United Nations Scientific Committee
on the Effects of Atomic Radiation

SURVEY.UNSCEAR.ORG

UNSCEAR **GLOBAL SURVEY ON MEDICAL EXPOSURE**

A USER MANUAL

DRAFT VERSION May 2015

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INTRODUCTION

The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) was established by the United Nations General Assembly in 1955 to assess and report levels and effects of all sources of ionizing radiation. UNSCEAR conducts regular surveys of medical radiation usage and exposure to identify trends in radiation exposure and to estimate the worldwide exposure levels. The surveys are also used to identify gaps in treatment capabilities and possible unwarranted dose variations for the same radiological procedure in the different countries.

The present user manual for the UNSCEAR Global Survey of Medical Radiation Usage and Exposure aspires to help in assisting survey participants to collect and provide accurate information. The manual is divided in three parts:

PART ONE. GENERAL INFORMATION

Provides background information on general aspects related to frequency and dose estimation, and on the use of the collective effective dose concept.

PART TWO. THE UNSCEAR ONLINE PLATFORM

Provides information and guidance on the use of the UNSCEAR online platform (registration, uploading data, updating profile information).

PART THREE. THE SURVEY QUESTIONNAIRES

Provides general information regarding the use and layout of the survey questionnaires and specific information on the technicalities of completing the specific questionnaires for the three disciplines: diagnostic and interventional radiology (RD), nuclear medicine (NM) and radiotherapy (RT).

This manual aims to help users to fill in information in the relevant questionnaires and to upload the collected data to the UNSCEAR online platform in order to have the data imported into the UNSCEAR database for further analysis and evaluation.

DATA COLLECTION, ANALYSIS AND EVALUATION

The main aim of the UNSCEAR Global Survey is to estimate the global collective effective dose from medical use of radiation. The global collective effective dose determination requires information on frequency and dose for all major types of medical examinations/procedures/treatments by country. For countries that do not provide any information, their contribution to the global estimate will be extrapolated. The UNSCEAR online platform (http://www.survey.unscear.org) has been designed to assist governments in providing national data on the use of radiation in medical diagnosis and treatment from 2006 onwards. Ideally, the submitted data should reflect the national level of practice as accurately as possible. However, incomplete information is also welcomed as it is useful for the global estimation of radiation levels.

For data analysis, management and report generation, UNSCEAR uses a dedicated database. Once the collected data files are uploaded and validated, the data will be imported to this database. An expert group will conduct a detailed analysis of the data, including a global dose estimate and the frequency of use of radiological examinations/procedures/treatments with breakdowns by age, sex, level of healthcare, region and country. Once the data evaluation is finalized, all contributors will be informed about the results.

NATIONAL CONTACT PERSONS (NCP)

The General Assembly, in its resolution (A/RES/69/84), encourages Member States to take part in the UNSCEAR Global Survey and to nominate national contact persons to facilitate the coordination of data collection and submission at country level. NCPs need to be nominated to UNSCEAR via official channels (e.g. Ministry of Foreign Affairs or Permanent Mission to the United Nations) to guarantee their authority and to ensure that the collected data are scientifically objective. NCPs will not be experts in all radiological exposure categories and, therefore, additional technical experts should support them. However, NCPs should know who has the relevant data in the country and they should be able to request such data or their collection for future submissions. Furthermore, NCPs and all other experts are requested to register with the UNSCEAR online platform to be able to access the protected area for downloading or uploading the UNSCEAR questionnaires. The submission of the collected data is possible only via the UNSCEAR online platform, which will be described in detail in the second part of this manual.

Besides their coordination role at country level, NCPs are also responsible for cooperation with the technical experts to complete the UNSCEAR questionnaires and to submit the data to UNSCEAR. Further, NCPs are requested to correspond with UNSCEAR in case of difficulties and to provide additional material (e.g. national reports) as relevant supporting information. All contributions to the survey will be acknowledged by UNSCEAR in the relevant report to the United Nations General Assembly.

PART ONE
General information

- Methods of data collection regarding frequency of examinations
- Method of collective effective dose estimation

This part provides background information on general aspects related to frequency and dose estimation and also on the use of the collective effective dose.

METHODS OF DATA COLLECTION REGARDING FREQUENCY OF EXAMINATIONS

The two most common methods for assessing the annual frequency of radiological examinations/procedures are as follows **[E1]**:

1. Annual numbers of examinations may be obtained directly from a representative sample of hospitals, clinics or practices and then scaled up to cover the whole country. Practically, examination data should be available in the hospital radiology information systems (RIS). The following important points could also be taken into account:
   - *(a)* The sample of hospital and radiological practices should be representative. This means including different types of radiological practices in the actual proportions that occur nationally.
   - *(b)* If dental radiology practices are to be included, it has to be considered that while effective doses are small and do not affect the collective dose significantly, they have a significant impact on the frequency of X-ray examinations. They may account for at least one third of all X-ray examinations in most countries.
   - *(c)* It is expected that examination codes may vary even locally. Users should make sure the correct examination data are retrieved from the RIS.

2. Annual numbers of examinations may be obtained from central statistics held by government departments or insurance companies for all (or at least a large proportion) of radiology practices in the country. If frequencies are derived from health insurance data, they are usually available at regular (annual) intervals. An important advantage in this case is that a chronological sequence enables recognition of inexplicable discrepancies in the data by comparing the figures for different years and correcting the mistakes. The following points should also be taken into account:
   - *(a)* The national statistical data provided by the government or health insurance companies need to be translated into the actual classification of examinations.
   - *(b)* Radiological coding systems may vary within countries even from year to year and systems differ from country to country. Therefore, the examination categorization used in this survey is a compromise and complete availability of frequency data for all examinations is not expected.

METHODS OF DATA COLLECTION REGARDING FREQUENCY OF EXAMINATIONS

Sources of uncertainty in frequency estimation

Algorithms for the estimation of the total frequency of radiological examinations might be error prone, introducing systematic or statistical errors. The following main sources of uncertainty in estimates have been identified **[E1]**:

(a) Converting RIS or health insurance coded data into actual numbers of examinations/procedures (e.g. non-uniform definition of "examination", double-counting, particularly with examinations of double-sided organs).

(b) Insufficiently differentiated examination codes in RIS and health insurance systems ("accumulative codes" including more than one type of examination).

(c) Splitting a complex examination into several parts, which are eventually considered as different examinations while they are merely different parts of the same examination.

(d) Bias and invalid assumptions in the process of selecting representative samples to scale up to national level data (non-representative sample of hospitals, incomplete central statistics).

(e) Lack of frequency data from major radiology service providers such as:

(i) Interventional procedures and fluoroscopy performed outside X-ray departments and not recorded by RIS.

(ii) Dentists practising privately and not included in central statistics.

(f) Errors in data recording and collection. Simple typing errors may occur or codes can be incorrectly interpreted and numbers assigned to the wrong type of examination.

When there is limited information on the frequency of specific examinations, assumptions need to be made by comparison to frequencies of other examinations for which sufficient data are available. There is a risk that these assumptions will not be 100% valid and will introduce errors in the frequency estimates. Although it is difficult to determine these errors accurately, it may be possible to assess the maximum likely uncertainty frequency estimates due to the assumptions made.

If the same code is used for multiple examination types, it is important to try to determine the distribution of the different examinations with the same code. This may be done, for example, with a limited survey or by assuming an equal distribution for all body regions. An evaluation of the impact of the maximum likely uncertainty associated with each of these options on the overall result should be performed. The efforts to reduce these uncertainties should be commensurate with the impact they have on the overall result.

A characteristic example of the problem of double counting is mammography. In some cases the number of examinations is the number of breasts examined while in other cases it is the number of patients. Sometimes different counting methods are applied to screening and to examinations of symptomatic patients. **It is essential to know which method is being used and to count an examination of both breasts on the same woman at the same time as one examination only.**

METHOD OF COLLECTIVE EFFECTIVE DOSE ESTIMATION

The concepts of *effective dose* and *collective effective dose* are used for the UNSCEAR evaluations. As the effective dose applies only to dose levels in radiology and nuclear medicine, it is not appropriate to assess the collective effective dose from radiation therapy treatments. Further, the collective effective dose estimation from medical diagnostic exposure ought to be used for comparative purposes of similar populations (e.g. patients) **[U1]**.

The effective dose E (Unit: sievert) is a calculated quantity that cannot be measured directly. It is defined as the weighted sum of the mean radiation doses to a number of radiosensitive tissues or organs in the body **[I5, I8]**. The International Commission on Radiological Protection (ICRP) publishes the weighting factors for the estimation of effective dose **[I5, I8]**.

In its most basic form, calculation of the effective dose requires the knowledge of mean radiation doses (in mGy) imparted to more than 20 organs/tissues. In most of the cases (photon and electron radiation) these values of mean absorbed doses mGy are the same as "equivalent doses" to organs or tissues (in mSv). These "equivalent dose" values would need to be multiplied by the specific ICRP weighting factors (depending on the organ or tissue). The tissue-weighted sum of the equivalent doses in all specified tissues and organs of the body constitutes the effective dose. Practically, effective dose estimation is usually performed using simpler methods. **Factors that have been determined through scientific research may be multiplied by easily measurable dose metrics to yield effective dose.** These factors are usually determined through Monte Carlo simulation methods in conjunction with humanoid computational phantoms. This is why the UNSCEAR Survey focuses on practical, widely available dose quantities that can be used for practical effective dose calculation. The respective dose section in this user manual will describe the most widely available practical metrics (basic multiplication factors by modality) for this purpose.

The collective effective dose in man-sieverts is then obtained by multiplying the mean effective dose E_e (Sv) for a procedure by the number of procedures N_e. The numerical value of N_e may be deduced from the annual frequency (number of procedures per 1,000 population) and the estimated population size. The collective effective dose S for the entire population is a summation of the effective dose from all radiological procedures: $S = \sum E_e N_e$.

