.5%	3.7%	4.7%	6.2%	5.8%	4.7%	4.0%	4.4%	4.7%	3.1%	2.0%	0.9%



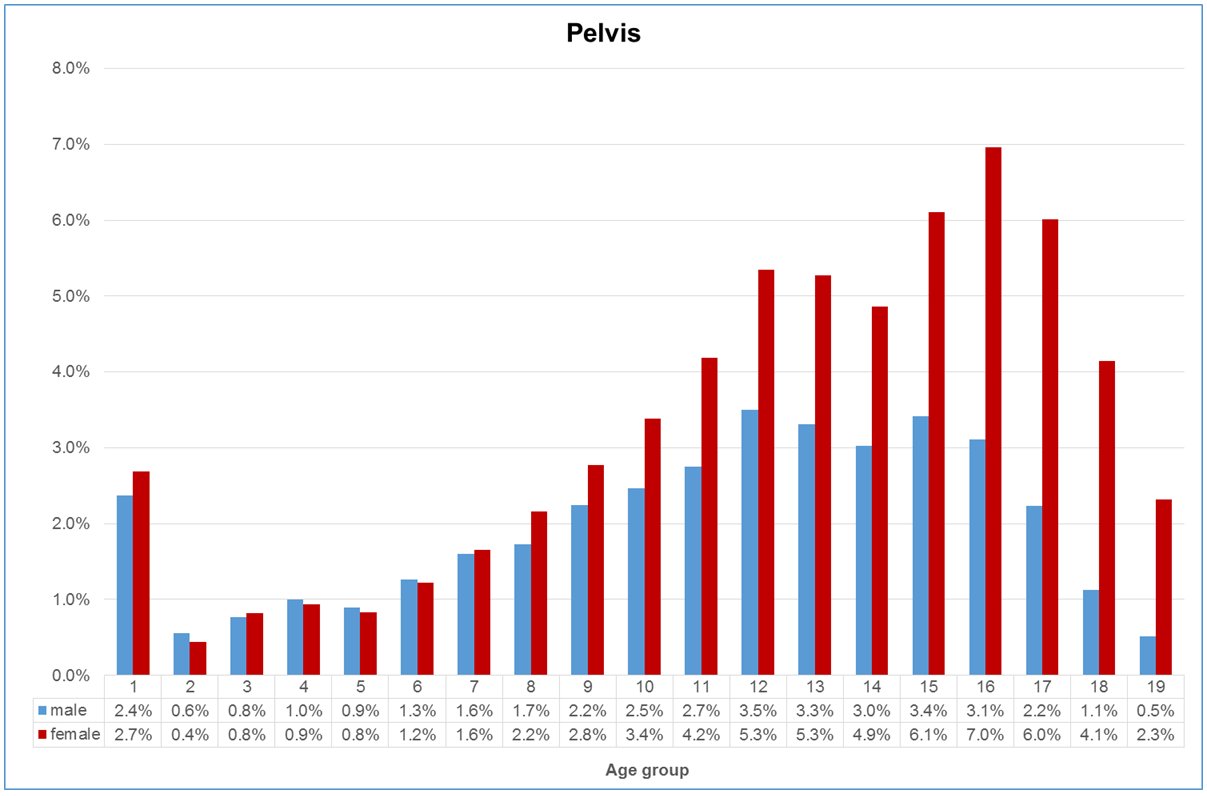
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
male	0.1%	0.2%	0.6%	1.4%	1.7%	2.3%	2.9%	3.1%	3.7%	3.6%	3.5%	3.8%	2.9%	2.4%	2.5%	2.2%	1.6%	0.8%	0.2%
female	0.1%	0.3%	1.0%	1.5%	1.6%	2.2%	2.9%	3.8%	4.2%	4.9%	5.5%	6.3%	5.0%	4.6%	5.0%	5.2%	3.9%	2.0%	0.9%



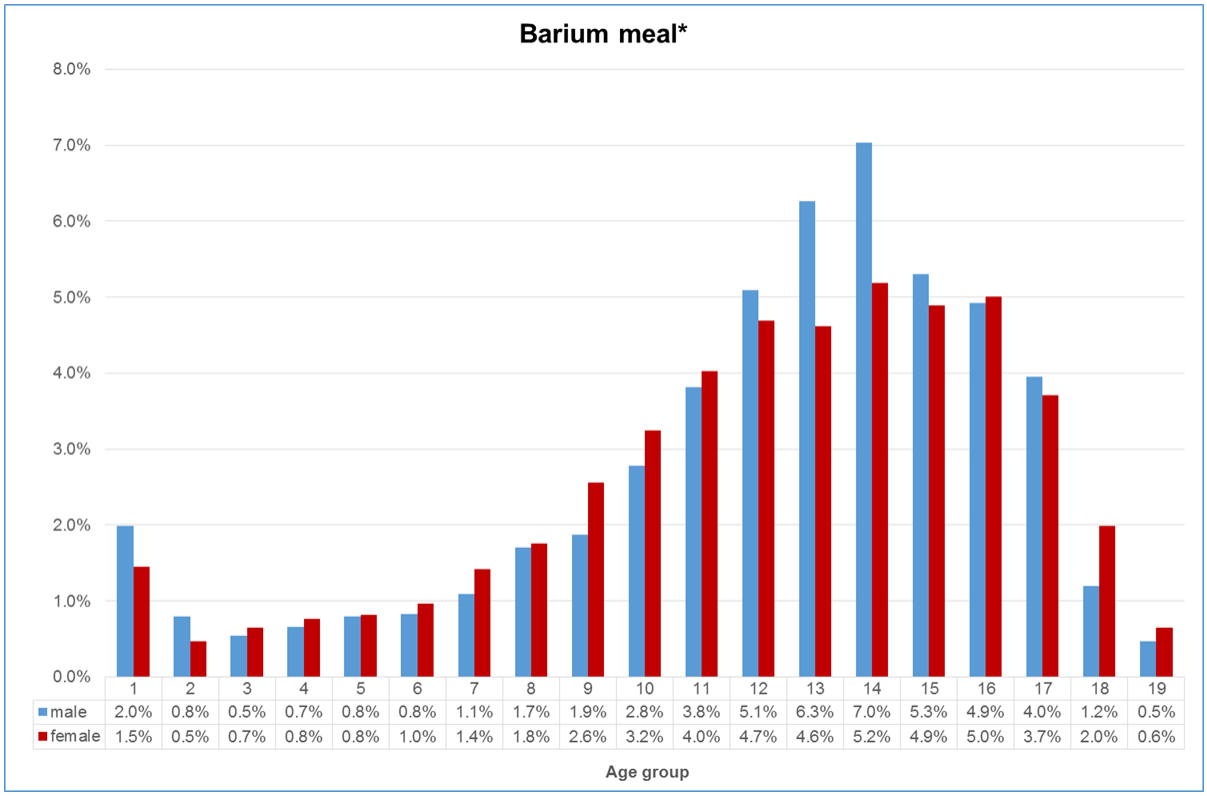
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
female	0.0%	0.0%	0.0%	0.0%	0.2%	0.5%	1.3%	3.3%	10.3%	12.0%	17.1%	17.0%	14.0%	10.6%	8.5%	3.3%	1.2%	0.4%	0.1%



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
male	2.2%	2.0%	1.7%	1.2%	1.4%	1.9%	2.0%	2.5%	3.0%	3.0%	3.2%	3.8%	4.0%	3.1%	3.4%	3.2%	2.8%	1.7%	0.7%
female	1.9%	2.1%	1.9%	2.3%	2.4%	2.7%	2.7%	3.2%	2.9%	3.4%	3.4%	3.4%	2.9%	2.6%	3.3%	3.7%	3.6%	2.8%	2.0%

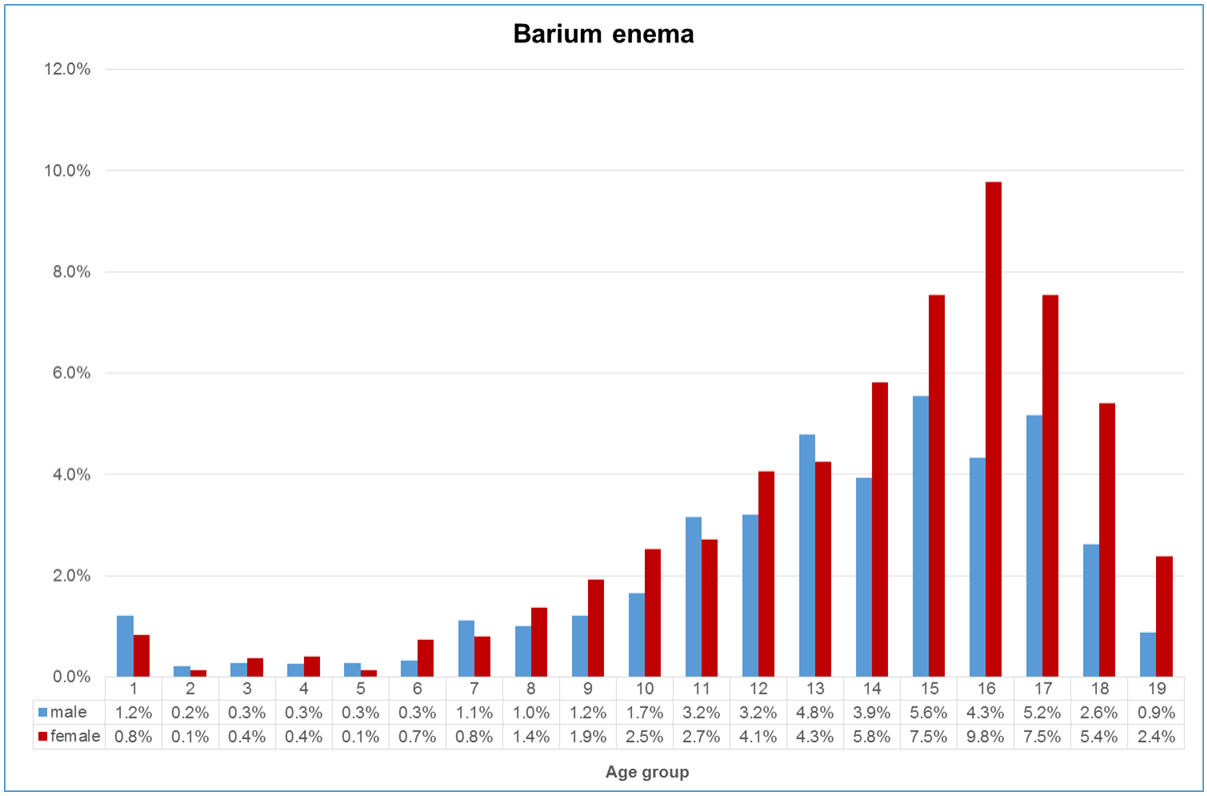


	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
male	2.4%	0.6%	0.8%	1.0%	0.9%	1.3%	1.6%	1.7%	2.2%	2.5%	2.7%	3.5%	3.3%	3.0%	3.4%	3.1%	2.2%	1.1%	0.5%
female	2.7%	0.4%	0.8%	0.9%	0.8%	1.2%	1.6%	2.2%	2.8%	3.4%	4.2%	5.3%	5.3%	4.9%	6.1%	7.0%	6.0%	4.1%	2.3%