METHOD OF COLLECTIVE EFFECTIVE DOSE ESTIMATION

Sources of uncertainty in collective effective dose estimation

The mean effective doses per examination may vary a lot among practices even in the same hospital. These variations might influence the collective effective dose estimation of a population **[E1]**. A typical national collective effective dose value should be based on a representative sample of average nationwide practices. In order to limit the uncertainty regarding dose estimation per examination, attention should be paid to the following:

(a) The number of practices included in the survey should represent the whole spectrum of variations in the different examinations/ procedures in the country;

(b) The number of sites included in the survey should represent all different kinds of equipment used in the country;

(c) Direct patient dose measurements should take into account the average patient size and clinical indication distribution. Ideally, doses should be measured or calculated for at least 10, and preferably 20, close-to-average size adult patients (e.g. weighing 60–80 kg). No complication leading to higher than usual doses or a premature termination of the examination should have occurred;

(d) Doses should be measured or calculated for a standard examination protocol that is representative for the average "typical" procedure used in each room/facility for average-sized adult patients. It would be ideal to investigate all protocols used in a room/facility to identify the average clinical practice; and

(e) For the purpose of the estimation of the global collective effective dose, child doses do not need to be considered separately as it is assumed that children receive the same mean effective dose as adults from the same type of examination. Protocols are selected to suit the smaller size of paediatric patients and this normally results in lower entrance doses and lower attenuation with similar effective doses. Collective effective dose, when used for comparison of paediatric patient groups, requires specific consideration.

PART TWO
UNSCEAR online platform

- Access to platform
- My country page

This part provides information and guidance on the use of the UNSCEAR online platform.

ACCESS TO PLATFORM

Registration

NCPs and other national experts are requested to register by clicking the "Register" link at the top right of the survey website (figure 1).

Figure 1. The "Register" and "Login" links are shown at top right corner of survey website

After clicking on the "Register" link, users will be directed to the registration page where information should be filled in as completely as possible (figure 2). In this step, users will have to indicate the country for which they are providing data.

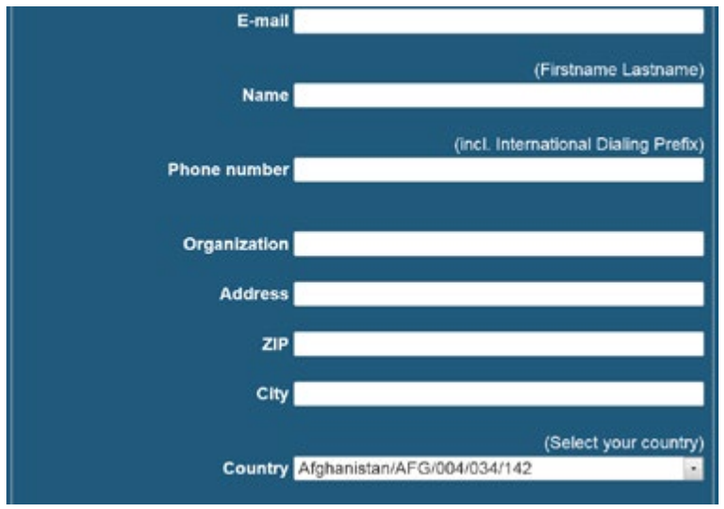

Figure 2. Basic information requested during registration

It should also be indicated whether the users are NCPs or not. Further, the area(s) of expertise or discipline(s) for which they contribute data should be indicated. More than one option can be selected (figure 3).

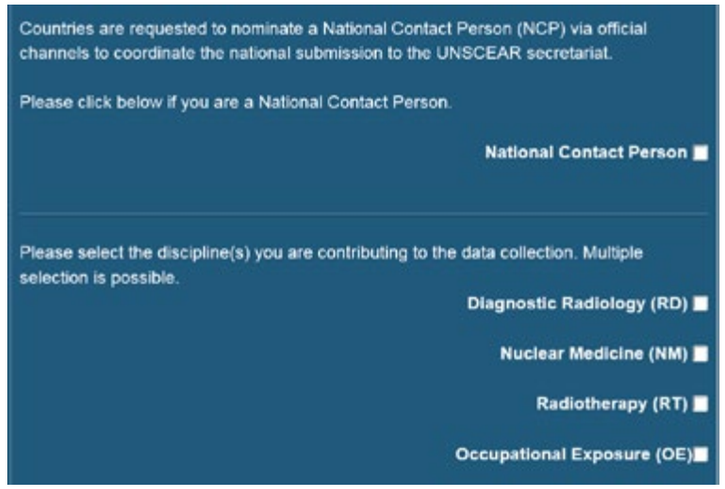

Figure 3. Users are requested to indicate if they are NCPs and which discipline(s) they contribute to

The registration will be validated before the system can be accessed. The validation process could take some time. It is vital that a valid e-mail address is supplied because after registration and validation, a confirmation e-mail including a password will be sent by e-mail. **This e-mail address is also used as login identification.**

ACCESS TO PLATFORM

Logging in

After registration, users can use the “Login” link at the top right of the survey website (figure 1), to access their account. Figure 4 shows a screenshot of the login page, in which users may enter their login credentials (e-mail address and password).

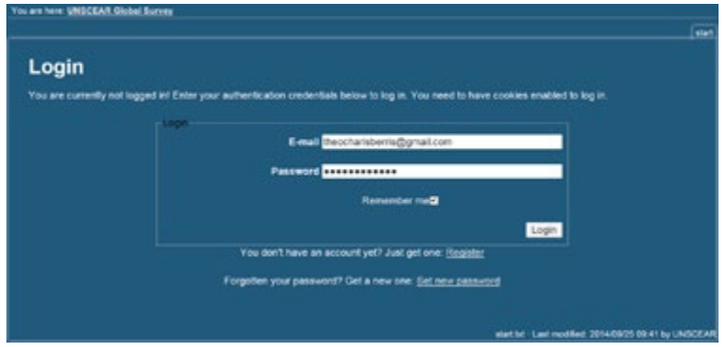

Figure 4. Screenshot of login page

Updating account profiles

Users may need to update their account details. This function may be accessed by the “Update Profile” link. This link is located at the top right of the screen when the user is logged in. Figure 5 also shows the update account page containing current user data. Information in these fields must be changed and then changes need to be saved in order to take effect.

Figure 5. Snapshot of update profile page—link marked with green arrow, top right

MY COUNTRY PAGE

Once logged in to the UNSCEAR online platform, users will be redirected to the specific page for their country. It may also be reached manually after a user has logged in by clicking on the “My country” page link on the left side menu (figure 6). On this page users can access their country’s information and use the appropriate functions for downloading and uploading the UNSCEAR questionnaires.

The UNSCEAR Global Survey uses three questionnaires for data collection; one for each discipline (RD, NM and RT) which can be accessed by each country from its country specific page.

Figure 6. “My country” page link on left side menu of survey website

MY COUNTRY PAGE

Questionnaire download and upload

The questionnaires can be downloaded by clicking on the links provided on the country specific “My country” page as shown in figure 7.

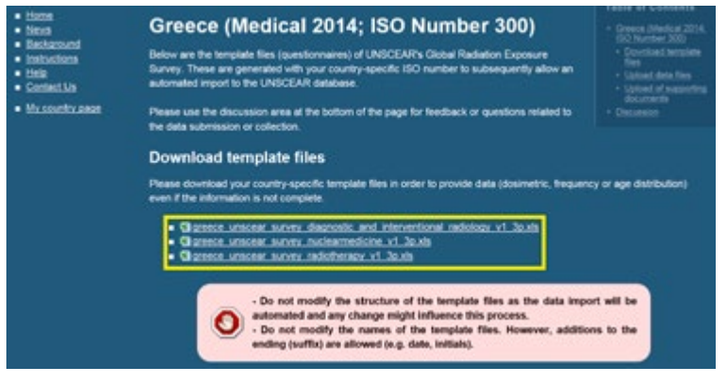

Figure 7. Questionnaire download links on “My country” page

The questionnaires are password protected and cannot be modified since they are to be used for the official data submission. In the following sections, this user manual provides information on how to complete the questionnaires. Some information is also contained within the questionnaire files as comments and in the help menu of the survey website (**www.survey.unscear.org**).

After data have been collected, files may be submitted by using the “Media upload” function. Users need to choose the file to upload by clicking on the “Choose file” button. A file browser window will open in which users need to locate and select the appropriate file. After selection of the data file, it can be uploaded by clicking on the “Upload” button as shown in figure 8. Supporting documents may be also uploaded by using the “Upload of supporting documents” function. A file browser window will open in which users need to locate and select the appropriate file. After selection of the data file, it can be uploaded by clicking the “Upload” button as shown in figure 8. Supporting documents may be also uploaded by using the “Upload of supporting documents” function.

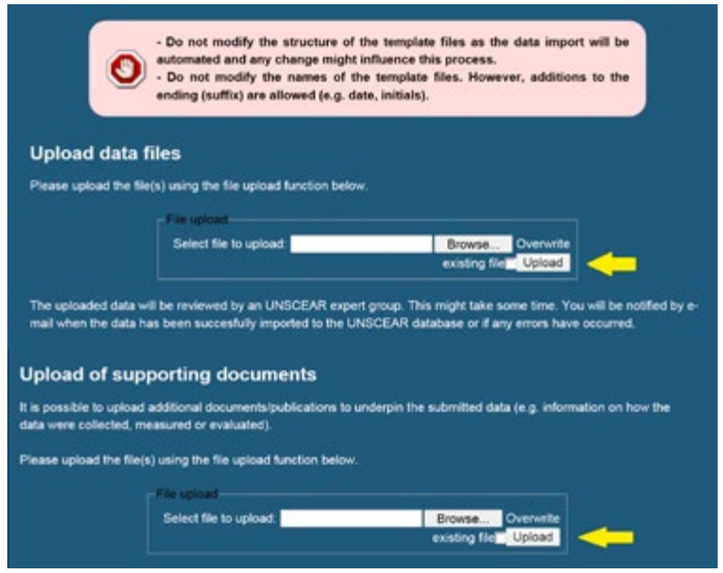

Figure 8. Screenshot of upload function of data files and supporting material on “My country” page

Submitted files will be validated with regard to completeness, quality and plausibility before their contents are transferred to the UNSCEAR database. **Notifications on the status of submitted data will be sent by e-mail to the NCP and all files will be archived on the country specific page.**

MY COUNTRY PAGE

Discussion area

A discussion area is provided at the bottom of each country specific page for communication between users of the platform and the UNSCEAR experts. The discussion area (figure 9) can be accessed only after users have been logged in to the UNSCEAR online platform.

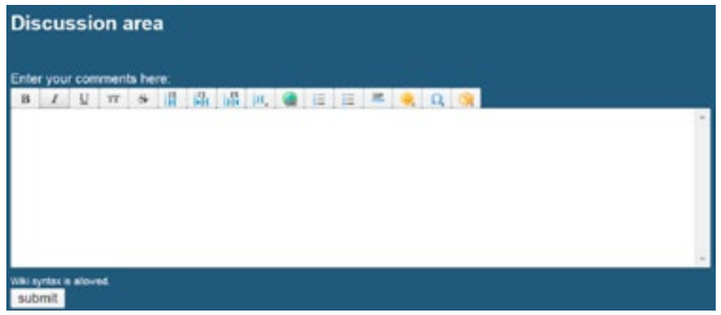

Figure 9. Screenshot of discussion section on country specific page

The discussion area is provided mainly in order to clarify issues that have been raised in the process of data collection and submission.