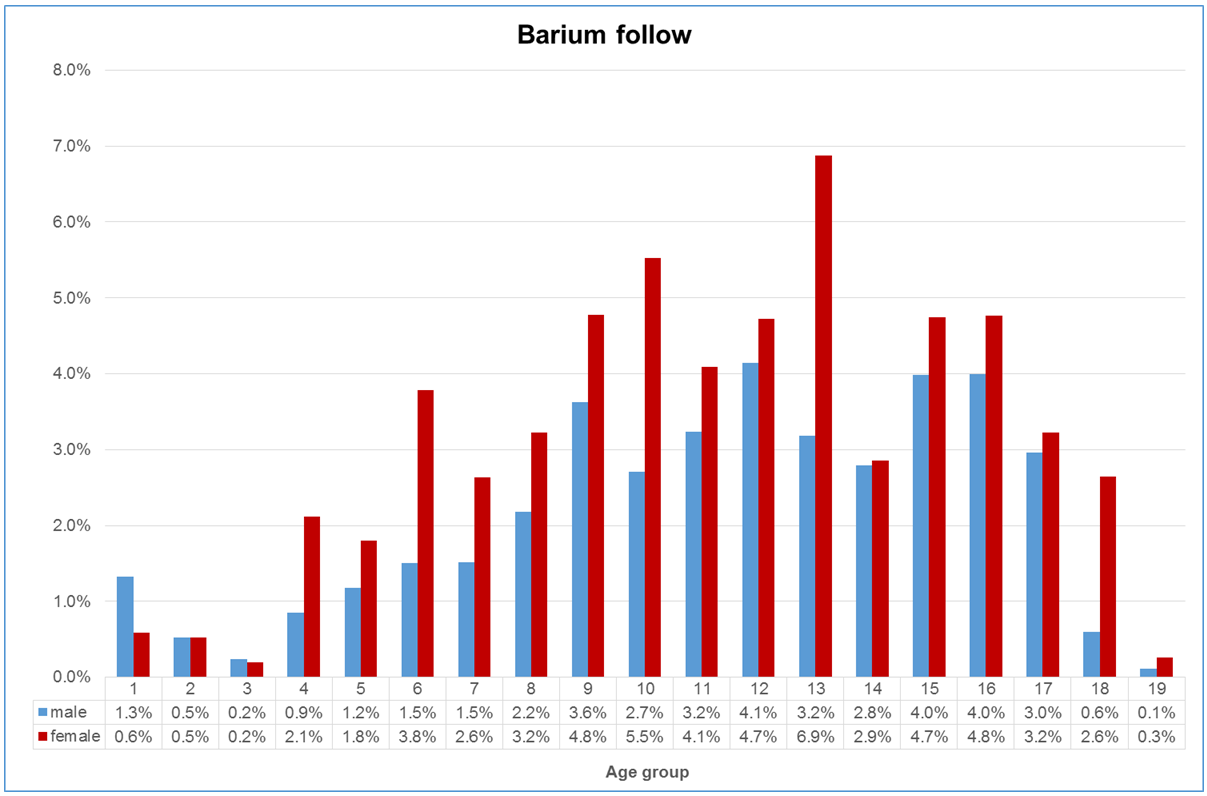


	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
male	2.0%	0.8%	0.5%	0.7%	0.8%	0.8%	1.1%	1.7%	1.9%	2.8%	3.8%	5.1%	6.3%	7.0%	5.3%	4.9%	4.0%	1.2%	0.5%
female	1.5%	0.5%	0.7%	0.8%	0.8%	1.0%	1.4%	1.8%	2.6%	3.2%	4.0%	4.7%	4.6%	5.2%	4.9%	5.0%	3.7%	2.0%	0.6%

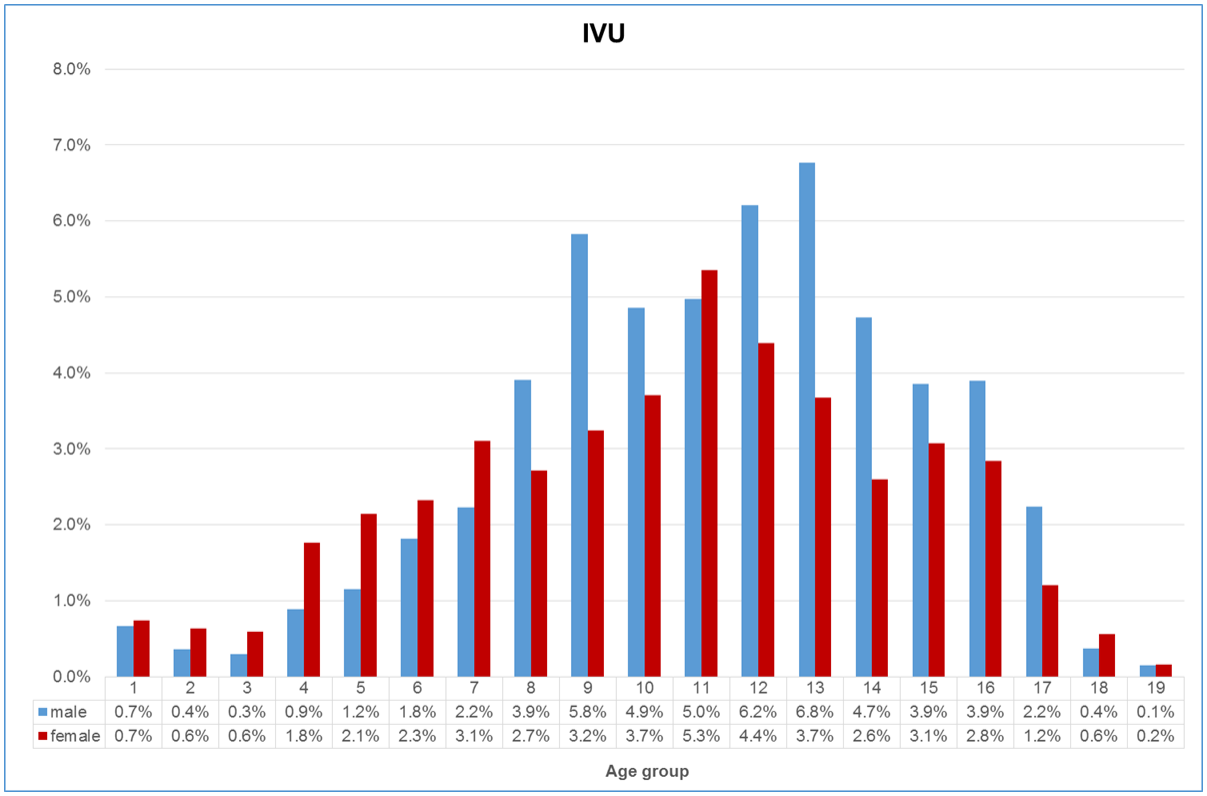
* Averaged values from HR, DK and SK only



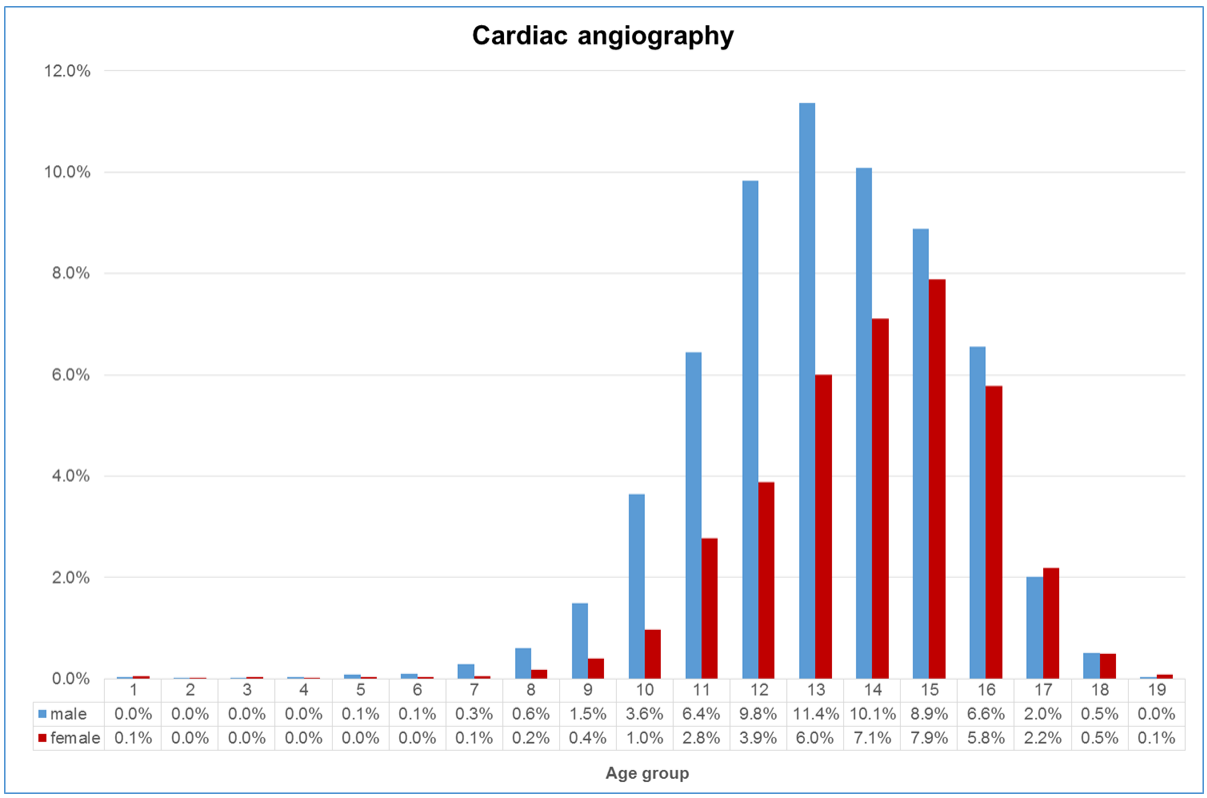
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
male	1.2%	0.2%	0.3%	0.3%	0.3%	0.3%	1.1%	1.0%	1.2%	1.7%	3.2%	3.2%	4.8%	3.9%	5.6%	4.3%	5.2%	2.6%	0.9%
female	0.8%	0.1%	0.4%	0.4%	0.1%	0.7%	0.8%	1.4%	1.9%	2.5%	2.7%	4.1%	4.3%	5.8%	7.5%	9.8%	7.5%	5.4%	2.4%



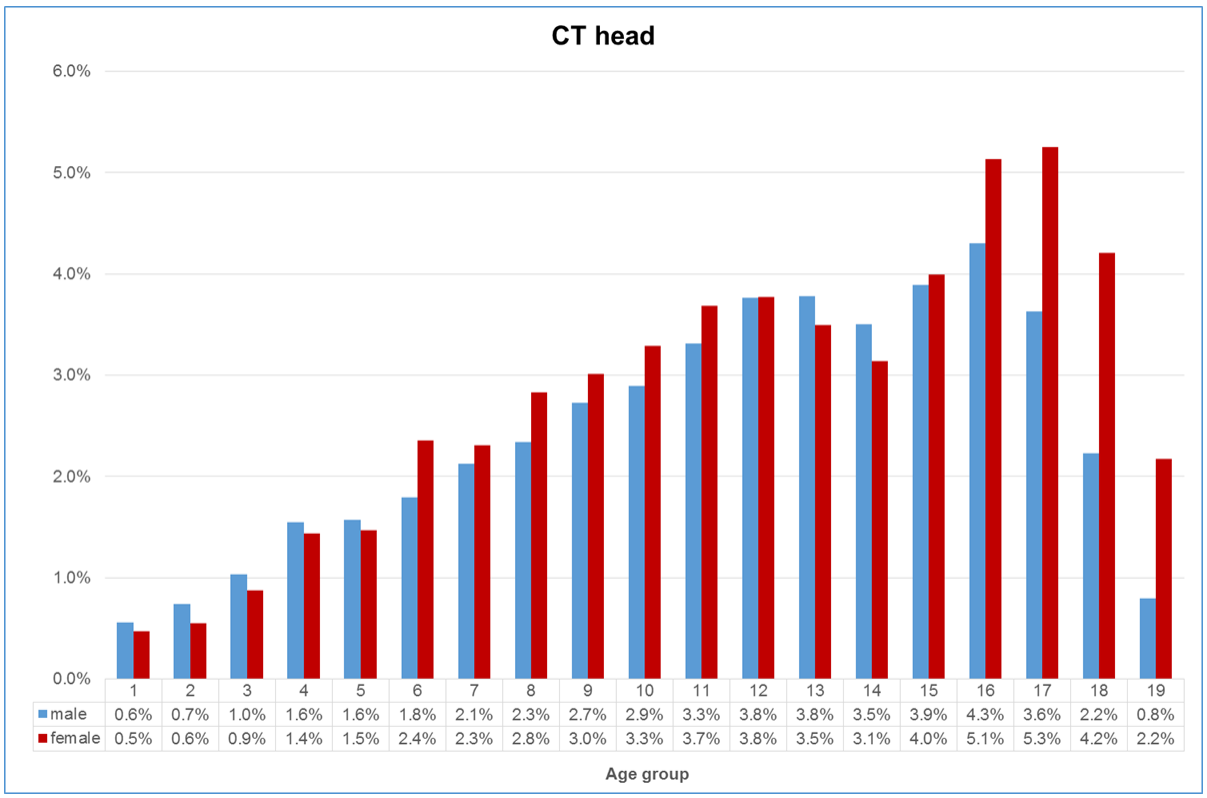
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
male	1.3%	0.5%	0.2%	0.9%	1.2%	1.5%	1.5%	2.2%	3.6%	2.7%	3.2%	4.1%	3.2%	2.8%	4.0%	4.0%	3.0%	0.6%	0.1%
female	0.6%	0.5%	0.2%	2.1%	1.8%	3.8%	2.6%	3.2%	4.8%	5.5%	4.1%	4.7%	6.9%	2.9%	4.7%	4.8%	3.2%	2.6%	0.3%



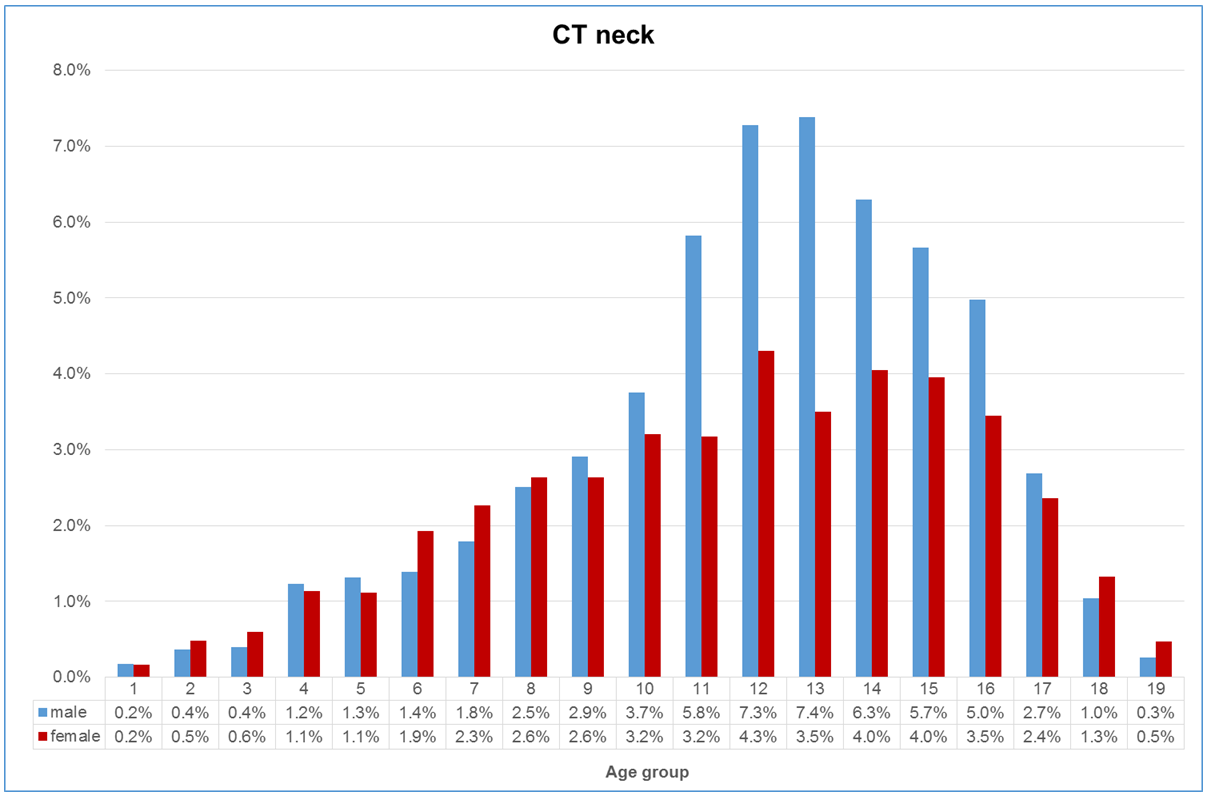
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
male	0.7%	0.4%	0.3%	0.9%	1.2%	1.8%	2.2%	3.9%	5.8%	4.9%	5.0%	6.2%	6.8%	4.7%	3.9%	3.9%	2.2%	0.4%	0.1%
female	0.7%	0.6%	0.6%	1.8%	2.1%	2.3%	3.1%	2.7%	3.2%	3.7%	5.3%	4.4%	3.7%	2.6%	3.1%	2.8%	1.2%	0.6%	0.2%



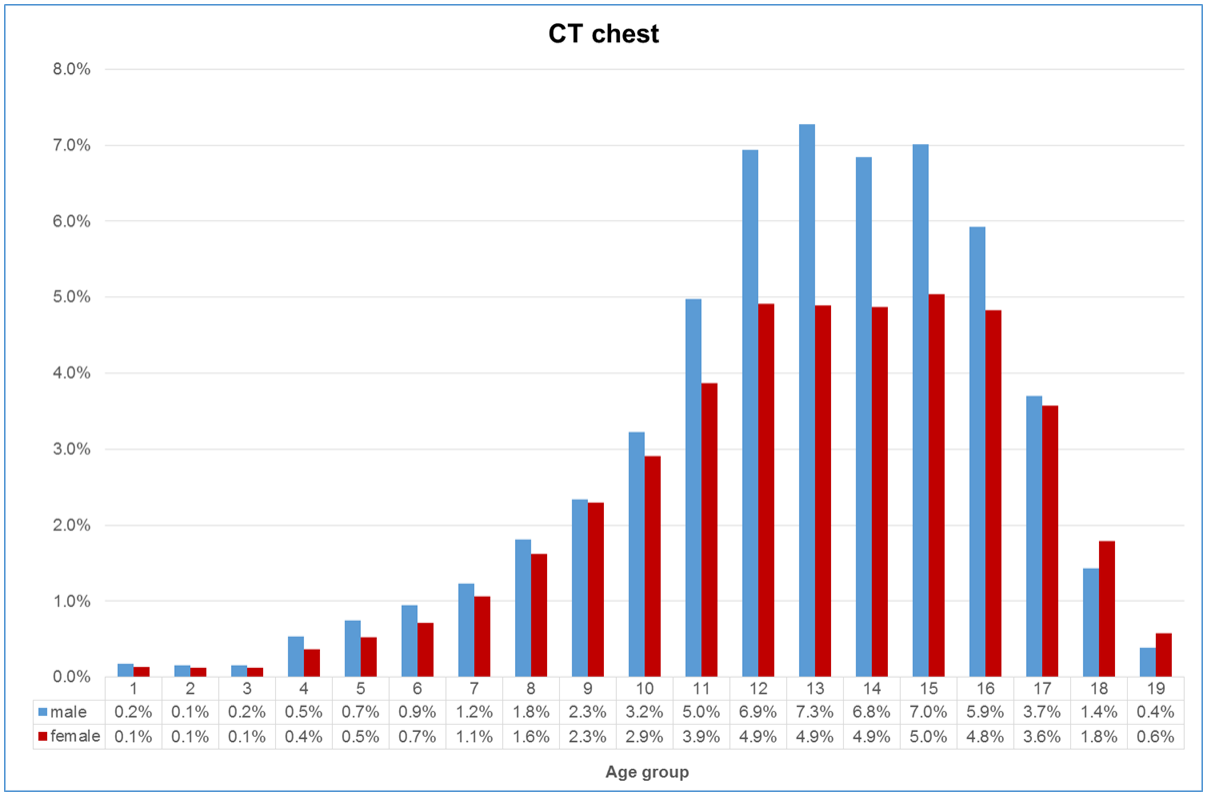
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
male	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.3%	0.6%	1.5%	3.6%	6.4%	9.8%	11.4%	10.1%	8.9%	6.6%	2.0%	0.5%	0.0%
female	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.4%	1.0%	2.8%	3.9%	6.0%	7.1%	7.9%	5.8%	2.2%	0.5%	0.1%



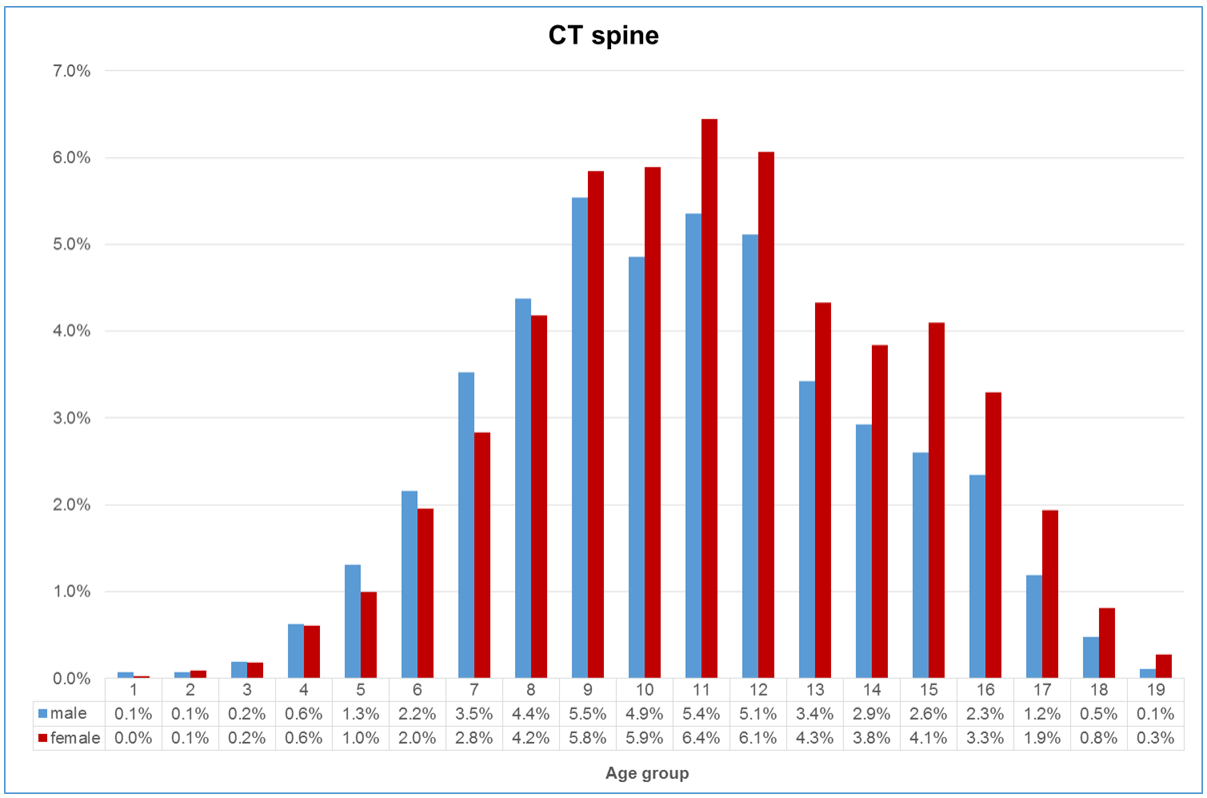
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
male	0.6%	0.7%	1.0%	1.6%	1.6%	1.8%	2.1%	2.3%	2.7%	2.9%	3.3%	3.8%	3.8%	3.5%	3.9%	4.3%	3.6%	2.2%	0.8%
female	0.5%	0.6%	0.9%	1.4%	1.5%	2.4%	2.3%	2.8%	3.0%	3.3%	3.7%	3.8%	3.5%	3.1%	4.0%	5.1%	5.3%	4.2%	2.2%



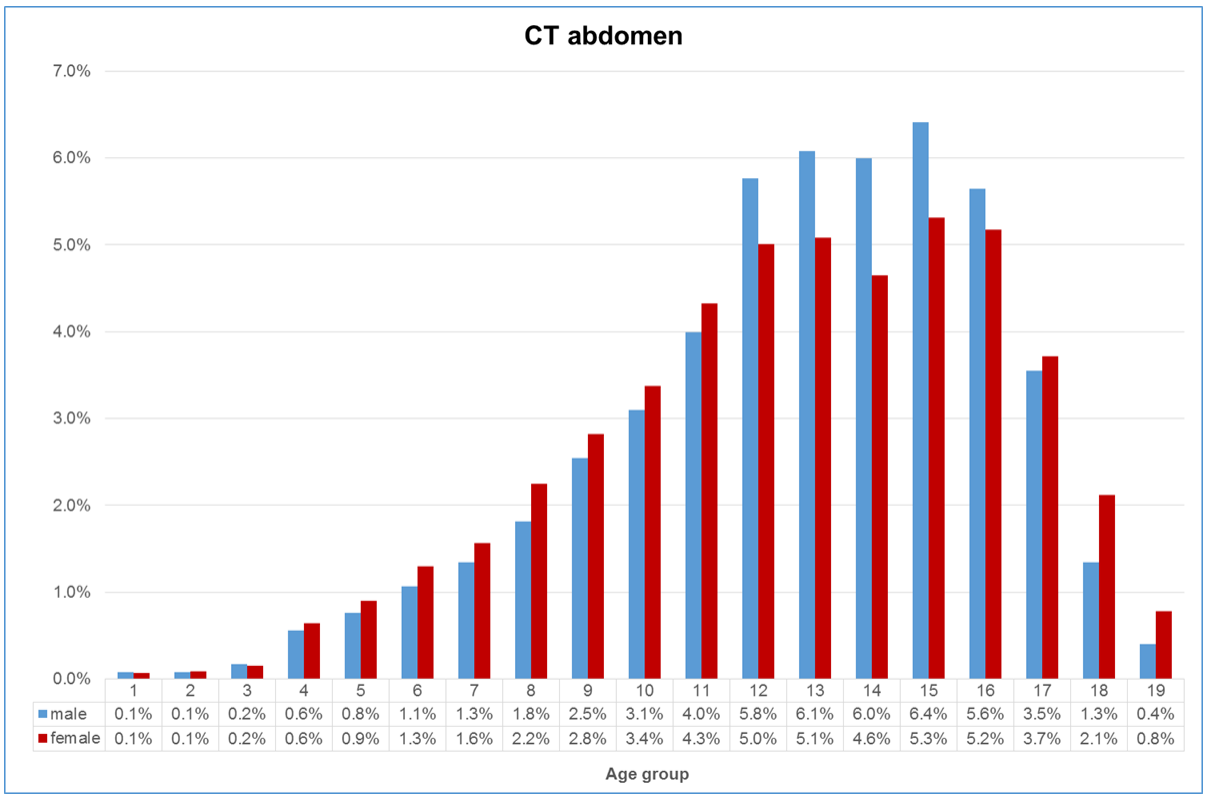
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
male	0.2%	0.4%	0.4%	1.2%	1.3%	1.4%	1.8%	2.5%	2.9%	3.7%	5.8%	7.3%	7.4%	6.3%	5.7%	5.0%	2.7%	1.0%	0.3%
female	0.2%	0.5%	0.6%	1.1%	1.1%	1.9%	2.3%	2.6%	2.6%	3.2%	3.2%	4.3%	3.5%	4.0%	4.0%	3.5%	2.4%	1.3%	0.5%