PART THREE
Survey questionnaires

- Diagnostic and interventional radiology (RD)
- Nuclear medicine (NM)
- Radiotherapy (RT)

This part provides general information regarding the use and layout of the survey questionnaires and specific information on the technicalities of filling in data for each questionnaire.

INTRODUCTION

This part provides general information regarding the use and layout of the survey questionnaires and specific information on the technicalities of filling in data for each questionnaire.

The UNSCEAR Global Survey consists of three questionnaires on the following primary disciplines:

- **Diagnostic and interventional radiology (RD)**
- **Nuclear medicine (NM)**
- **Radiotherapy (RT)**

This user manual is dedicated to providing specific information for data collection for each discipline (RD, NM and RT), corresponding with the three questionnaires, which will be addressed separately in the following subchapters.

The survey questionnaires are available as **Microsoft Excel** spreadsheets, which are widely used on personal computers. The spreadsheets comprise editable cells in which information can be added. The rest of the cells are locked and their content cannot be altered. Further, the questionnaire structure should not be changed. **It is vital that the questionnaire structure is not altered as the files will be used to import data automatically to the UNSCEAR database.**

The three questionnaires (spreadsheets) consist of four sections (sheets). Each section collects a different set of information relevant to the UNSCEAR Global Survey. Users may navigate to any of the sections (sheets) by clicking on the respective sheet name on the navigation pane of Microsoft Excel (figure 10).

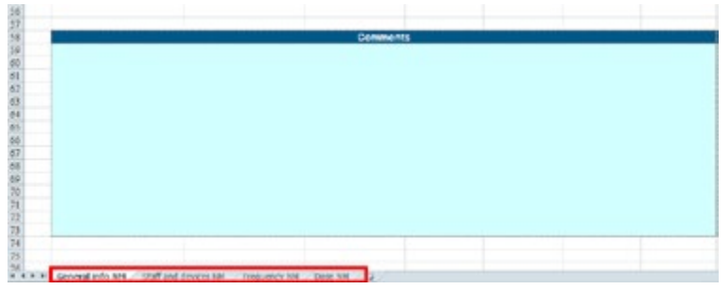

Figure 10. Sheet navigation pane of the NM questionnaire in Microsoft Excel

General remarks regarding the completion of any of the three questionnaires are presented:

- Please add the value “0” in a cell only when you are sure that the value is nil. Do not use the “0” value to indicate absence of data. **If data are not available, leave the cell blank.**
- Information on how representative the collected data are, compared to the whole country, is requested to assess the quality of the provided data and to calculate related uncertainties.
- Fields requesting obligatory information are called required fields. They are marked with a red asterisk as shown in figure 11. These fields request information on NCP contact details, the survey period and the population size.
- Some cells in the questionnaires include a small red triangle in the upper right corner. This indicates that a comment is appended to the specific cell. Users may read the comment by just hovering the mouse pointer over the cell. Figure 11 also shows such a pop-up comment.

INTRODUCTION

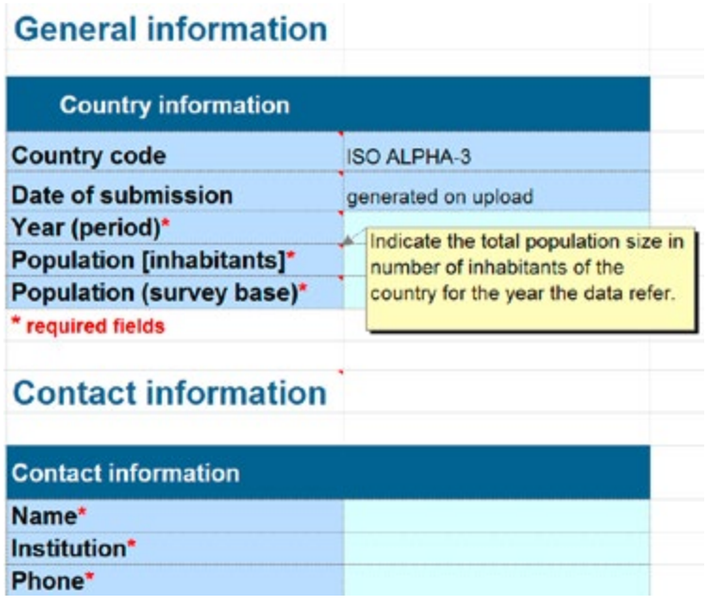

Figure 11. Screenshot of required fields and pop-up comments which appear when the mouse pointer hovers over a cell.

Each section (sheet) in the questionnaires includes a "comments" field at the bottom of the page (figure 12) for additional clarification and information that could be of use during the data review process. **Additional information about the survey data requested in the questionnaire should be added in the "comments" field.**

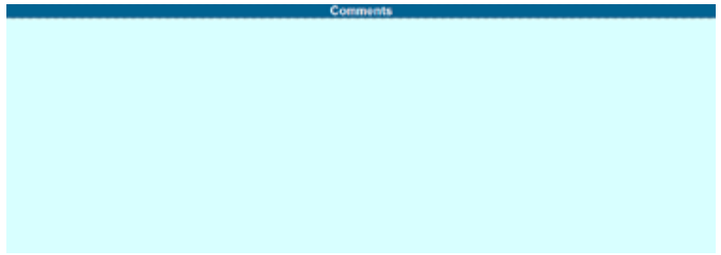

Figure 12. Screenshot of "comments" field at the bottom of each questionnaire sheet

DIAGNOSTIC AND INTERVENTIONAL RADIOLOGY

In this subchapter, information is provided to facilitate the completion of the diagnostic and interventional radiology questionnaire. The information requested is organized according to the four main sections (sheets) of the questionnaire, namely:

- **General information:** for general information about the country, its population, the survey period and contact details of contributors.
- **Staff and devices:** for information on staffing levels and the equipment available.
- **Frequency:** for data on frequency of examinations and on optional data regarding the age and the sex distribution of the population undergoing these examinations.
- **Dose:** for information on mean doses from different examinations.

DIAGNOSTIC AND INTERVENTIONAL RADIOLOGY

General information

In this section, contributors are requested to fill in their contact details and general information about their country such as:

- **Year:** Indicate the year (or period) to which the data refers.
- **Population (inhabitants):** Indicate the total population size in number of inhabitants of the country for the year the data refers to.
- **Population (survey base):** Indicate the size of population in number of inhabitants if the data collected are for a particular region, city or hospital only. **Provide the total population size of the country if the information provided is for the whole country.** When a smaller fraction of the population is used as a basis to assess the situation in the whole country, an estimation of how representative the data is with regard to the entire country should be provided for each examination separately. Such information is requested in the frequency sheet.
- Contact information: The data submitted should be signed off by the national contact person (NCP), registered on the UNSCEAR online platform, including name, institution and contact details (e-mail/phone) to facilitate any feedback. Please, indicate contact details of any other persons who have provided information and who should be acknowledged in the final report. **Contact details for at least one person are required as this information will be transferred to the UNSCEAR database.**

The country code is provided automatically, and the date of submission will be generated during the upload of the file.

DIAGNOSTIC AND INTERVENTIONAL RADIOLOGY

Collected information on staffing and equipment may be correlated with frequency and dose information and provide useful insights on the effect of equipment and staffing levels on population doses from medical radiation.

Staff and devices

Staff

Information about the number and type of professionals working in diagnostic and interventional radiology should be provided in this sheet. The numbers should reflect the situation in the entire country as accurately as possible and could be based on data originating from national registries or professional associations. Data should reflect the situation regarding professionals working in both hospital and private practice. Please note that:

- Only practising professionals should be included and their actual occupancy time should be taken **roughly** into account. For example, two part-time nurses, each working 50% of the normal working hours, count as one full-time professional.
- Persons working in two areas or more should be counted according to their **main activity**.
- Some data about professionals not working in diagnostic or interventional radiology are also requested. For example the number of **general practitioners**.

The number of practising individuals working in the following categories is sought in the RD questionnaire:

- **Physicians:** All physicians in the country irrespective of their medical specialization.
- **General practitioners:** Medical doctors usually acting as primary care providers at an early stage of a disease's onset. In some countries they are called family doctors.
- **Dentists:** Only physicians specialized in dental medicine. In some countries they are also known as dental surgeons.
- **Radiologists:** Only medical doctors specialized in radiology, excluding interventional radiologists.
- **Other physicians conducting radiological examinations:** All other physicians using X-rays (e.g. orthopaedic surgeons, gynaecologists, gastroenterologists).
- **Interventional radiologists:** Only radiologists with additional specialization in performing interventional procedures.
- **Interventional cardiologists:** Only cardiologists who are specialized or licensed to perform interventional cardiology procedures.
- **Other physicians conducting interventional procedures:** Physicians who are not radiologists or cardiologists but are specialized or licensed to perform interventional procedures: e.g. urologists, vascular surgeons or general surgeons.
- **Medical physicists in radiology/imaging:** Medical physicists licensed or authorized to practise in diagnostic and interventional radiology.
- **Radiation technologists in radiology/imaging:** Radiation technologists licensed or authorized to perform examinations or procedures in diagnostic and interventional radiology.
- **Nurses in radiology/imaging:** Nurses practising in diagnostic or interventional radiology or working as radiation technologists.

DIAGNOSTIC AND INTERVENTIONAL RADIOLOGY

Staff and devices

Devices

A wide range of different radiological devices are used in diagnostic and interventional radiology. Some general information and guidelines on how to list the different devices are provided here:

- Only data on the numbers of **actually operating equipment** are required.
- Data about analogue and digital diagnostic radiology systems should be listed **separately**. Only systems with a fully digital image receptor, such as the ones comprising flat panel detectors, are defined as digital devices.
- Computed radiography systems are not considered full digital systems and are categorized under “image processing modalities”.
- Systems with multiple X-ray tubes are counted as one device.
- CT system components of nuclear medicine hybrid systems should not be listed in the diagnostic and interventional radiology questionnaire.

The number of MRI scanners is requested even though MRI does not use ionizing radiation for imaging. Collecting data about the number of MRI machines is important to provide a more complete overview of the level of medical imaging in a country.