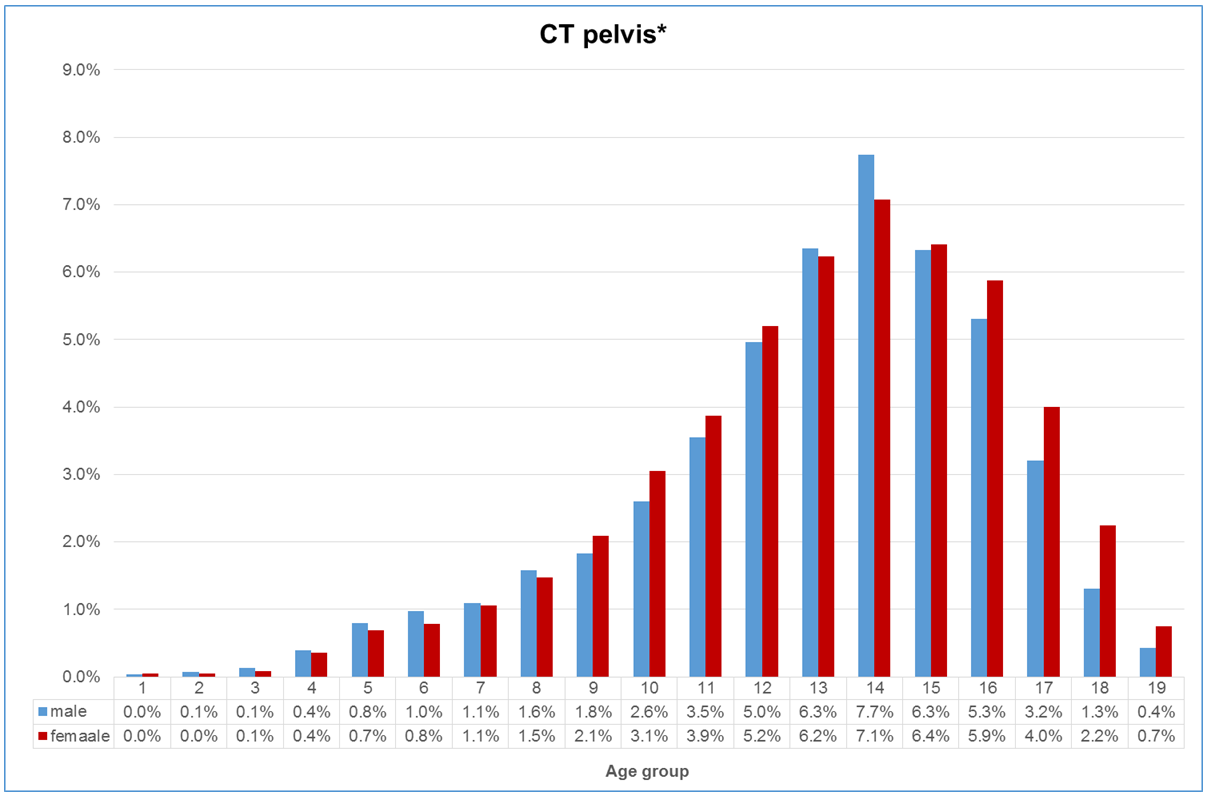
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
male	0.2%	0.1%	0.2%	0.5%	0.7%	0.9%	1.2%	1.8%	2.3%	3.2%	5.0%	6.9%	7.3%	6.8%	7.0%	5.9%	3.7%	1.4%	0.4%
female	0.1%	0.1%	0.1%	0.4%	0.5%	0.7%	1.1%	1.6%	2.3%	2.9%	3.9%	4.9%	4.9%	4.9%	5.0%	4.8%	3.6%	1.8%	0.6%



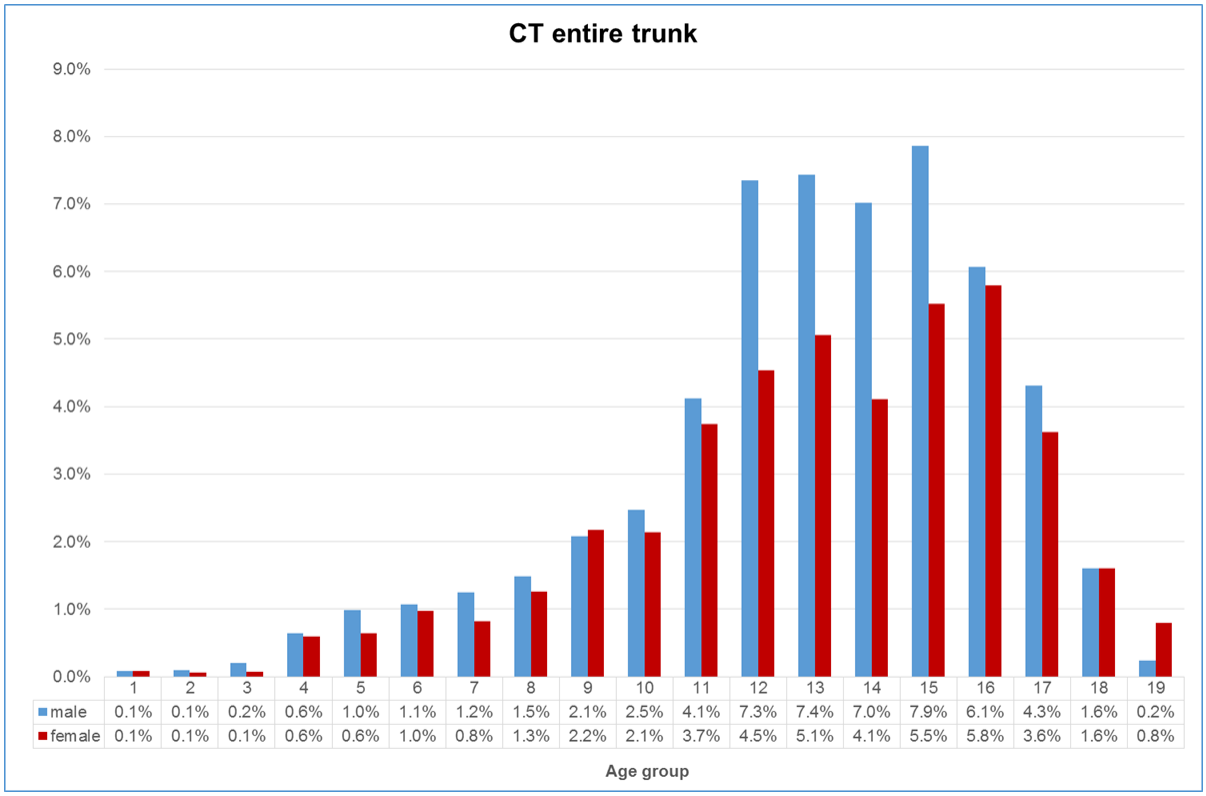
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
male	0.1%	0.1%	0.2%	0.6%	1.3%	2.2%	3.5%	4.4%	5.5%	4.9%	5.4%	5.1%	3.4%	2.9%	2.6%	2.3%	1.2%	0.5%	0.1%
female	0.0%	0.1%	0.2%	0.6%	1.0%	2.0%	2.8%	4.2%	5.8%	5.9%	6.4%	6.1%	4.3%	3.8%	4.1%	3.3%	1.9%	0.8%	0.3%

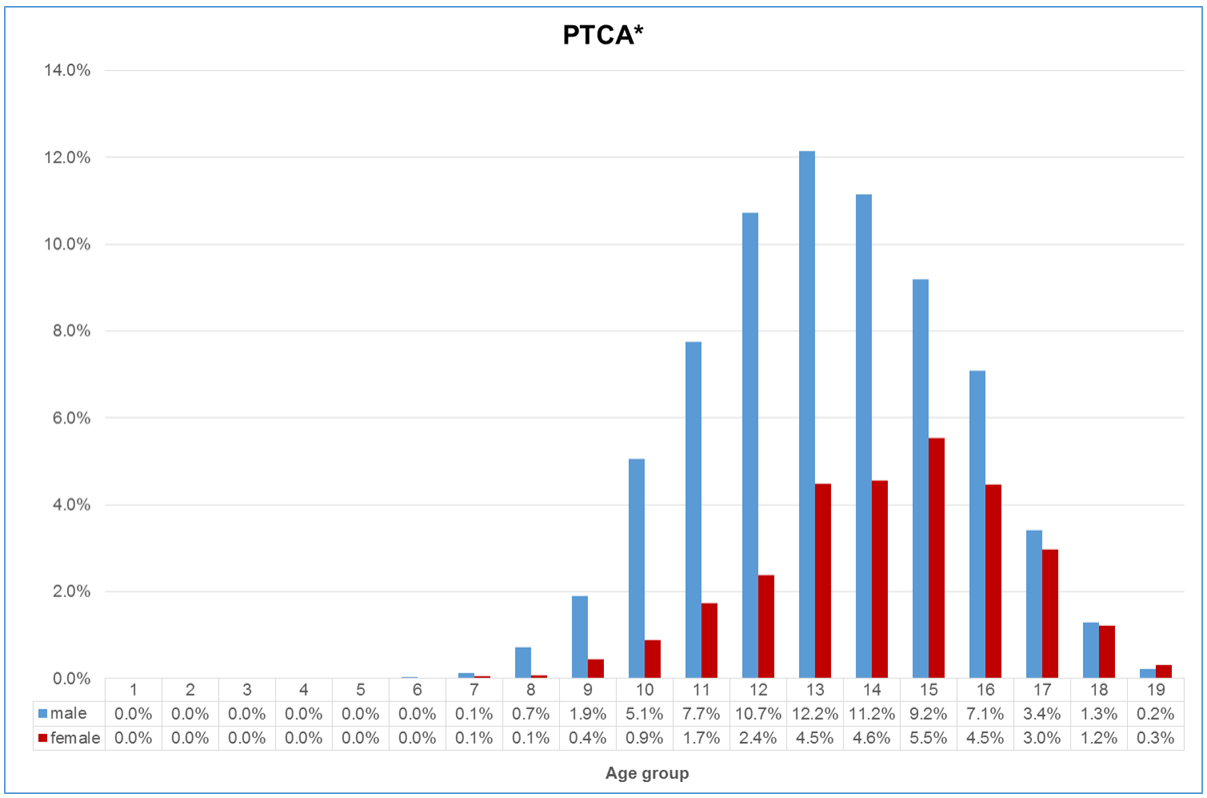


	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
male	0.1%	0.1%	0.2%	0.6%	0.8%	1.1%	1.3%	1.8%	2.5%	3.1%	4.0%	5.8%	6.1%	6.0%	6.4%	5.6%	3.5%	1.3%	0.4%
female	0.1%	0.1%	0.2%	0.6%	0.9%	1.3%	1.6%	2.2%	2.8%	3.4%	4.3%	5.0%	5.1%	4.6%	5.3%	5.2%	3.7%	2.1%	0.8%



* Averaged values from HR, DK and SK only





	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
male	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.7%	1.9%	5.1%	7.7%	10.7%	12.2%	11.2%	9.2%	7.1%	3.4%	1.3%	0.2%
female	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.4%	0.9%	1.7%	2.4%	4.5%	4.6%	5.5%	4.5%	3.0%	1.2%	0.3%

* Averaged values from HR, DK and SK only

Figure 8.1. Averaged European age/sex distributions for the Top 20 x-ray examinations of patients

9.9 Annex 9 - GUIDANCE ON THE INTERPRETATIONS OF RP154 IN CATEGORISATION OF CODES

This Annex discuss the interpretation of the "European Guidance on Estimating Population Doses from Medical X-ray procedures" (RP154) concerning how to categorize and count the X-ray examinations, as communicated to the national contact points during the DDM2 project.

There is no harmonised or common radiological classification system in Europe established by the radiological society. Different countries have their national systems that may serve several purposes; i) to monitor operation and trends in radiology (all modalities), ii) as part of the reimbursement system (to reflect complexity and costs), and iii) to assess trends in population doses (Xray, CT, nuclear medicine). For the latter, the examination frequencies have to be matched with appropriate dose values. Guidance in this respect has been provided by the European Commission in the Dose DataMed 1 (DDM1) project (2004 – 2007), published as Radiation Protection Report 154 (RP154), and has been tested in Dose DataMed 2 (DDM2) project (2011 – 2012) (www.ddmed.eu).

The detailed level in the national radiological classification systems in Europe has shown to be very different. The guidance RP154 represents a commendable attempt to establish a common approach for categorizing the examinations, so that the frequencies may be compared between countries. However, since the purpose of the RP154 guideline is to estimate the population doses on a national level, the methodology is only applicable to modalities based on ionising radiation (x-ray, CT), and less described for nuclear medicine.

9.9.1 The RP154 methodology for categorization of X-ray examinations

'An x-ray examination or interventional procedure is defined as one or a series of x-ray exposures of one anatomical region/organ/organ system, using a single imaging modality (i.e. radiography/ fluoroscopy or CT), needed to answer a specific diagnostic problem or clinical question, during one visit to the radiology department, hospital or clinic' [RP 154].

RP154 provides three optional methods to estimate the population dose, namely based on: i) 225 specific examination types, ii) 72 broader categories of examinations, or 3) a list of 20 examination recognized to be most important for the total population dose; the "TOP20". Only the two first methods give an estimate of the total population dose. The examinations or categories are systemized according to the four modalities: Plain film radiography, Radiography& Fluoroscopy, CT and Interventional procedures. In addition the list of examinations or categories is sorted according to regions of the body or organ system (Table 9.1).

Table 9.1. The number of specific examinations and categories of examinations according to the RP154 methodology

PLAIN FILM RADIOGRAPHY (RP154 Chap 3 Table 2)
72 specific examinations – 27 categories of examinations
Regions of body; head, neck, chest/thorax, abdomen, pelvis, limbs, trunk, head&trunk, teeth&gums, breast
RADIOGRAPHY (RP154 Chap 3 Table 3)
57 specific examinations – 17 categories of examinations
GI tract, bilary tract, uro-genital tract, spinal cord, joints, angiography, lymphangiography
COMPUTED TOMOGRAPHY (RP154 Chap 3 Table 4)
52 specific examinations – 18 categories of examinations
Head, neck, chest, abdomen, pelvis, neck+chest+abdomen, chest+abdomen, abdomen+pelvis, chest+abdomen+pelvis, limbs
INTERVENTIONAL PROCEDURES (RP154 Chap 3 Table 5)
38 specific examinations – 10 categories of examinations
Head&neck, chest, abdomen, pelvis, limbs

The list of the identified examinations that contributed mostly to the collective effective dose in 2002, the TOP20 list, is shown in Table 9.2. The importance of various examinations will vary between countries and change over time. The list as such may however be useful to follow trends and compare countries in a consistent way. Furthermore, in fact these examinations are in some respect categories of examinations as well. Appendix 1 to RP154 provides four tables (A 1.1 – A 1.4) that list the indications for each of the TOP20 examinations. It appears then that the procedures may vary considerably, i.e. these procedures may represent many different codes in the national classification or code system.

The three optional methods in the RP154 open for a variety of questions. It is of great concern that the national contact points interpret the methodology in the same way, so that the national frequencies can be compared unbiased and without great uncertainties. Is there always a clear and unique key between a TOP20 examination type, a group of 225 exams or a 72 category of examinations? To guide the national contact points in the DDM2 project (2010 – 12) the excel templates were designed to fill inn data, and references were made to RP154 guidelines in the sheets. A list of questions and proposed answers were prepared in advance, they are reproduced in the following. In fact very few contact points did ask questions in how to interpret the RP154 guidelines, which is somehow precarious. Most countries in the DDM2 project applied the TOP20 methodology alone to estimate the collective effective dose. The interpretation of a certain TOP20 exam has to do with the allocation of an appropriate dose figure as well; a dose figure that reflects the variety of procedures involved.

Table 9.2. The list of the types of X-ray based examinations that contributed most significant to the population dose in 2002 [RP 154]

Exam type or category	% of total frequency*	% of total S*
Plain film radiography		
1. Chest/thorax	12 - 29	0.7 – 5.2
2. Cervical spine	2.0 – 5.4	0.05 – 2.3
3. Thoracic spine	1.0 – 3.1	0.5 – 3.7
4. Lumbar spine (inc. LSJ)	2.8 – 9.6	2.0 - 17
5. Mammography	0.3 – 15	0.6 – 4.7
6. Abdomen	1.1 – 4.3	1.1 – 4.7
7. Pelvis & hip	6.3 – 10	2.8 – 9.4
Radiography/Fluoroscopy		
8. Ba meal	0.3 – 0.9	0.8 – 5.9
9. Ba enema	0.1 – 2.0	0.5 - 13
10. Ba follow	0.05 – 0.3	0.2 – 1.6
11. IVU	0.3 – 2.0	1.2 – 8.7
12. Cardiac angiography	0.2 – 1.3	1.0 – 9.9
All angiography	*1.1 – 2.4*	*6.4 - 16*
CT		
13. CT head	1.8 – 5.4	3.0 – 7.9
14. CT neck	0.06 – 0.9	0.1 – 1.1
15. CT chest	0.5 – 1.5	6.1 - 12
16. CT spine	0.3 – 2.8	1.5 - 13
17. CT abdomen	0.01 – 3.0	1.9 - 26
18. CT pelvis	0.03 – 1.5	0.3 – 9.7
19. CT trunk	0.1 – 5.6	1.1 - 27
All CT	*4.5 – 15*	*28 - 59*
Interventional		
20. PTCA	0.1 – 0.3	0.5 – 3.6
All interventional	*0.2 – 1.3*	*3.5 - 14*
TOTAL 1-20	**50-70**	**70-90**

9.9.2 A list of prearranged questions provided to the national contact points

All questions refer to the “European Guidance on Estimating Population Doses from Medical X-ray procedures” (RP154) on how to interpret a specific “TOP20” examination. All national contact points were urged to go into their national radiological classification or code system to find out which of the specific 225 examination types, or 72 examination categories, should be included in the “TOP20” type. We did not address all TOP20 examinations, only those there could be confusions or interpretations.

9.9.2.1 Radiography of Chest

Common indications for the “TOP20” examination Nr.1. Chest/lung are provided in Appendix 1 to RP154 Table A1.1 PLAIN FILM RADIOGRAPHY (without contrast media):

Exam Type	Specific exams included in "Exam type"	Common technique	Common indications
1. Chest/lung	Lungs & ribs Thoracic inlet	PA radiograph LAT radiograph	Adult pneumonia, chest pain, pericarditis, pleural effusion, pneumothorax. A LAT is taken after PA **only if** necessary to locate a pulmonary nodule or a hilar projection shadow more precisely

From RP154 Chap 3/ Table 2: Plain film radiography:

Chest	Thoracic spine	Thoracis spine
	Shoulder blades/ scapulae Collar bone(s) / clavicle(s) Acromio-clavicular joint Sterno-clavicular joint Manubrio-sternal joint Sternum	Shoulder girdle
	Ribs	Ribs
	Lung Thoracic inlet Bronchography	Chest/thorax/lung

Interpretation:

- In the Chest/Thorax regions there are eleven examinations specified and four categories.
- TOP20 Chest/lung corresponds to 225 Ribs + Lung + Thoracic inlet
- TOP20 Chest/lung corresponds to 72 categories Ribs + Chest/thorax/lung
- Examinations involving the thoracic spine or shoulder girdle should not be counted as part of TOP20 Chest/lung
- Bronchography should not be counted as part of TOP20 Chest/lung

9.9.2.2 Radiography of Pelvis & Hip

Common indications for "TOP20" examinations Nr.7. Pelvis&hip are provided in Appendix 1 to RP154 Table A1.1 PLAIN FILM RADIOGRAPHY (without contrast media):

7. Pelvis & hip	Pelvis (one or both hips)	AP radiograph or AP & LAT radiographs	Trauma, rheumatology, dysplasia

From RP154 Chap 3/ Table 2: Plain film radiography:

Pelvis	Pelvis bones - Illum/ischium - Sacrum - Sacro-iliac joint - Coccyx	Pelvic bone
	Pelvimetry (obstetric)	
	1 or both hips	Hips
	Pelvis (soft tissue)	Pelvis (soft tissue)

Interpretation:

- In the Pelvic region there are eight examination specified, and three categories
- The indications listed for "TOP 20 Nr. 7 Pelvi & Hip" are quite general (trauma, rheumatology, dysplasia), i.e.
- All eight exams and all three categories are part of the TOP 20 Nr. 7

9.9.2.3 Radiography/Fluoroscopy of the GI tract

Common indications for "TOP20" examinations Nr. 8, 9 and 10 Ba Meal, Ba enema and Ba follow are provided in Appendix 1 to RP154 Table A1.2 RADIOGRAPHY/FLUOROSCOPY (use of contrast media):

Exam type	Specific exams included in "Exam type"	Common technique	Common indications
8. Ba meal	Ba meal (stomach & duodenum)	2-3 minutes fluoroscopy 5-20 images	Preoperative analysis for certain stomach lesions and for postoperative monitoring after gastric and oesophageal surgery
9. Ba enema	Ba enema (colon)	About 2 minutes fluoroscopy 5-10 images	Inflammation, suspected tumour, control after surgery and for occlusive syndromes
10. Ba follow	Ba follow (small intestine) Small bowel enema	About 5 minutes fluoroscopy 5-20 images	Small bowel disease (e.g. Crohn's disease, malabsorption syndromes)

From RP154 Chap 3/ Table 3 Radiography/fluoroscopy (excluding interventional procedures):

GI tract (Neck + chest + abdomen)	Oesophagus (Ba swallow) Stomach & duodenum (Ba meal) Small intestine (Ba follow) Enteroclysis (small intestine enema)	Oesoph. & stomach & small intestine
	Colon (Ba enema)	Colon
	Defecography	Defecography

Interpretation:

- For the gastro intestinal tract (GI) there are six examination specified, and three categories.

- The indications listed for “TOP 20” Nr. 8 Ba meal and 10 Ba follow” ARE BOTH INCLUDED IN “72 category” Oesophagus&stomack&small intestine”, i.e. in this case you have more detailed information using the “TOP 20” approach.
- “TOP 20” Nr. 9 Ba enema corresponds to “72 category” Colon.
- Neither Enteroclysis (small intestine enema) nor Defecography should be counted as part of the “TOP” methodology

9.9.2.4 CT in the Head region

Common indications for “TOP20” examination Nr.13. CT head are provided in Appendix 1 to RP154 Table A1.3 COMPUTED TOMOGRAPHY:

Exam Type	Specific exams included in “Exam type”	Common technique	Examples of indications
13. CT head	Head, brain, facial bones	With or without contrast	Brain lesion, acute stroke. Chronic rhinosinusitis, nasal obstruction, nasosinusitis polyposis, anosmia. Facial trauma. Chronic inflammation of middle ear, petrosal bone trauma. Congenital malformations.

From RP154 Chap 3/ Table 4 CT Examinations:

Head	Skull - Orbits - Temporal bone o Petrous bone - Temporal mandibular joint - Sella turcica Face Dental	Skull & facial bones
	Brain - Cerebrum - Posterior fossa - Brain vascular Pituitary gland	Brain
	Sinuses Internal auditory meatus Nasal cavity Mouth	Head soft tissue

Interpretation:

- For CT examinations in the head region there are 17 examinations defined and three categories.
- From the list of indications it actually seems like the “TOP 20” Nr. 13 CT head involve all three categories (scull&facial bones, brain, head soft tissue).
- However, it is interpreted that dental CT should not be counted as part of Nr.13. CT head.

9.9.2.5 CT in the neck region

Common indications for "TOP20" examination Nr.14. CT neck are provided in Appendix 1 to RP154 Table A1.3 COMPUTED TOMOGRAPHY:

Exam Type	Specific exams included in "Exam type"	Common technique	Examples of indications
14. CT neck	Soft tissue in neck, cervical spine	No contrast	Trauma, cervical pain/ neuralgia, medullary compression syndrome, extra- or intra-spinal tumors

From RP154 Chap 3/ Table 4 CT Examinations:

Region of body	Specific exam types	DOSE DATAMED exam categories
Neck	Cervical spine	Cervical spine
	Neck Larynx Pharynx Neck vascular	Neck

Interpretation:

- For CT examinations of the neck region there are five examinations defined and two categories.
- From the list of indications you should interpret both category "Cervical spine" and "Neck" as part of "TOP 20" Nr. 14 CT neck.
- No use of contrast for soft tissue indications?

9.9.2.6 CT in the chest/abdomen/pelvis region

Common indications for CT examinations in the trunk region are provided in Appendix 1 to RP154 Table A1.3 COMPUTED TOMOGRAPHY:

15. CT chest	Chest/thorax	With or without contrast Std or high resolution	Mediastinal/pleural/pulmonary pathology. Diffuse infiltrative lung disease, bronchial diseases, lung cancer
16. CT spine	CT of lumbosacral spine	With or without contrast	Trauma, lumbar pain, lumboradiculalgia, sciatica, cauda equina syndrome
17. CT abdomen	Abdominal organs	With or without contrast	Cancer diagnosis and staging, infectious lesions, inflammatory diseases, major trauma. Acute abdominal pain. Suspected haemorrhage. Chronic hepatic illness, liver metastases or suspected obstruction of hepatic vessels.
18. CT pelvis	Pelvic bone &/or organs	With or without contrast	Cancer diagnosis and staging, location of stones/lesions/tumours resulting in obstruction of urinary channels. Suspected extrinsic compression or malformation of the urinary channels. Pelvimetry.