Note that equipment that should be listed in the radiotherapy questionnaire also includes imaging devices. These may be different from the ones used in the radiology department and may be for exclusive use for radiotherapy purposes. **If this is not the case and the same equipment (e.g. CT) is also used in diagnostic radiology, then it should be listed only once in the radiology section of the questionnaire.** Patient doses resulting from CT uses for radiotherapy planning are not taken into account in the UNSCEAR survey.

Table 1 describes the different types of equipment used in diagnostic and interventional radiology.

Table 1. Diagnostic and interventional radiological devices listed in the RD questionnaire

Descriptions and images are provided in order to help recognize and categorize the different devices.

Diagnostic radiological systems

Radiography systems	Systems which consist of one or more X-ray tubes and use two-dimensional image receptors for image acquisition. The image receptors may be based on radiographic film usually used in conjunction with intensifying screen cassettes or on computed radiography cassettes containing a receptor which is read out by a digital reader. **Digital systems comprise fully digital image receptors capable of directly producing two-dimensional radiographic images. However, computed radiography is categorized as an image processing modality.**	
Fluoroscopy systems	Systems that comprise a C-shaped arm (C-arm). On the one end of the arm there is an X-ray tube and on the other end an image receptor. Analogue systems sport image intensifiers which resemble bulky cylindrical devices. Digital systems comprise flat panel detectors similar to the ones used in digital radiography systems. Some radiography systems have fluoroscopy capabilities, mostly used for patient positioning. Such systems do not include a C-arm and should be listed under radiography systems and not under fluoroscopy systems. **A bi-plane system sporting two C-arms should also be considered as one system.**	
Mammography systems	Mammography systems comprise an X-ray tube capable of producing a low-energy X-ray beam. These systems include a breast-compressing device in order to even out the thickness of the breast tissue. The console is shielded by an appropriate shielding wall and is usually in the same room as the X-ray tube. There are digital and analogue mammography systems depending on the type of the detector.	

Table 1. Diagnostic and interventional radiological devices listed in the RD questionnaire

Dental X-ray systems	*(a)* Plain dental X-ray systems: usually consist of a flexible arm with an X-ray generator at its end. The image receptors may be films or digital devices placed into the mouth. *(b)* Orthopantomographs: devices comprising an X-ray source that spins around the patient's head with the synchronous movement of an image receptor. **Please list all dental imaging devices in this category except dental cone beam CTs. These are listed separately in their own category.**	
Angiography systems	Angiography systems are dedicated fluoroscopy systems used for vascular imaging. These systems produce images through the use of contrast agents injected into the patient's blood vessels. Angiography systems are used for all vascular interventions, including cardiac ones.	
Bone densitometry systems	Bone densitometry systems are used for the evaluation of patient bone density. Reduced bone density is linked with the onset of osteoporosis. Bone densitometry devices comprise a patient bed and a moving X-ray source under the patient's body. This source produces a pencil or fan beam which is detected by a detector arm moving simultaneously over the patient's body.	

Table 1. Diagnostic and interventional radiological devices listed in the RD questionnaire

Image processing modalities

Chemical development systems	Chemical development systems are used to develop radiographic film. After image acquisition, the radiological technologist enters the dark room and removes the film from its cassette. The film is immediately inserted into the receiver of the development system, located inside the dark room. After a while, a developed film comes out of the system. The exit point of the films is usually outside the dark room. Development systems that can be used in any lighting conditions are called daylight developers and contain mechanisms that automatically unload the radiographic film from the cassette inside the housing of the machine avoiding exposure to natural light. Similar to dark room developing systems, they use chemicals for the development of X-ray films.	
Computed radiography systems	Computed radiography systems resemble chemical development systems. However, the development is not chemical and does not need a dark room. The CR cassettes are fed directly into the CR reader and the image is read out. The cassette emerges from the system erased and ready for reuse. Please count only CR readers in this category. X-ray machines should be counted under radiography systems. CR systems are readers only and are not connected to X-ray tubes.	

Table 1. Diagnostic and interventional radiological devices listed in the RD questionnaire

Computed tomography scanners

Single slice CT	Cross-sectional imaging devices with only one row of imaging detectors. These devices produce only one cross-sectional image per rotation. They comprise a gantry wide enough for a patient to be placed inside. The detector rows and the X-ray tube are placed opposite each other and move around the patient together in order to acquire images.	
Multi-slice CT	Cross-sectional imaging devices with multiple rows of imaging detectors. These devices may produce more than 300 images per rotation (slices) and cover wide ranges of human anatomy, such as whole organs. They comprise a gantry wide enough for a patient to be placed inside. The detector rows and the X-ray tube are placed opposite each other and move around the patient together in order to acquire images.	
Dual source CT	CT machines that comprise two X-ray tubes in 90-degree angle configuration. The two tubes produce different energy photon spectra and may help in image enhancement and quicker image acquisition, especially for cardiac imaging.	
Dental CT	Dental CTs are usually cone beam CT systems with smaller fields of view suited for dental imaging. The machines comprise a patient chair and a head immobilization device. The X-ray tube and the digital image receptor are opposite each other and spin around the patient's head in order to acquire images. These devices often resemble the extremity or head and neck CBCT systems. In this category, please list only CBCT used in dental practice.	

Table 1. Diagnostic and interventional radiological devices listed in the RD questionnaire

Cone beam CT	Cone beam CT machines may look a lot like digital fluoroscopy or angiography machines or comprise a full 360-degree gantry. In fact, some modern fluoroscopy and angiography machines may be used for CBCT image reconstruction. Such machines usually contain a digital image receptor and may perform a 180-360 degree rotation around the patient. Extremity and head and neck CBCT systems may resemble dental CBCTs but usually have wider fields of vision. Flat panel detectors for cone beam CTs have been mounted on CT or CT-like gantries. This is sometimes called flat panel CT. **Please only include systems that are dedicated to CBCT imaging in this category.**	
MRI scanners		
1.5 Tesla **> 1.5 Tesla**	They comprise gantries with bore holes similar to CT scanners. The gantries are usually more bulky than the CT ones. MRI scanners use strong magnetic fields to investigate the anatomy and physiology of the body.	

DIAGNOSTIC AND INTERVENTIONAL RADIOLOGY

Frequency

This questionnaire section (sheet) is for information collection on the frequency of various diagnostic examinations. **This information is very relevant in order to assess levels of practice in a country as the frequency of radiological examinations is the most important factor in determining medical radiation exposure for a population.** Examinations have been categorized by modality and anatomical regions.

Categorization of examinations

The categorization of examinations in this survey follows the four main modalities used in radiology:

- Projection radiography (without contrast media)
- Radiography and fluoroscopy (mostly with contrast media)
- Computed tomography (CT)
- Image-guided interventional procedures (IGIP)

The categorization of radiological diagnostic examinations used in this survey considers the anatomical regions that might have been exposed. For a single radiological examination a different number of projections may be used. Such differences in clinical practice make it difficult to define all radiological examinations clearly. Thus, for this survey "**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" **[E1]**.

The examination categories used in this survey follow the DOSE DATAMED approach which has identified more than 200 radiological examinations and has grouped them into about 70 categories **[E1]**. The categories and the specific examinations are listed in the following table 2.

Table 2. Categorization of specific radiological examinations used in the UNSCEAR Global Survey

Modality	*Examination category*	*Specific examinations*	*Comments*
Projection radiography (without contrast media)	Head (skull and facial bones)	Skull and facial bones, head – Orbits – Temporal bones – Petrous bone – Mastoids – Sphenoid bone – Sella turcica – Sphenoid fissures Facial bones – Nose – Sinuses – Zygomas – Temporo-mandibular joint – Cervico-occipital hinge – Maxilla – Mandible – Cephalometry	If only one head examination category is available, please provide the data in this category.
	Head (soft tissue)	Dacryocystography (tear ducts) Sialography (salivary glands) Eyes/orbits	
	Neck (cervical spine)	Cervical spine	Common techniques: AP and LAT/Oblique. If only one neck examination category is available, please provide the data in this category.
	Neck (soft tissue)	Larynx Pharynx Trachea	

Table 2. Categorization of specific radiological examinations used in the UNSCEAR Global Survey

Modality	*Examination category*	*Specific examinations*	*Comments*
Projection radiography (without contrast media)	Chest/Thorax (lungs PA and LAT)	Lung Thoracic inlet Bronchography	Common techniques: PA and LAT If only one chest examination category is available, please provide the data in this category.
	Chest (thoracic spine)	Thoracic spine	Common techniques: AP and LAT
	Chest (shoulder girdle & ribs)	Shoulder blades/scapulae Collar bone(s)/clavicle(s) Acromio-clavicular joint Sterno-clavicular joint Manubrio-sternal joint Sternum Ribs	
	Mammography	Symptomatic: One or two views of one or two breasts	A mammography examination (bilateral) consists of two views for each breast. Thus, the number of unilateral examinations should be divided by two and included in this category. If different, explain it in the comment field. Common techniques: medio-lateral oblique and cranio-caudal for one or two breasts. If only one mammography examination category is available, please provide the data in this category.
	Mammography (screening)	One or two views of one or two breasts	Common technique: A screening mammography examination (bilateral) consists of two views for each breast.
	Lumbar spine	Lumbar spine	Common technique: AP and LAT

Table 2. Categorization of specific radiological examinations used in the UNSCEAR Global Survey

Modality	*Examination category*	*Specific examinations*	*Comments*
Projection radiography (without contrast media)	Lumbo-sacral joint only	Lumbo-sacral joint	
	Abdomen	Abdomen (plain film, patient supine or erect)	Common technique: AP
	Pelvis and hips (bone)	Pelvic bones – Ilium/ischium/pubis – Sacrum – Sacro-iliac joint – Coccyx – Pelvimetry (obstetric) Hips – One or both hips	Common technique: AP only or AP and LAT If only one pelvis examination category is available, please provide the data in this category
	Pelvis (soft tissue)	Pelvis (soft tissue)	
	Limbs and joints	Elbow Forearm (radius and ulna) Wrist (scaphoid) Hand – Fingers and thumbs Femur Knee Knee cap (patella) Lower leg (tibia and fibula) Ankle Foot Calcaneum (heel) Toes Whole leg	
	Whole spine (trunk)	Scoliosis	

Table 2. Categorization of specific radiological examinations used in the UNSCEAR Global Survey