19. CT trunk	CT of chest, abdomen & pelvis CT of thoracic/ abdominal aorta	With or without contrast With contrast	Metastases from unknown primary tumour, lymphoma, trauma. Thoracic/abdominal aorta disease: aneurysm, occlusion, dissection, inflammation, embolism, malformation.

From RP154 Chap 3/ Table 4 CT Examinations:

Chest	Thoracic spine	Thoracic spine
	Mediastinum Lungs standard Lungs high resolution Heart Thoracic aorta Lungs vascular	
Abdomen	Lumbar spine	Lumbar spine
	Full abdomen Upper abdomen	Abdomen
	Liver/ pancreas Kidney/ Supra-renal glands	Liver, pancreas & kidneys
Pelvis	Hip/ pelvic bone Sacrum/ coccyx Sacro-illac joint	Pelvic bones
	Pelvimetry (obstetric)	Pelvimetry
	Pelvis (soft tissue/ vascular)	Pelvis
Neck + chest + abdomen	Full spine	Full spine
Chest + abdomen	Chest/ abdomen	Chest & abdomen
Abdomen + pelvis	Abdomen/pelvis	Abdomen & pelvis
Chest + abdomen + pelvis	Whole trunk	Chest, abdomen & pelvis

Interpretation:

- There are in total 21 examinations defined and 11 categories for CT examinations in the trunk region. They involve chest, abdomen and pelvis, however, some CT procedures cover several regions of the trunk, even the neck region (“72 category” Full spine).
- “TOP 20” Nr. 15 CT chest corresponds to the “72 category” Chest/Thorax. NB The “72 category” Thoracic spine should neither be counted as part of Nr. 15 CT chest nor Nr. 16. CT spine.
- “TOP 20” Nr. 16 CT spine involves only CT of lumbar spine.> “TOP 20” Nr. 17 CT abdomen should include both 72 category “abdomen” and “ Liver, pancreas&kidneys”.
- “TOP 20” exam Nr. 18. CT pelvis includes NB NB three categories of examinations: Pelvic bones, Pelvimetry and Pelvis.
- “TOP 20” exam Nr. 19. CT trunk corresponds directly “72 category” Chest, abdomen & pelvis.
- The “72 categories” Full spine, Chest & abdomen and Abdomen & pelvis open for registration of CT procedures that cover several regions, but there is no “TOP 20” examination which reflects those. This may be a problem, since it is very usual to do Abdomen/Pelvis and register it as Abdomen.

9.9.3 Categorisation of radiological procedures – further discussion

Experience from the DDM2 project indicates that certain issues should be addressed in revising the European guidance RP154, generally:

- To understand the trends in radiology, both concerning frequency and collective effective dose, the development of non-ionising modalities such as magnetic resonance imaging (MR) and ultrasound (US) should be surveyed as well (Fig. 9.1).

- The introduction of multi-modality imaging equipment such as positron emission tomography (PET) in combination with CT or MR must be taken into account in the definition of what is considered as “One examination or procedure”.

- The examinations or categories are according to RP154 systemized into the four modalities: Plain film radiography, Radiography& Fluoroscopy, CT and Interventional procedures. Plain film radiography should be names “Plain radiography”. The distinctiveness between “Plain radiography” and “Radiography&Fluoroscopy” is anyhow subtle, since fluoroscopy on modern equipment often is used for positioning of the patient.

- In addition the distinction between fluoroscopy, angiography and interventional procedures may be difficult to sort out; these procedures may start as a diagnostic procedure but transfer to an interventional one, as indicated from findings during patient investigation.

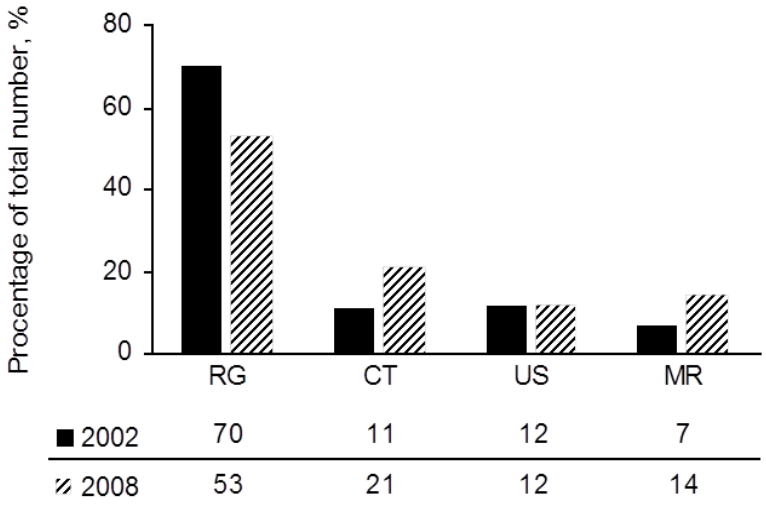


Figure 9.1 Trends in examination frequency and population doses in Norway, 2002 – 2008.

More specifically to the interpretation of the categorization system, the development of new technology and modalities will open for new procedures or changing the procedure itself. Generally film based systems are faced out in Europe, and with digital imaging techniques there is a trend towards more processing and three dimensional reconstruction (3D). That means the definition of 225 specific examination or 72 broader categories must be updated and revised from time to time. Obviously there is a need for radiological competence in the development of a revised system. The following gives some input to the revision of the categorization:

Radiography examinations:

- How cone beam computed tomography (CBCT) examinations in the maxilla/facial region are accounted for as opposed to the conventional dental imaging? CBCT should be accounted as a new modality; it is not either a CT examination. And how about bone

densitometry examinations (DEXA) or imaging based on Compton scatter instead of transmitted photons?

- The categorization of spine examinations is not obvious, as already discussed. You have procedures involving almost all combinations of cervical-, thoracal- and lumbal columna as well as the iliosacral joint. Some have certain codes for “total columna”, some use several codes to reflect the same examination.

Radiography& Fluoroscopy:

- Fluoroscopy is currently being used for lots of new procedures, which do not have a specific name in the RP154 “225 approach”, for example investigations of the neural system (epidurography), investigations of abscess or fistulas, etc.

- There is a multitude of new angiograpy procedures, which do not have a specific names in the RP154 “225 approach”, for example investigations of the arteries in the neck, subclavia, mamm interna, as well as spinal angiography and 168rocedures168s arteries. This applies to venography 168rocedures as well; investigations of the veins in the neck, right side hart catheter, portal veins, cavernosography, etc.

- The categorization of angiography and venography examinations is all but obvious, since such procedures will cover many regions of the body; head, neck, thorax, abdomen, pelvis and/or limbs in all combinations.

Computed tomography (CT):

- With the introduction of helical multidetector CT (MDCT) with rapid tube rotation times the procedures tend to be more comprehensive and may involve several contrast series. In addition the post processing techniques and 3D modeling makes it possible to make virtual journals through the body. This has opened for new procedures like CT colon, CT urography and CT intestine.

- You have got a range of CT angiography procedures since the EU guidance RP154 was established, and that calls for an update of the “225 approach” list. In this case you have the same challenges and pitfalls as for the categorization of conventional angiographies, since the CT arteriographies and venographies cover all regions of the body.

- You have certain CT examinations of the limbs as well, as well as CT pelvimetry; and how to account for simple scout view used in measurements of the length of the limbs.

- CT guided interventional procedures are being used more and more; for biopsies in cancer investigations, for radiofrequency ablation of tumors, etc This must be reflected in the methodology.

- In addition CT and CBCT are used for dose planning, simulation and verification in radiotherapy. It needs to be clarified what kinds of these procedures should be considered as diagnostic procedures, as contributing to the collective effective dose from radiodiagnostics.

Interventional procedures:

- Fluoroscopy and CT are currently being used for guiding a whole range of new interventional procedures since the last ten years. Example of such procedures are various kinds of percutaneous angioplastic, treatment of thrombus, embolism, fistula or defects, installation of stents, bypass or catheters, injections in organs or tissues, removal of foreign objects, biopsies and punctures.

- This issue needs strongly input from interventional radiologists and medical professions. It should however be discussed whether these procedures should be accounted for in

the collective effective dose estimate, since it is used in the treatment of patients not only for diagnosis.

9.10 Annex 10 - ADDITIONAL GUIDANCE FOR ESTIMATING POPULATION DOSE

The existing European Guidelines on population dose estimations (RP 154) has been used and tested as a basis of the present estimation of the collective effective dose to the European population. For x-ray procedures, the comprehensive estimation based on all x-ray procedures (72, 225 or more categories of procedures) has been carried out in six countries, while in all the other countries, the TOP 20 has been the only available choice. This estimation has brought about a number of practical experiences and observations on the feasibility of the TOP 20 approach which should be taken into account when revising the guidelines (RP 154). For NM procedures, the RP 154 does not provide specific guidance but the present estimation of population dose for NM procedures has provided practical experience and a good methodological basis to develop and supplement RP 154 with specific guidelines for NM procedures as well.

The purpose of the present work was not to revise RP 154 but the major observations and conclusions for such future work, based on the present results and experiences are summarized in the following. Besides the observations of this Annex, the information presented in this report for population dose database (Section 5), effect of tissue weighting factors (Annex 12) and age and sex distributions (Section 7) provide summaries which should be important supplements to the update of RP 154.

9.10.1 Guidelines for x-ray procedures

9.10.1.1 Categorization of examinations

There is no harmonized or common system for the classification of radiological examinations in European countries. RP 154 presents the first commendable attempt to establish a common approach to categorize examinations, so that the frequencies could be compared between countries and for the purpose of population dose estimation. RP 154 provides three optional methods of categorizing examinations: (1) 225 specific examination types as the most comprehensive approach, (2) 72 broader categories of examinations, and (3) a list of 20 examinations (TOP 20) recognized to be most important for the total population dose.

For TOP 20, RP 154 provides a list of the indications for each of the TOP 20 groups; it appears then that these procedures may represent many different codes in the national classification or code system. To perform a population dose analysis on the basis of TOP 20 system (or using 72 or 225 categories), the equivalence of the national codes of examinations to these systems need to be determined at a national level, i.e. to find out which of the national codes should be included in each TOP 20 group (or each of the 72 or 225 categories). To make this sorting in a consistent way, so that the national frequencies could be compared unbiased and without great uncertainties, specific guidance were developed in the context of developing the DDM2 questionnaires and within the related discussions and data analysis. This guidance was partly comprised by a list of frequently asked questions (FAQ) developed at the project website. Further, some analysis of completely new procedures which are not included in the present 225 specific examinations, have been produced.

The detailed guidance on the recommended sorting of the national codes and interpretations to be made, including some advice or discussion on the completely new types of examinations, are presented in Annex 9.

9.10.1.2 Estimation of frequencies

The Top 20 method should only be used for estimating population dose. It is not appropriate if an approximation of the overall frequency is needed. In fact, as can be seen from Table 5.4, Top 20 examinations as defined in RP 154 contribute on average only about half to the overall frequency. Considering the broader examination groups, only the overall frequency of CT examinations is adequately covered (89 % on average). The Top 20 categories of plain

radiography, fluoroscopy, and interventional radiology include, however, less than half of the overall frequencies in many countries (31 -49 % on average). For interventional radiology, in particular, the coverage of the respective Top 20 group (only one procedure, PTCA) is on average only 31 %. In case of plain radiography, the low coverage is mainly due to the fact that dental examinations and examinations of the extremities are not included in Top 20, both examination categories being associated with very low effective doses and therefore contributing only minor to the total collective doses from all x-ray examinations.

Particularly, the frequencies of dental examinations can be a high portion of the total frequency (from about 14 to 45 % for six countries in this report). It is advisable, therefore, that the frequency of dental examinations is given separately when reporting overall frequencies for plain radiography.

9.10.1.3 Estimation of population doses: Conclusions for TOP 20 method

As can be seen from Table 5.17 and Fig. 5.12, TOP 20 method provides a reasonable estimate of the overall population dose: TOP 20 examinations as defined in RP 154 on the average contribute to about 77 % of the overall population dose. The coverage of TOP 20 groups is the worst in interventional radiology, only about 34 %, due to only one procedure (PTCA) included in this TOP 20 group.

In Table 10.1, for four European countries, the types of x-ray examinations are shown which have the highest contribution to the total population dose. It can be seen that within the 20 most important ones, there are 4-6 types of examinations beyond the present Top 20 list of RP 154. In particular, this includes some IR procedures and CT procedures (e.g. CT chest/abdomen). On the other hand, some of the present Top 20 groups are becoming of decreasing or low importance for the population dose in these countries, in particular Top 20/2 (cervical spine), Top 20/3 (thoracic spine), Top 20/10 (Ba follow) and Top 20/ 11 (IVU).

Table 10.1. The types of examinations having the highest contribution to the population dose in four European countries, in descending order of importance. The types beyond Top 20 groups correspond to the specific examinations (225 codes of RP 154; FI, CH and UK) or examination categories (72 categories of RP 154; FR). (RA: plain radiography, FL: fluoroscopy, CT: computed tomography, IR: interventional radiology).

	Finland	Switzerland	UK	France
1	Top 20/ 19.	Top 20/ 17.	Top 20/ 19.	CT Abdomen and pelvis
2	Top 20/ 17.	Top 20/ 15.	Top 20/ 15.	Top 20/ 15.
3	Top 20/ 13.	Top 20/ 4.	Top 20/ 17.	Top 20/ 14.
4	Top 20/ 15.	CT Abdomen/pelvis	CT Abdomen/pelvis	Top 20/ 7.
5	Top 20/ 20.	Top 20/ 7.	Top 20/ 13.	Top 20/ 6.
6	Top 20/ 4.	Top 20/ 12	Top 20/ 5.	Top 20/ 4.
7	Top 20/ 12	CT Full spine	CT Chest/abdomen	Top 20/ 13.
8	Top 20/ 5.	Top 20/ 20.	Top 20/ 12	Top 20/ 12
9	Top 20/ 1.	CT Chest/abdomen	Top 20/ 18.	Top 20/ 17.
10	IR Pelvic vessel dilatation	Top 20/ 16.	Top 20/ 20.	Top 20/ 20.
11	Top 20/ 7.	Top 20/ 13.	Top 20/ 6.	CT Limbs
12	Top 20/ 16.	Top 20/ 18.	Top 20/ 4.	Top 20/ 19.
13	Top 20/ 6.	Top 20/ 14.	Top 20/ 9.	Top 20/ 8. & Top 20/ 10.
14	Top 20/ 10.	Top 20/ 6.	Top 20/ 7.	FL Thoracic angiography
15	IR Abdominal region biopsy	Top 20/ 8.	Top 20/ 14.	CT Full spine
16	IR Pelvic vessel embolisation	Top 20/ 1.	CT Full spine	Top 20/ 9.
17	CT Chest/abdomen	Top 20/ 19.	IR Renal artery dilatation/stenting	Top 20/ 5.
18	FL Upper & lower limb arteriography	Top 20/ 9.	Top 20/ 16.	Top 20/ 1.
19	Top 20/ 9.	Top 20/ 5.	IR Abdominal embolisation	RA Whole spine
20	Top 20/ 14.	Upper & lower limb arteriography	FL Oesophagus (Ba swallow)	RA shoulder girdle

	Finland	Switzerland	UK	France
21	Top 20/ 18.	Bile duct drainage	Top 20/ 11	Top 20/ 2.
22	Thoracic region biopsy	CT Thoracic spine	FL Endoscopic retrograde cholangio-pancreatography (ERCP)	Top 20/ 11
23	Cerebral angiography	Top 20/ 3.	Top 20/ 1.	FL Gynaecological
24	Lower limb dilatation	Micturitional cysto-urethrography (MCU)	IR Thoracic dilatation/stenting	Top 20/ 3.
25	Oesophagus (Ba swallow)	Endoscopic retrograde cholangio-pancreatography (ERCP)	IR Renal drainage	FL Bladder and urethra
26	Top 20/ 3.	Abdominal aortography	IR Pelvic vessel dilatation	RA Skeletal survey
27	Abdominal aortography	Defecography	Top 20/ 3.	RA Intra-oral < 3 films
28	Endoscopic retrograde cholangio-pancreatography (ERCP)	Pelvic arteriography	Top 20/ 8.	Top 20/ 18.
29	Defecography	Abdominal embolisation	IR Abdominal dilatation/stenting	RA Bones
30	Top 20/ 2.	Lumbar myelography	FL Upper & lower limb arteriography	FL Defecography
	37. Top 20/ 11	31. Top 20/ 2.	32. Top 20/ 10.	52.Top 20/ 16
	56. Top 20/ 8.	32. Top 20/ 11	53. Top 20/ 2.	
		51. Top 20/ 10.		

In Table 10.2, the contribution of the 20 most important examinations (as shown in Table 10.1) to the overall collective effective dose, is compared with the contribution of the present Top 20 list of RP 154. It can be seen, that the new “national Top 20” instead of that of RP 154 for these countries would improve the accuracy of the population dose estimation on the average by about 10 % (the data from FR should be excluded from the comparison because it relates to broader groups than that of the three other countries). Table 10.1 also identifies, how many types of examinations (in terms of the 225 codes of RP 154) are needed to cover certain percentage of the overall collective effective dose. It can be seen that with a “national TOP 20” list the coverage of about 90 % is achievable, while the coverage of 95 % would require about 30 types of examination.

Table 10.2. Coverage of overall collective effective dose: comparisons of Top 20 nationals with that of RP 154, and the number of examination types to achieve a given coverage in %.

Country	TOP 20 RP 154, % of overall E	TOP 20 national, % of overall E	Difference, % of overall E	How many examination types is needed for the coverage of x % from overall E?			
				x= 80%	x=90%	x=95%	x=99%
Finland (FI)	77,0	89,8	12,8	13	21	30	55
France (FR)	96,2	97,2	1,0	10	14	17	26
Switzerland (CH)	86,3	90,4	4,1	12	20	34	65
UK (UK)	78,5	91,3	12,8	12	19	28	50
Mean	84,5	92,2	7,7	11,8	18,5	27,3	49,0
Mean without FR	80,6	90,5	9,9	12,3	20,0	30,7	56,7

Based on the above, for a good estimation of the overall population dose when comprehensive data for all examinations is not available, it is recommended to supplement the TOP 20 groups of RP 154 by 4-6 extra examination categories, known or suspected to yield significant contribution to the overall population dose. Table 10.1 provides some insight on possible extra categories; in particular, some IR procedures and CT procedures (outside the present TOP 20 list) should be considered. This would enable to provide an estimate of about 90 % of the overall population dose (on the average). However, Table 10.1 reviews the situation in only four countries; in other countries some other, e.g. plain radiography or fluoroscopy procedures, might be of more importance.

In general, it can be concluded that the TOP 20 method with the present list of 20 examinations (RP 154) can still provide a reasonable estimate of the overall population dose, i.e. from about 60 % to 90 % of the overall dose. This can be significantly improved by supplementing the analysis with 4-6 extra examinations. The present TOP 20 list can be retained and should be changed not earlier than certain examinations become insignificant in the majority of EU countries. This will facilitate comparisons of data between countries and enable easy follow-up and analysis of the trends in population dose.

9.10.2 Nuclear Medicine procedures

For nuclear medicine examinations, no previous guidance on “Top 20 or equivalent” has been available. The preparation of the EXCEL files for the data collection in this project was based on the knowledge of a number of most common examinations in a few partner countries, and this list of 28 different types of examinations turned out to be rather exhaustive; for most of the countries, data of none or only a few extra examinations (outside the list) were provided through the replies. Furthermore, most of these extra examinations having a significant contribution to the overall population dose could be assigned to one of the 7 broader groups shown in Table 5. (Section 5.2.2.2).

For nuclear medicine examinations, an approach analogous to Top 20 of x-ray procedures is proposed here, based on the analysis of the European data in Section 5.2.2.2. The seven groups identified in Table 5. (Section 5.2.2.2) contribute on the average more than 90 % to the overall collective effective dose from all NM procedures; hence this group of examinations gives on the average a good estimate of the overall population dose. This is defined here as “Top 7” method and recommended as the basis of European guidance for population dose estimation of nuclear medicine procedures.

9.11 Annex 11 - POPULATION DOSE DATABASE

The aim of the population dose database is the support of the evaluation of the collected data and to enable a continuous follow-up and update of population doses in Europe. Furthermore, it should be possible to compare and analyse trends during follow-up projects.

This section contains only an overview of the Dose Datamed Database (DDMedDB). Detailed technical information, developed software programmes and the data itself are available on the Dose Datamed II Resource CD.

9.11.1 Data acquisition and analysis workflow

The data collection workflow is shown in Figure 11.1. The data in the different participating countries was collected using an Internet-based online Questionnaire System (1). This enabled an easy to control access to the questions without the need to install software. As the collection of the complex dose data would have been difficult, the frequency and dose data itself was collected with two dedicated Excel templates (2). Software has been developed to transfer the collected data into the DDMedDB (3). From the database, different views provided the basis for the dynamic web pages on ddmed.eu/database (4). The database exports have been the base for the data verification and evaluation (5). The team has prepared the necessary tables and charts using Excel and included them, together with the associated descriptions into the final DDM2 report (6).

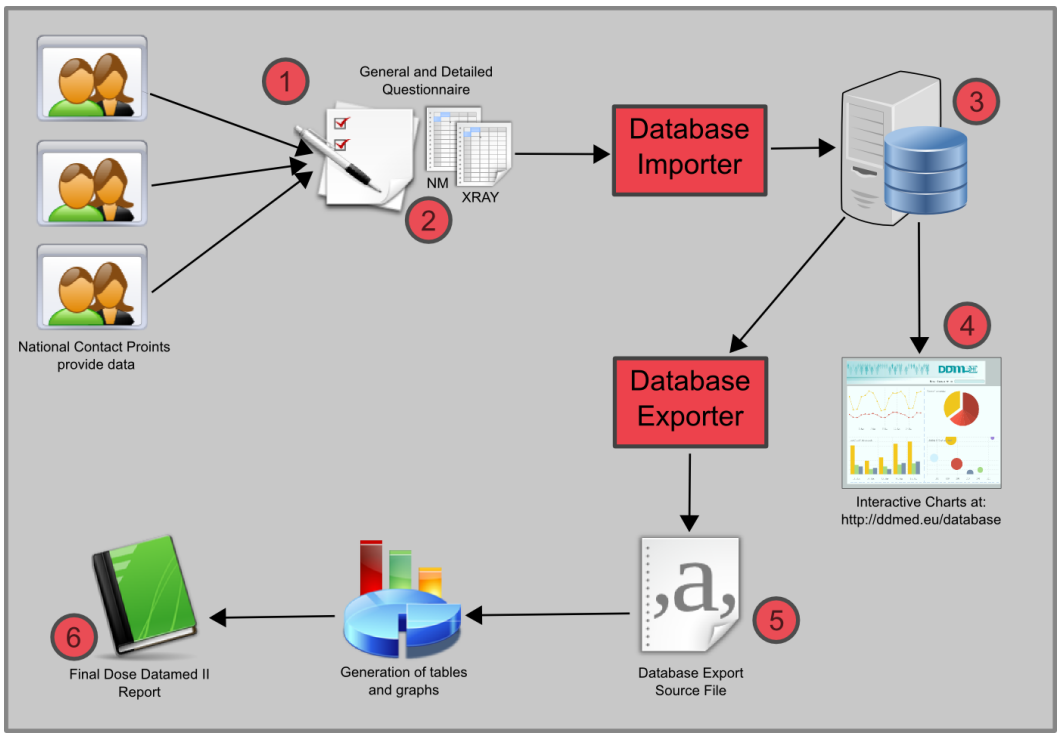


Figure 11.1. Workflow of the collected data within DDM2 project.

9.11.2 Design and technical implementation of the Database

During the implementation, importance was attached to the fact, that only standard technologies have been used. This reduces the technical dependency of the provided solution.

To support the data evaluation, different database views have been implemented. A database view 175rganizes the data in the database to show specific aspects of the collected data without duplicating the data. The following views are available:

- Type and number of healthcare providers per country in Europe.

- Overview of healthcare professionals in Europe; Status and date the countries provided the data.
- Equipment available in the different countries per modality.
- X-ray TOP20 overview of the frequencies.
- Categorization of the x-ray frequency per million into the four classes: Plain radiography, Fluoroscopy, CT and Interventional. This view is available as an interactive chart at the web site.
- Overview of the x-ray frequency uncertainties per country
- X-ray TOP 20 overview of the typical effective dose.
- Categorization of the typical effective doses into the four classes: Plain radiography, Fluoroscopy, CT and Interventional. This view is available as interactive chart at the web site.
- X-ray TOP 20 overview of the collective effective dose per million.
- Categorization of the collective x-ray effective dose per million into the four classes: Plain radiography, Fluoroscopy, CT and Interventional. This view is available as an interactive chart at the web site.
- Overview of the x-ray dose uncertainties per country
- Overview of the frequencies of the dental examinations.
- Overview of the typical effective dose value for all countries and dental examination types.
- Lists the TOP 28 NM examination frequencies for all countries.
- Lists the TOP 28 NM mean activities for all countries
- Has PET-CT increasingly used in your country [Y,N,UNK] for all countries

Those views have been used to create the dynamic diagrams on ddmed.eu/database, data checking, data analysis and during report writing. The following dynamic diagrams are available:

- TOP20 Frequency by Examination Category
- TOP20 Typical Effective Dose per Examination Category
- TOP20 Collective Effective Dose per Examination Category
- X-RAY Diagnostic Reference Level Map
- NM Diagnostic Reference Level Map.