Modality	*Examination category*	*Specific examinations*	*Comments*
Projection radiography (without contrast media)	Skeletal survey (head and trunk)	Skeletal survey (head and trunk)	
	Dental intraoral	Intra-oral <3 films – 1–2 periapical films – 1–2 bitewing films – 1 occlusal film Intra-oral >2 films – >2 periapical films – Periapical full mouth survey – >2 bitewing films	
	Dental panoramic	Panoramic full mouth scan	
Radiography and fluoroscopy (mostly with contrast media)	Gastrointestinal tract (barium studies)	Oesophagus (Ba swallow) Stomach and duodenum (Ba meal) Small intestine (Ba follow) Enteroclysis (small intestine enema) Colon (Ba enema)	Common techniques: Meal: 2–3 minutes fluoroscopy (5–20 images) Enema: ~2 minutes fluoroscopy (5–10 images) Follow: ~5 minutes fluoroscopy (5–20 images)
	Gastrointestinal tract (defecography)	Defecography	
	Biliary tract (cholangiography)	Retrograde cholangiography Operative cholangiography Intravenous cholangiography T-drain cholangiography Transhepatic cholangiography	
	Biliary tract (ERCP)	Endoscopic retrograde cholangiopancreatography (ERCP) Retrograde pancreatography	

Table 2. Categorization of specific radiological examinations used in the UNSCEAR Global Survey

Modality	*Examination category*	*Specific examinations*	*Comments*
Radiography and fluoroscopy (mostly with contrast media)	Biliary tract (cholecystography)	Cholecystography	
	Uro-genital tract (IVU)	Intravenous urography (IVU)	Common technique: Several AP radiographs after IV injection of iodine contrast medium
	Uro-genital tract (kidney, bladder and urethra)	Kidneys and ureters – Retrograde pyelography – Nephrostography Bladder and urethra – Retrograde cystography – Micturitional cysto-urethrography (MCU) – Urethrography	
	Myelography	Cervical myelography Thoracic myelography Lumbar myelography Sacral myelography Whole spine myelography	
	Arthrography	Temporal-mandibular joint arthrography Shoulder arthrography Hip arthrography Elbow arthrography Wrist arthrography Knee arthrography Ankle arthrography	
	Cerebral angiography	Cerebral angiography Petrous phlebography	

Table 2. Categorization of specific radiological examinations used in the UNSCEAR Global Survey

Modality	*Examination category*	*Specific examinations*	*Comments*
Radiography and fluoroscopy (mostly with contrast media)	Cardiac angiography	Coronary angiography (CA) – Coronary arteries only – Coronary arteries + L ventricle – Coronary arteries + L ventricle + aorta Thoracic aortography	Common technique: ~5 minutes fluoroscopy Several hundred images
	Thoracic angiography	Bronchial arteriography Pulmonary arteriography Upper venacavography	
	Abdominal angiography	Abdominal aortography Renal arteriography Mesenteric arteriography Lower venacavography Renal phlebography Suprarenal phlebography	
	Pelvic angiography	Pelvic arteriography Ovarian phlebography Spermatic phlebography	
	Peripheral angiography	Upper and lower limb arteriography Upper and lower limb phlebography	
	Lymphangiography	Thoracic lymphangiography Abdominal lymphangiography Pelvic lymphangiography Upper and lower limb lymphangiography	

Table 2. Categorization of specific radiological examinations used in the UNSCEAR Global Survey

Modality	*Examination Category*	*Specific Examinations*	*Comments*
Computed tomography (CT)*	CT-head (skull and facial bones)	Skull – Orbits – Temporal bone – Petrous bone – Temporal-mandibular joint – Sella turcica Face Dental	
	CT-head (soft tissue and brain)	Brain – Cerebrum – Posterior fossa – Brain vascular Pituitary gland Head soft tissues – Sinuses – Internal auditory meatus – Nasal cavity – Mouth	
	CT-neck (cervical spine)	Cervical spine	No contrast
	CT-neck (soft tissue)	Neck Larynx Pharynx Neck vascular	
	CT-chest (thoracic spine)	Thoracic spine	

* CT examinations may comprise more than one phase or multiple scans. These should be counted as one single examination. **The possible difference in patient doses should be reflected in the dosimetry part, namely in the dose length product (DLP) of the specific examinations.**

Table 2. Categorization of specific radiological examinations used in the UNSCEAR Global Survey

Modality	*Examination category*	*Specific examinations*	*Comments*
Computed tomography (CT)*	CT-chest (thorax)	Mediastinum Lungs standard Lungs high resolution Heart Thoracic aorta Lungs vascular	With or without contrast Standard or high resolution
	CT-abdomen (lumbar spine)	Lumbar spine	With or without contrast
	CT-abdomen (abdomen)	Full abdomen Upper abdomen	With or without contrast
	CT-abdomen (liver, pancreas, kidneys)	Liver/pancreas Kidneys/supra-renal glands	With or without contrast
	CT-pelvis (pelvic bones)	Hip/pelvic bone Sacrum/coccyx Sacro-iliac joint	With or without contrast
	CT-pelvis (pelvic soft tissue and vascular)	Pelvic soft tissue and vascular	
	CT-pelvis (pelvimetry)	Pelvimetry	
	CT-full spine (neck + chest + abdomen)	Full spine	
	CT-trunk (chest + abdomen + pelvis)	Whole trunk	

* CT examinations may comprise more than one phase or multiple scans. These should be counted as one single examination. **The possible difference in patient doses should be reflected in the dosimetry part, namely in the dose length product (DLP) of the specific examinations.**

Table 2. Categorization of specific radiological examinations used in the UNSCEAR Global Survey

Modality	*Examination category*	*Specific examinations*	*Comments*
Computed tomography (CT)*	CT-limbs	Shoulder	
		Elbow	
		Wrist	
		Hand	
		Leg	
		Thigh	
		Knee	
		Calcaneum	
		Ankle	
		Foot	
	CT-dental	Dental examinations in CT scanners	
	CBCT-dental	All CBCT examinations in dedicated dental CBCT systems	
	CBCT-others	CBCT used in every other occasion except dental	
	Head (celebral intervention)	Cerebral dilatation/stenting	
		Cerebral emboliation (AVM, aneurysm, tumour)	
		Cerebral thrombolysis	
		Head and neck puncture	
	PTCA	Coronary dilatation/stenting	
		Percutaneous transluminal coronary angioplasty (PTCA)	
	Chest (pacemaker)	Cardiac pacemaker fitting (temporary or permanent)	

* CT examinations may comprise more than one phase or multiple scans. These should be counted as one single examination. **The possible difference in patient doses should be reflected in the dosimetry part, namely in the dose length product (DLP) of the specific examinations.**

Table 2. Categorization of specific radiological examinations used in the UNSCEAR Global Survey

Modality	*Examination category*	*Specific examinations*	*Comments*
Computed tomography (CT)*	Thoracic intervention (other)	Cardiac thermo-ablation	
		Valvuloplasty	
		IVC (caval) filter fitting	
		Oesophagus dilatation/stenting	
		Thoracic dilatation/stenting	
		Thoracic embolization	
		Thoracic thrombolysis	
		Thoracic region biopsy	
		Electrophysiology	
	Abdomen (bilary and urinary intervention)	Bile duct dilatation/stenting	
		Bile duct drainage	
		Bile duct stone extraction	
		Renal artery dilatation/stenting	
		Renal drainage	
		Lithotripsy	
		Nephrostomy	
	Abdomen (TIPS)	Transjugular intrahepatic portosystemic shunt (TIPS) (liver)	
	Abdominal interventions (other)	Abdominal dilatation/stenting	
		Abdominal embolization	
		Abdominal thrombolysis	
		Abdominal region biopsy	
	Pelvic interventions	Pelvic vessel dilatation	
		Pelvic vessel embolization	
		Pelvic vessel thrombolysis	

* CT examinations may comprise more than one phase or multiple scans. These should be counted as one single examination. **The possible difference in patient doses should be reflected in the dosimetry part, namely in the dose length product (DLP) of the specific examinations.**

Table 2. Categorization of specific radiological examinations used in the UNSCEAR Global Survey

Modality	*Examination category*	*Specific examinations*	*Comments*
Computed tomography (CT)*	Limb interventions	Upper limb dilatation	
		Upper limb embolization	
		Upper limb thrombolysis	
		Popliteal dilatation (behind knee)	
		Lower limb dilatation	
		Lower limb embolization	
		Lower limb thrombolysis	
		Limbs biopsy	

* CT examinations may comprise more than one phase or multiple scans. These should be counted as one single examination. **The possible difference in patient doses should be reflected in the dosimetry part, namely in the dose length product (DLP) of the specific examinations.**

SURVEY QUESTIONNAIRES

Frequency

Top RD examinations

From the very wide range of radiological examinations, only few make up for the majority of the delivered population dose. The DOSE DATAMED project identified the "Top 20" examinations, which contribute 50–70% of the total frequency and 70–90% of the total collective effective dose **[E1]**. **Data related to these categories are of high priority and are marked in orange on the survey spreadsheets and on table 2.**

Pop-up comments are included in some of the high priority cells referring to anatomical regions for which two or more categories of examinations are listed. These comments advise users to fill in information into the corresponding rows when data for only one of the relevant examination categories are available. An example is shown in figure 13. Considering that only data about chest examinations in the regions of shoulder girdle and ribs are available, these data should be provided in the "Chest/Thorax (lungs PA&LAT)" row.

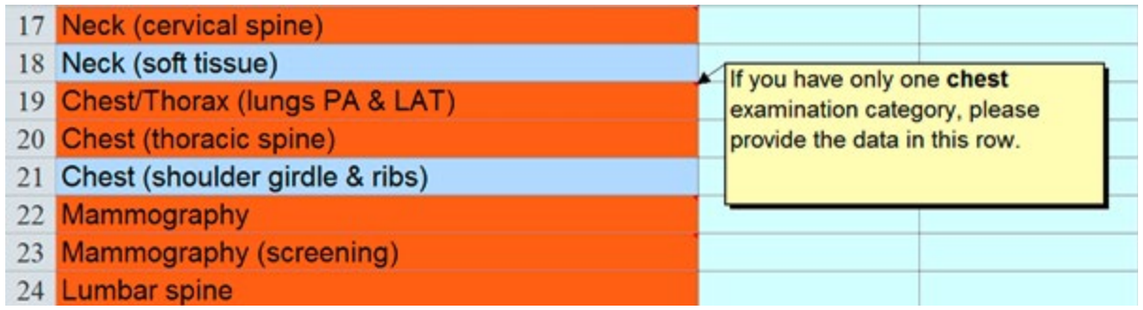

Figure 13. Screenshot of pop-up comment field requesting information to be filled into corresponding rows when data for only one relevant examination category are available.