9.11.3 Database content and future updates

The database contains all the data collected during the data collection of the DDM2 project. This includes comments received from the national contact points until end of 2012. The database is designed to support several data sets from future studies. This will allow a future project to compare the collected data and calculate trends.

Adding additional data, the environment has to be prepared and configured. The following actions have to be performed at technical level:

- Configuration of the DDM2 database (needs to be running)
- Configuration of the input Excel files. The input files have to be based on the templates developed during the project and are available on the resource CD.
- Definition of a new study.
- Execution of the Import and Export Software components to import the new data and optionally export the data.

All configuration changes need to be performed in the source code of the different software components. If the Excel templates are changed, those changes have to be taken into account as well within the Database Importer Software component. If additional view are needed, for example to compare different studies, those have to be added to the database and optionally to the Database Export Software component.

The maintenance of the database was guaranteed by the DDM2 consortium during the project duration.

9.11.4 DDM2 database as a tool to monitor patient doses in Europe

The database developed during this project is a good basis to establish a set of data to monitor and follow up the use of medical exposures in Europe. Even though there have not been enough resources to establish a system with sophisticated user interface, the system can handle data from several years/studies.

A future project might (1) extend the database with a web interface to upload data (2) establish a scientific committee that reviews the submitted data (3) develops the necessary comparative methods and database views and (4) gives interactive access of the collected data to the radiation protection community.

Future updates of the data are a long-term activity. Therefore the database should be put into the custodial care of an organisation dealing with radiation protection issues.

9.12 Annex 12 - EFFECT OF TISSUE RISK WEIGHTING FACTORS ON THE ESTIMATION OF EFFECTIVE DOSE FOR X-RAY PROCEDURES

9.12.1 Evolution in tissue weighting factors

Effective dose (E) was developed by the International Commission on Radiological Protection (ICRP) to allow the summation of doses, whether whole or partial-body, from internal or external sources, as part of its system of protection (ICRP, 2007). The quantity provides a single measure of the dose to a reference person (of average age and gender) that is roughly proportional to the total 'radiation detriment' from stochastic effects associated with exposure to ionising radiation. E is calculated as a weighted sum of the mean absorbed doses (or strictly the mean equivalent doses) to those organs and tissues in the body that are prone to radiation cancer or heritable effects:

$$E = \sum_T w_T H_T = \sum_T w_T \sum_R w_R D_{T,R} = \sum_T w_T D_{T,x-rays}$$

where H_T is the equivalent dose in organ or tissue T, $D_{T,R}$ is the mean absorbed dose in organ or tissue T due to radiation of type R, w_R is the radiation weighting factor for radiation R (equal to unity for diagnostic x-rays), w_T is the tissue weighting factor for tissue T and $\sum w_T = 1$.

The tissue weighting factors (w_T) are chosen for protection purposes by ICRP (2007) to represent the contributions of individual organs or tissues to overall 'radiation detriment' from stochastic effects. This process takes into account the life lost from fatal cancers and heritable effects, and the reduced quality of life associated with non-fatal cancers and heritable effects.

The concept of a detriment-weighted dose quantity was first developed by ICRP (1977) in Publication 26, with the name 'effective dose equivalent' and tissue weighting factors reflecting risk for fatal cancers and hereditary effects. The quantity known as effective dose was subsequently introduced by ICRP (1991) in its 1990 recommendations on the basis of updated research on radiation effects and tissue weighting factors that related to an aggregated representation of detriment, including non-fatal cancers as well as fatal cancers and severe hereditary effects. Effective dose was further updated with new tissue weighting factors in the 2007 recommendations of ICRP (2007).

Error! Reference source not found.12.1 presents a summary of the evolution (1977 to 2007) in the ICRP tissue weighting factors. The number of organs with specific tissue weighting factors has increased and values for particular organs have changed following updated analyses of risk and radiation detriment. In particular, there has been a significant reduction in relation to the tissue weighting factor for dose to the gonads and hereditary risks. There have also been changes and improved clarity in the treatment of so-called 'remainder' organs or tissues not otherwise having specific tissue weighting factors. In Publication 26 (ICRP, 1977), the remainder tissue weighting factor of 0.3 was split between the 5 (unspecified) other organs receiving the highest doses. In Publication 60 (ICRP, 1991), the tissue weighting factor of 0.05 was split between 10 particular organs, although, under the so-called 'remainder rule', a tissue weighting factor of 0.025 was applied to any remainder organ receiving a higher dose than any organ with a specific tissue weighting factor, with 0.025 then being applied to the mean dose for the rest of the remainder. Most recently in Publication 103 (ICRP, 2007), the remainder tissue weighting factor of 0.12 is applied to the arithmetic mean of the doses to 13 particular organs. The more detailed and prescriptive approach in this latter development has improved consistency in the calculation of effective dose and ensured that the quantity is now truly additive.

Table 12.1. Evolution in tissue weighting factors recommended by ICRP for the calculation of effective dose equivalent and effective dose.

Organ or tissue	Publication 26[a] (ICRP, 1977)	Publication 60[b] (ICRP, 1991)	Publication 103[b] (ICRP, 2007)
Gonads	0,25	0,20	0,08
Bone marrow (red)	0,12	0,12	0,12
Lung	0,12	0,12	0,12
Breast	0,15	0,05	0,12
Thyroid	0,03	0,05	0,04
Bone surfaces	0,03	0,01	0,01
Remainder	0,30[c]	0,05[d]	0,12[e]
Colon	-	0,12	0,12
Stomach	-	0,12	0,12
Bladder	-	0,05	0,04
Liver	-	0,05	0,04
Oesophagus	-	0,05	0,04
Skin	-	0,01	0,01
Salivary glands	-	-	0,01
Brain	-	-	0,01

[a] Effective dose equivalent.
[b] Effective dose.
[c] 0.06 to each of the 5 organs or tissues of the 'remainder' receiving the highest doses.
[d] Remainder composed of 10 particular organs and tissues: adrenals, brain, upper large intestine, small intestine, kidney, muscle, pancreas, spleen, thymus and uterus. Weighting split equally between any single remainder organ receiving a higher dose than any of those with specific tissue weighting factors and the mean dose to the rest of the remainder (the 'remainder rule').
[e] 0.12 applies to the arithmetic mean of the doses to 13 particular organs and tissues for each sex: adrenals, extrathoracic region, gall bladder, heart, kidneys, lymphatic nodes, muscle, oral mucosa, pancreas, prostate (male), small intestine, spleen, thymus and uterus/cervix (female).

For the highly non-uniform dose distributions arising from the partial-body irradiations common in diagnostic radiology, such changes in the ICRP tissue weighting factors can have a significant influence on the estimated doses. Previous analysis has shown that values of effective dose (E_{60}) calculated following the methodology in ICRP 60 (1991) could differ from corresponding values of effective dose equivalent (ICRP, 1977) by up to a factor of two (NRPB, 1993). Differences were largest for examinations of the head (where 'remainder organs' make relatively large contributions to the total dose), but were within 20% for most examinations of the trunk. Similarly significant differences are also apparent between values of effective dose according to Publication 60 (ICRP, 1991), E_{60}, and Publication 103 (ICRP, 2007), E_{103}, as summarised in Table 12.2 in relation to some typical x-ray examinations on the basis of modelling utilising the adult MIRD anthropomorphic mathematical phantom and typical UK practice for adults (Wall et al, 2011).

Table 12.2. Ratios for corresponding estimates of effective dose, according to ICRP 103 and ICRP 60 definitions, for common x-ray procedures on adults (Wall et al, 2011).

X-ray procedure		Ratio E_{103} / E_{60}
Radiography	Head (skull)	1,36
	Cervical spine	1,00
	Shoulder	0,92
	Chest	1,00
	Thoracic spine	1,03
	Lumbar spine	0,91
	Abdomen	0,91
	Pelvis	0,62
	Single hip	0,58
	Both hips	0,54
	Femur	0,55
	Knee	0,50
	Foot	1,00
	Intravenous urography (IVU)	0,91
Fluoroscopy	Barium swallow	1,07
	Barium follow	0,87
	Barium enema	0,73
	Coronary angiography	1,00
	Femoral angiography	0,82
Computed tomography (CT)	CT head	0,84
	CT chest	1,14
	CT abdomen	1,09
	CT abdomen and pelvis	0,98
	CT chest, abdomen and pelvis	1,09

Once again, variations by up to a factor of 2 are apparent between corresponding estimates of effective dose following the 2007 (E103) and 1991 (E60) definitions. The ratio E103/ E60 ranges from about 0.5 for radiographic examinations of the pelvis, hips and femur (owing to the relatively high gonad doses and the reduced tissue weighting factor for heritable effects in E103 compared to E60) to around 1.4 for radiographic examination of the head (owing to the inclusion of the highly-irradiated salivary glands, oral mucosa and extrathoracic tissues in E103). For most other types of x-ray examination, differences are within ±20% and most commonly within ±10%. The low ratio for CT head (compared to the high ratio for radiography of the head), is due to the high brain dose from CT head and application of the 'remainder rule' for E60 (where a tissue weighting factor of 0.025 is thus applied to the brain) but not for E103 (where the tissue weighting factor for brain is specifically 0.01). The ratio of 1.14 for CT of the chest is due to the relatively high breast dose and higher tissue weighting factor for the breast in E103 (0.12) compared with E60 (0.05).

In summary, the most recent revision in tissue weighting factors from ICRP 60 (E60) to ICRP 103 (E103) will have a significant impact (by more than a few tens of percent) for only a few types of x-ray examination. Furthermore, when applied to an assessment of the population dose from all x-ray examinations in the UK for 2008, the estimate based on E103 was only slightly higher (by 2%) than when based on E60 (Hart et al, 2010). However, estimates of effective dose should always be analysed with knowledge of the tissue weighting factors applied in order to interpret correctly any changes arising from differences in radiology practice.

9.12.2 Evolution in anthropomorphic reference patients

Effective dose cannot, of course, be measured directly and its estimation requires knowledge of the mean doses to a range of organs that in turn can only be assessed using dose coefficients determined for reference patients by measurement in physical phantoms or calculation using Monte Carlo techniques and virtual phantoms (ICRU, 2005; UNSCEAR, 2010). These organ

doses can be expressed relative to simpler quantities that can be more easily measured in practice such as entrance surface dose per radiograph, dose-area product per complete radiographic or fluoroscopic examination and, for CT, volume-weighted CT dose index (IAEA, 2007). Inevitably, therefore, estimates of effective dose depend on the particular dose model and reference patient assumed.

In the past, organ and effective dose modelling for x-ray examinations has commonly been based on the hermaphrodite mathematical phantoms first developed by Oak Ridge National Laboratory in the USA, originally in relation to calculations for internal dosimetry and known as the MIRD (medical internal radiation dosimetry) phantoms (ICRU, 2005). These provide stylised representations of human anatomy based on simple geometric shapes. In recent times, more anatomically realistic tomographic or voxel ('volume pixel') phantoms have been developed based on detailed whole body images (CT or MRI) of real patients. In particular, ICRP has recommended the use of the adult reference computational phantoms, adult male (AM) and adult female (AF), for the estimation of mean organ doses for the calculation of effective dose (ICRP, 2009).

Whereas both the MIRD and the ICRP (AM and AF) phantoms provide representations of reference patients based on typical (reference) organ masses for a general population, there are significant differences in appearance between these phantoms in terms of the shape and location of individual organs, which in turn can significantly affect estimated values of organ and effective dose under similar conditions of exposure. There are also differences in the models applied in relation, for example, to bone dosimetry (affecting estimated mean doses to red marrow and endostial tissues). Table presents, for example, a summary of the differences in estimates of normalised E103 between an updated MIRD phantom (HPA18+) and the ICRP AM and AF voxel phantoms for some standard CT examinations (Jansen and Shrimpton, 2011). Doses are presented relative to data for the MIRD phantom and represent mean results over a range of CT scanner models. Effective doses assessed on the basis of mean organ doses averaged over the AM and AF voxel reference phantoms are in general larger than those based on the MIRD phantom, by up to 40% in the case of scans of the abdomen.

Table 12.3. Variation in normalised effective dose for standard CT examinations simulated for different adult reference patients (Jansen and Shrimpton, 2011).

CT examination	Relative normalised effective dose (E_{103})			
	HPA 18+[a]	AM[b]	AF[b]	AM+AF[b]
Head	1,0	0,9	1,2	1,1
Chest	1,0	1,2	1,4	1,3
Abdomen	1,0	1,4	1,3	1,4
Pelvis	1,0	0,7	1,2	1,0
Whole body	1,0	1,0	1,1	1,1

[a] Updated adult MIRD mathematical phantom.
[b] ICRP adult reference computational phantoms (ICRP, 2009).

In summary, estimates of effective dose are dependent on the models assumed for the underlying assessments of mean organ doses. Values of effective dose (2007 definition) for x-ray examinations based on the new ICRP adult reference computational phantoms (AM and AF) can vary from those based on the old adult MIRD phantom by up to a few tens of percent. Estimates of effective dose should always be analysed with knowledge of the underlying reference patient and dose models assumed in order to interpret correctly any changes arising from differences in radiology practice.