SURVEY QUESTIONNAIRES

Frequency

Number of examinations

Indicate the number of examinations performed for the reported year or period. In diagnostic and interventional radiology, often patients undergo multiple examinations within a short period. Therefore, the number of examinations are requested and NOT the number of patients. **If positioning with fluoroscopy is used in radiographic examinations, this should be reflected in the mean dose per examination (see dose section) but not counted as separate examinations.**

If one or more examinations are missing in the questionnaire and seem relevant for the evaluation, they should be added under the appropriate cells "Others (please specify)".

Representation (percentage)

The approximate percentage of representation or coverage of the data for the whole country is requested for each examination type in order to accurately extrapolate data and reduce uncertainty. If you don't have this information, please make a rough estimate in order to make the UNSCEAR assessment as accurate as possible.

Age and sex distribution of patients

As demographic data differs from country to country, it is desirable to collect data on the age and sex distribution of patients undergoing radiological examinations from as many countries as possible. **This part is optional; however, the information on age and sex distribution is very important for the evaluation, and even incomplete data might be useful for the survey.** Please consider collecting such data for future evaluations.

The number provided by age and sex should also reflect the total performed examinations and not the number of patients.

The recent UNSCEAR classification has 20 age bands for each sex and provides more detailed information than the old UNSCEAR classification of just three broad age bands (0–15 years, 16–40 years and >40 years) for each sex. However, the old UNSCEAR classification can still be used (figure 14). **Use the new UNSCEAR classification, if possible, to provide detailed information, or the old UNSCEAR classification if detailed numbers are not available.**

0-1		2-4		<5		5-9		10-14		0-14		15-19		20-24		25-29		30-34		35-39		15-39		40-44		45-49		50-54	
male	female	male	female	male	female	male	female	male	female	male	female	male	female	male	female	male	female	male	female	male	female	male	female	male	female	male	female	male	female

Figure 14. Current and old UNSCEAR classification for age and sex distribution.

SURVEY QUESTIONNAIRES

Dose

This section of the questionnaire aims to collect dose related information for the major examinations/ procedures in diagnostic and interventional radiology. The classification of examination categories is similar to the one used in the frequency sheet and will not be repeated here. **The purpose of the collection of mean doses (including mean effective doses) is for the estimation of the global collective effective dose.** UNSCEAR is not looking for diagnostic reference levels (DRLs) per examination as these would overestimate the population dose. Depending on the modality, different dose quantities are requested. This section provides information about effective dose calculation and about the physical dose quantities used in this survey.

Dose quantities for diagnostic radiography examinations and interventional procedures

The dose area product (DAP), also named kerma-area product (KAP) represents the product of the air kerma (usually in mGy) at the centre of a certain plane of the X-ray beam (e.g. surface of the patient) multiplied by the area of the X-ray field at that plane (usually in cm^2). Generally, the DAP/KAP is expressed in $Gy \cdot cm^2$.

The DAP/KAP is the most widely used dose metric in projection radiography and fluoroscopy. The usefulness of the DAP/KAP is that it can be directly multiplied by examination dependent factors to provide an estimation of effective dose. These factors will be presented in the section dealing with effective dose calculation. In case DAP/KAP values are not available, other dose quantities need to be provided with the corresponding units and variation in the respective fields (figure 15).

Sample size	Mean dose per exam						Mean effective dose [mSv]	Variation [SD]
	DAP [Gy cm2]	Variation [SD]	Other quantity	Unit	Value	Variation [SD]		

Figure 15. Screenshot of dosimetry quantities for diagnostic and interventional radiography.

SURVEY QUESTIONNAIRES

Dose

Computed tomography (CT) is based on different physical principles from those applying to projection radiography and fluoroscopy. The main dose quantities used for CT dosimetry are the volume computed tomography dose index ($CTDI_{vol}$) and the dose length product (DLP). The $CTDI_{vol}$ provides an assessment of the average dose to the scanned volume of the standard acrylic CT phantom independently of the specific pitch value. This quantity is important because, multiplied by the scan length, it yields the DLP which in turn leads to the calculation of effective dose by use of examination specific conversion factors. These factors will also be presented in the section dealing with effective dose calculation. **CT examinations which comprise more than one phase/scan should reflect this in the total DLP to determine the appropriate effective dose per examination.**

Some cone beam computed tomography (CBCT) machines use DAP/KAP for dose reporting. These CBCTs may additionally provide these values along with $CTDI_{vol}$ and DLP. All values available for CBCT ($CTDI_{vol}$, DLP or DAP/KAP) should be provided in the relevant section of the questionnaire (figure 16).

Information on radiation dose quantities required in the dosimetry section of the RD questionnaire are summarized in table 3.

Sample size	Mean dose per exam						Mean effective dose [mSv]	Variation [SD]
	CTDIvol [mGy]	Variation [SD]	DLP [mGy cm]	Variation [SD]	DAP [Gy cm2]	Variation [SD]		

Figure 16. Screenshot of dosimetry quantities for CT and CBCT.

Table 3. Information on radiation dose quantities in diagnostic and interventional radiology used in the UNSCEAR Global Survey

Radiation dose quantity	*Description/definition*	*Information and remarks*
Effective dose	Effective dose E (Unit: sievert), is defined as the weighted sum of the mean radiation doses to a number of radiosensitive tissues or organs in the body **[I5, I8]**.	Mean effective dose values per examination/ procedure. The variation in terms of standard deviation. Provide further information on the method used to determine the effective dose (e.g. ICRP weighting factors). Please leave the field empty if no effective doses were calculated for the national survey.
	Quantities used in projection radiography, fluoroscopy and interventional procedures	
Dose area product (DAP)/ kerma area product (KAP)	Dose area product (DAP), also named kerma-area product (KAP), represents the product of the air kerma (usually in mGy) at the centre of a certain plane of the X-ray beam (e.g. the surface of the patient) multiplied by the area of the X-ray field at that plane (usually in cm^2). Generally DAP/KAP is expressed in $Gy{\cdot}cm^2$. DAP/ KAP values can be multiplied by anatomy and procedure specific factors in order to deduce effective dose values. DAP/KAP values may be displayed on the console of radiography/fluoroscopy machines.	Average DAP/KAP values per examination/ procedure. The variation in terms of standard deviation.
	Possible alternative quantities if DAP/KAP is not available	
Air kerma free in air	The air kerma free in air [K_a] is the dose absorbed to air free in air. This quantity is directly measured with an appropriate calibrated dosimeter at 1 m distance (radiography) or 50 cm distance (fluoroscopy). Unit: mGy If it is normalized to the (tube current—exposure time product) is then called “dose yield” or “X-ray tube output”. Unit: mGy/mAs	Average value of quantity per examination/ procedure. Units of quantity. The variation in terms of standard deviation.

Table 3. Information on radiation dose quantities in diagnostic and interventional radiology used in the UNSCEAR Global Survey

Radiation dose quantity	*Description/definition*	*Information and remarks*
Incident air kerma [$K_{\alpha,i}$]:	Incident air kerma is measured free in air on the central axis of the X-ray beam at the focus skin distance, (FSD). It is related to air kerma free in air by the inverse square law: $K_{\alpha,i} = K(d)_{\alpha} \times (d/dFSD)^2$, where $K(d)_{\alpha}$ is the air kerma free in air at a distance d from the focus. Unit: mGy	Average value of quantity per examination/ procedure. Units of quantity. The variation in terms of standard deviation.
Entrance surface dose (ESD) or Entrance surface air kerma (ESAK)	Entrance surface dose (ESD) or entrance surface air kerma (ESAK) [$K_{\alpha,e}$]: this quantity equals the air kerma multiplied by a backscatter factor B. $K_{\alpha,e} = K_{\alpha,i} \times B$ Unit: mGy The ESD is useful as it can be calculated by using the tube output, the distance from the focus of the X-ray beam and the backscatter factor.	Average value of quantity per examination/ procedure. Units of quantity. The variation in terms of standard deviation.
Mean glandular dose (MGD)	Mean glandular dose (MGD) is a quantity used in mammography in conjunction with age/sex-specific risk factors for radiation-induced breast cancer. MGD is the average dose to the radiosensitive glandular tissue of the breast. It can be calculated from the incident air kerma [$K_{a,i}$] by using appropriate Monte Carlo based conversion factors provided for various radiation qualities and breast thicknesses and compositions. Unit: mGy **MGD is of interest although the effective dose may be calculated without using it.**	Average value of quantity per examination/ procedure. Units of quantity. The variation in terms of standard deviation.

Table 3. Information on radiation dose quantities in diagnostic and interventional radiology used in the UNSCEAR Global Survey

Radiation dose quantity	*Description/definition*	*Information and remarks*
Quantities used in computed tomography and cone beam computed tomography		
Volume computed tomography dose index ($CTDI_{vol}$):	The volume CTDI ($CTDI_{vol}$) is equal to the value of $CTDI_w$ divided by the CT pitch factor. $CTDI_{vol}$ is a corrected-by-the-pitch-factor $CTDI_w$. It provides an assessment of the average dose to the scanned volume of the standard acrylic CT phantom independently from the specific pitch value. Unit: mGy	Average $CTDI_{vol}$ values per examination/ procedure. The variation in terms of standard deviation.
Dose length product (DLP)	DLP equals $CTDI_{vol}$ multiplied by the scan length. DLP may be used along with computationally derived factors for the assessment of effective dose in CT examinations. Unit: mGy × cm	Average DLP values per examination/ procedure. The variation in terms of standard deviation.
Dose area product (DAP)/ kerma area product (KAP) in CBCT	Dose area product (DAP), also named kerma area product (KAP) represents the product of the air kerma (usually in mGy) at the centre of a certain plane of the X-ray beam (e.g. the surface of the patient) multiplied by the area of the X-ray field at that plane (usually in cm^2). Generally DAP/KAP is expressed in $Gy{\cdot}cm^2$.	Average DAP/KAP values per examination/ procedure. The variation in terms of standard deviation.

DIAGNOSTIC AND INTERVENTIONAL RADIOLOGY

Dose

Sample size

The sample size (number of measurements) is used for the estimation of the mean dosimetry value per examination or procedure. If information on effective doses is provided, the sample size could reflect the number of measurements that were the base of each calculation.

Variation

All dose values should be provided as average values per examination or procedure or as mean effective dose per examination or procedure. For uncertainty calculation, it is important to know the variation of these mean values in terms of standard deviation. Standard deviations should be provided separately in the appropriate column for each dose quantity.

Effective dose

For the UNSCEAR Global Survey, users are encouraged to calculate the mean effective dose for the different examinations/procedures reported. The dose quantities requested in this section (e.g. DAP/KAP and DLP) could be used for these calculations by multiplying appropriate conversion factors. **As the calculation methods may vary, additional information about the method used should be included in the "comments" field of the dosimetry section (sheet).**

Due to the relatively recent update of the ICRP effective dose weighting factors, users are kindly requested to apply the latest factors **[I8]** whenever possible. **If the old ICRP factors are used [I5] please state this clearly in the "comments" field.**

DAP/KAP can be directly multiplied by examination/anatomy dependent factors to provide an estimation of effective dose. These factors have been determined by Monte Carlo simulation methods in conjunction with humanoid computational phantoms. Tables 4 and 5 list dose conversion factors for basic radiographic and fluoroscopic examinations and for image-guided interventional procedures.

Table 4. Generalized dose conversion coefficients for radiographic/fluoroscopic examinations (adapted from **[E1]**)

Examination type	*Dose conversion coefficient (DCCE) [mSv·(Gy·cm2)$^{-1}$]*
Chest (PA + Lat) high kV	0.18
Chest (PA + Lat) low kV	0.10
Thoracic spine	0.19
Lumbar spine	0.21
Abdomen	0.26
Pelvis and hip	0.29
Barium meal	0.20
Barium enema	0.28
Barium follow	0.22
IVU	0.18
Cardiac angio	0.20

Table 5. Factors for estimation of effective dose from image-guided interventional procedures (adapted from **[N1]**)

Groups/Subgroups	*Examinations*	*Dose conversion coefficient (DCCE) [mSv·(Gy·cm²)⁻¹]*
Urinary studies	Cystometrography, cystography, excretory urography, micturating cysto-urethrography, urethrography	0.18
Endoscopic retrograde cholangiopancreatography (ERCP)		0.26
Arthrograms		0.1
Orthopedic procedures		0.01
Vertebroplasty		0.20
Obstetrics and gynaecology	Pelvimetry, hysterosalpingogram	0.29
	Non-cardiac diagnostic procedures	
Peripheral vascular	Arteriography (all types)	0.26
	Peripheral phlebography/venography	0.10
	Carotid and cerebral angiography	0.087
Renal	Antegrade pyelography, retrograde pyelography	0.18
		0.26
	Renal angiogram, abdominal aortography	0.12
	Thoracic aortography, arch angiogram	
Neurological	Cervical spine	0.13
	Thoracic spine	0.19
	Lumbar spine	0.21
	Pulmonary angiography, venacavogram	0.12

Table 5. Factors for estimation of effective dose from image-guided interventional procedures (adapted from **[N1]**)

Groups/Subgroups	*Examinations*	*Dose conversion coefficient (DCCE) [mSv·(Gy·cm²)⁻¹]*
	Non-cardiac interventional vascular procedures	
Percutaneous transluminal angioplasty (PTCA)		0.26
Stent placement	Renal/visceral PTCA with stent, Iliac PTCA with stent, bile duct, dilation and stenting	0.26
	Carotid stent	0.087
Inferior vena cava filters	Filter placement only, hepatic	0.26
Embolization	Chemoembolization, pelvic arterial embolization, pelvic vein embolization: ovarian vein, other tumour embolization, embolization	0.26
	Pulmonary angiography with filter, bronchial artery embolization	0.12
	Thrombolytic therapy	0.26
	Transjugular intrahepatic portosystemic shunt (TIPS)	0.26
	Cardiac procedures	
Diagnostic coronary angiography		0.12
Interventional procedures	Angioplasty	0.20-0.26
	Percutaneous transluminal coronary angioplasty	0.18-0.28
	Embolization	0.26
	Cardiac radiofrequency ablation	0.10-0.23

If DAP/KAP is not available and other dose quantities are used, the respective dose conversion coefficients need to be indicated in order to be able to reproduce the calculations.

The mean glandular dose (MGD) is the main quantity used in mammography in conjunction with age/sex-specific risk factors for radiation-induced breast cancer. However, the effective dose may be derived by incident air kerma by the use of a set of factors that connect incident air kerma and effective dose in mammography for typical mammography exposure conditions (table 6).

Table 6. $E/K_{a,i}$ coefficients for some typical exposure conditions in mammography (adapted from **[E1]**)

Exposure conditions				*$E/K_{a,i}$ (mSv/mGy)*	
Anode/filter	*Tube voltage*	*Breast thickness*	*HVL (mm Al)*	*One breast*	*Two breasts*
Mo/Mo	28 kV	50 mm	0.32	0.0043	0.0087
Mo/Rh	28 kV	50 mm	0.4	0.0053	0.011
Mo/Mo	28 kV	40 mm	0.32	0.0052	0.010
Mo/Mo	28 kV	60 mm	0.32	0.0034	0.0068
Mo/Rh	28 kV	60 mm	0.4	0.0043	0.0086

The DLP values may be used along with computationally derived factors for the assessment of effective dose in CT examinations. Such generalized factors are presented in table 7.

Table 7. Generalized E/DLP coefficients for CT examinations (adapted from **[E1]**)

Region of body scanned	*E/DLP (mSv/mGy cm)*
Head	0.0021
Neck	0.0059
Chest	0.014
Abdomen and pelvis	0.015
Pelvis	0.015
Trunk	0.015

Some CT examinations comprise more than one phase and multiple scans. **In such cases, the total DLP should be reported so that estimation of the total effective dose per examination is possible.**

Generalized cone beam CT dose conversion coefficients are not yet available.

NUCLEAR MEDICINE

In this section, information is provided to facilitate the completion of the UNSCEAR nuclear medicine (NM) questionnaire. The information requested is organized according to the four main sections (sheets) of the questionnaire, namely:

- **General information:** for general information about the country, its population, the survey period and contact details of contributors.
- **Staff and devices:** for information on the staffing levels and the available equipment.
- **Frequency:** for data on frequency of procedures and “optional” data regarding the age and the sex distribution of the population undergoing these procedures.
- **Dose:** for information on mean doses from different procedures.

NUCLEAR MEDICINE

General information

In this section, contributors are requested to fill in their contact details and general information about their country such as:

- **Year:** Indicate the year (or period) to which the data refer.
- **Population (inhabitants):** Indicate the total population size in number of inhabitants of the country for the year to which the data refers.
- **Population (survey base):** Indicate the size of population in number of inhabitants if the data collected are for a particular region, city or hospital only. Provide the total population size of the country if the information provided is for the whole country. When a smaller fraction of the population is used as a basis for assessing the situation in the whole country, an estimation of how representative the data are with regard to the entire country should be provided for each procedure separately. Such information is requested in the frequency sheet of the questionnaire.
- **Contact information:** The data submitted should be signed off by the national contact person (NCP), registered on the UNSCEAR online platform, including name, institution and contact details (e-mail/phone) to facilitate any feedback. Please, indicate contact details of any other persons who have provided information and who should be acknowledged in the final report.
  Contact details for at least one person are required as this information will be transferred to the UNSCEAR database.

The country code is provided automatically, and the date of submission will be generated during upload of the file.

NUCLEAR MEDICINE

Staff and devices

Collected information on staffing and equipment may be correlated with frequency and dose information and provide useful insights on the effect of equipment and staffing levels on population doses from medical radiation.

Staff

Information about the number and type of professionals working in nuclear medicine should be provided in this sheet. The numbers should reflect the situation in the entire country as accurately as possible and could be based on data originating from national registries or professional associations. Data should reflect the situation regarding professionals working in both hospital and private practice. Please note that:

- Only practising professionals should be included and their actual occupancy time should be taken roughly into account. For example, two part-time physicians, each working 50% of the normal working hours, count as one full-time professional.
- Persons working in two areas or more should be counted according to their main activity.
- Some data about professionals not working in nuclear medicine are also requested. For example, the number of general practitioners.

The number of practising individuals working in the following categories is sought in the NM questionnaire:

- **Physicians:** All physicians in the country irrespective of their medical specialization.
- **General practitioners:** Medical doctors usually acting as primary care providers at an early stage of a disease's onset. In some countries they are called family doctors.
- **Nuclear medicine physicians:** Only medical doctors specialized in nuclear medicine.
- **Other physicians conducting nuclear medicine procedures:** Physicians who are not nuclear medicine physicians, but are specialized or licensed to perform nuclear medicine procedures (for example cardiologists performing stress tests for heart disease).
- **Medical physicists in nuclear medicine imaging:** Medical physicists licensed or authorized to practise in nuclear medicine.
- **Radiation technologists in nuclear medicine imaging:** Radiation technologists licensed or authorized to perform procedures in nuclear medicine.
- **Nurses in nuclear medicine imaging:** Nurses practising in nuclear medicine or working as radiation technologists.

NUCLEAR MEDICINE

Staff and devices

Devices

A wide range of different radiological devices are used in nuclear medicine. Some general information and guidelines on how to list the different devices are provided here:

- Only data on the numbers of **actually operating equipment** are required.
- Systems with multiple detectors (or more than one gantry, such as in the case of some hybrid systems) are counted as one device.
- **Hybrid systems used in nuclear medicine departments which include CT or MRI components should be listed in the nuclear medicine questionnaire** and not in the one dealing with diagnostic and interventional radiology.

Table 8 describes the different types of equipment used in nuclear medicine.

Table 8. Nuclear medicine devices listed in the NM questionnaire

Descriptions and images are provided in order to help recognize and categorize the different devices.

Nuclear medicine imaging systems

Planar gamma camera systems	Planar gamma camera systems comprise arms holding a single detector. The detector is usually positioned over or under the patient's body. The camera does not move during imaging. This method produces 2-dimensional images of the radiopharmaceutical distribution inside the patient's body.	
SPECT systems	Single-photon emission computed tomography (SPECT) systems usually comprise two gamma cameras that spin around the patient. The cameras may be opposite to each other or at right angles. The 2-dimensional projections are then reconstructed into 3-dimensional imaging datasets.	
SPECT-CT systems	SPECT-CTs are hybrid imaging systems combining nuclear medicine and CT imaging. They are capable of providing images of the patient anatomy with overlapping physiological/functional information through the use of SPECT. SPECT-CT systems comprise a gantry in a similar manner as in CT scanners. The gantry usually houses the CT imaging system. The gamma cameras are also appended on the same gantry. The two imaging procedures may be carried out simultaneously keeping the patient immobile on the couch. This helps in acquiring co-registered images.	

Table 8. Nuclear medicine devices listed in the NM questionnaire

PET systems	Positron emission tomography (PET) scanners comprise a gantry housing a ring of PET detectors. This ring of detectors is capable of detecting coincident photons originating form electron-positron annihilation inside the patient's body. Positron emmitting radionuclides such as ^{18}F are used in PET imaging. The only moving part in such scanners is the patient couch. Otherwise the PET scanners do not move during imaging.	
PET-CT systems	PET-CTs are hybrid imaging systems combining nuclear medicine and X-ray imaging. They are capable of providing X-ray images of the patient anatomy with overlapping physiological/functional information through the use of PET. PET-CT systems comprise a gantry in a similar manner as in CT scanners. The gantry in some cases houses the PET detector rows and the CT imaging system. In other cases, there may be two gantries—each one housing one of the two modalities. In such cases, the two imaging procedures happen sequentially, keeping the patient immobile on the same couch. This helps in acquiring co-registered images.	
PET-MRI systems	PET-MRI systems are hybrid imaging systems combining nuclear medicine imaging with the soft tissue imaging capabilities of magnetic resonance imaging (MRI). These systems are capable of providing magnetic resonance images of the patient anatomy with overlapping physiological/functional information through the use of PET. Similar to PET-CTs, PET-MRI systems may comprise one or two gantries.	
Other equipment: Single channel spectrometer	Equipment used for I-123 uptake in thyroid and renography with I-123-hippuran examinations. These devices consist of a single channel detector comprising a NaITl scintillator.	

NUCLEAR MEDICINE

Frequency

This questionnaire sheet is for data collection on the frequency of various nuclear medicine procedures (diagnostic or therapeutic). **This information is vital to assessing levels of practice in a country because frequency of specific procedures is the most important factor in determining the medical radiation exposure of a population.** In the frequency sheet, diagnostic procedures have been categorized under modality, and anatomy/condition, while therapeutic procedures are in a separate category. In the following, the categorization of nuclear medicine procedures will be described in more detail.

Categorization of procedures

The categorization of procedures in this survey follows:

- Diagnostic procedures using gamma cameras and SPECT or SPECT-CT or other photon detectors, such as single channel spectrometers (uptake probes)
- Diagnostic procedures using PET and PET-CT
- Therapeutic procedures

Further, the categorization of nuclear medicine procedures considers the anatomical regions of interest and the existing medical conditions. A single modality may also be used in different ways. For instance, different radiopharmaceuticals may be used for the same diagnostic procedure. For this survey, similar to the definition of a radiological examination, **a nuclear medicine diagnostic or therapeutic procedure is defined as one or a series of relevant processes for the investigation or therapy of one anatomical region/organ/system, using a single imaging modality (e.g. SPECT, PET-CT, etc.), a single specific radiopharmaceutical and a single administration to a patient, needed to address a specific diagnostic/clinical problem or treat a specific condition, during one visit to the nuclear medicine department, hospital or clinic.**

Table 9 shows the types of procedures used in this survey. Categories were selected according to former UNSCEAR surveys and the Nuclear Medicine Database (NUMDAB) of the International Atomic Energy Agency **[U1, U2, I1]**. The main categories and the specific nuclear medicine procedures used in the UNSCEAR Global Survey are listed in table 9.

Table 9. Categorization of specific nuclear medicine procedures used in the UNSCEAR Global Survey

Modality category	*Procedure category*	*Specific procedures*	*Radionuclide*
Diagnostic procedures using gamma cameras* and SPECT or SPECT-CT**	Nervous system	Brain perfusion (HMPAO or ECD) Brain receptor scan (DAT-Scan/IBZM) Cisternogram (including V-P shunt evaluation)	Tc-99m
	Nervous system		I-123
	Skeletal	Bone scan Bone marrow scan	Tc-99m
	Cardiovascular	Myocardial perfusion imaging	Tl-201
	Cardiovascular	Myocardial perfusion imaging Radionuclide ventriculography (MUGA)	Tc-99m
	Pulmonary	Lung perfusion Lung ventilation	Tc-99m
	Endocrine	Thyroid Tc-99m scan Parathyroid, adrenal scan	Tc-99m
	Endocrine	Thyroid I-123 or I-131 uptake and scan	I-123
	Gastrointestinal	Esophageal transit Gastro-esophageal reflux Gastric emptying Hepatobiliary Hepatic hemangioma GI bleed Meckel's diverticulum Schilling's test C-14 urea breath test for H. pylori	Tc-99m

* Procedures performed with other types of equipment (e.g. single channel spectrometers) should be added under "Other".

** Dose arising from CT scans in hybrid systems should be reflected in the dosimetry part, namely in the dose length product (DLP) of the specific procedures. CT imaging processes in SPECT-CT or PET-CT may comprise more than one phase or multiple scans. The total DLP due to all phases of the process should be included.

Table 9. Categorization of specific nuclear medicine procedures used in the UNSCEAR Global Survey

Modality category	*Procedure category*	*Specific procedures*	*Radionuclide*
Diagnostic procedures using gamma cameras* and SPECT or SPECT-CT**	Genitourinary	Renal scan (renogram)	Tc-99m
		– Renogram with Captopril	
		– Renogram with Furosemide	
		Renal cortical study (DMSA)	
		Nuclear cystogram	
		Genital system scans	
	Oncology	Gallium scan	
		In-111 Octreotide scan	
		(I-131 or I-123) MIBG scan	
		Sestamibi/Tl-201 scan	
		Gallium scan	
	Infection/inflammation	Salivary glands	
		Lymphoscintigraphy (peripheral)	
		Lymphoscintigraphy for sentinel node	
		Gallium scan for infections	
		In-111 or Tc-99m leukocyte study (Infection or IBD)	
Diagnostic procedures using PET, PET-CT and PET-MRI**	Oncology		F-18
	Oncology (other than F-18)		
	Nervous system	Brain perfusion	O-15
		Brain tumour	C-11
		Cerebral glucose metabolism	F-18
	Skeletal	Bone scan	F-18
		Bone marrow scan	
	Cardiovascular		F-18
	Cardiovascular (other than F-18)		N-15
	Infection/inflammation		

* Procedures performed with other types of equipment (e.g. single channel spectrometers) should be added under “Other”.

** Dose arising from CT scans in hybrid systems should be reflected in the dosimetry part, namely in the dose length product (DLP) of the specific procedures. CT imaging processes in SPECT-CT or PET-CT may comprise more than one phase or multiple scans. The total DLP due to all phases of the process should be included.

Table 9. Categorization of specific nuclear medicine procedures used in the UNSCEAR Global Survey

Modality category	*Procedure category*	*Specific procedures*	*Radionuclide*
Therapeutic procedures	^{131}I for malignant thyroid disease		I-131
	^{131}I for benign thyroid disease		I-131
	Therapy with ^{131}I MIBG		I-131
	Peptide Receptor Radionuclide Therapy (PRRT)		
	Selective internal radiation therapy (SIRT)		Y-90
	Polycythaemia vera		P-32
	Bone metastases (palliation)		Sr-89 Sm-153
	Radiosynovectomy		Au-198
	Radioguided surgery		

NUCLEAR MEDICINE

Frequency

Top NM procedures

From the very wide range of nuclear medicine procedures, only a few contribute to the overall delivered population dose. **Data related to these procedure categories are of high priority and are marked in orange on the survey spreadsheets and on table 9.**

Radionuclides

The radionuclide used in a procedure plays a major role in patient dose. If the radionuclide is not already provided in the questionnaire, it is essential to provide this information in the appropriate cells. If a procedure listed in the questionnaire is performed with a different radionuclide, the used radionuclide should be added in the appropriate editable cell.

Number of procedures

As patients often undergo multiple procedures within a short period, indicate the number of nuclear medicine procedures with separate administrations of radiopharmaceuticals performed for the reported year or period and **not the number of patients**. If procedures are missing in the questionnaire and seem relevant for the evaluation, they should be added under the appropriate cells “Other (please specify)”. Therapeutic procedures are not fractionated in NM and any new therapeutic administration should be considered as a new procedure.

Representation (percentage)

The approximate percentage of representation or coverage of the data for the whole country is requested for each procedure type in order to accurately extrapolate data and reduce uncertainty. If you don’t know this information, please make a rough estimate in order to make the UNSCEAR assessment as accurate as possible.

Age and sex distribution of patients

As demographic data differs from country to country, it is desirable to collect data on the age and sex distribution of patients undergoing nuclear medicine procedures from as many countries as possible. **This part is optional; however, the information on age and sex distribution is very important for the evaluation, and even incomplete data might be useful for the survey.** Please consider collecting such data for future evaluations.

The data collected on age and sex should also reflect the total performed procedures and not the number of patients.

NUCLEAR MEDICINE

Frequency

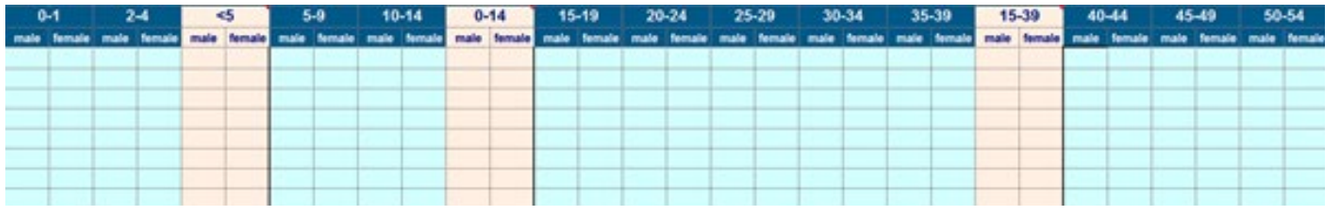

Figure 17. Current and old UNSCEAR classification for age and sex distribution

The recent UNSCEAR classification has 20 age bands for each sex and provides more detailed information than the old UNSCEAR classification of just three broad age bands (0–14 years, 15–39 years and >40 years) for each sex. However, the old UNSCEAR classification can still be used (figure 17). **Use the new UNSCEAR classification, if possible, to provide detailed information, or the old UNSCEAR classification if detailed numbers are not available.**

NUCLEAR MEDICINE

Dose

This section aims to collect dose related information for the diagnostic and therapeutic procedures in nuclear medicine. The classification of procedure categories is similar to the one used in the frequency section and will not be repeated here. The purpose of the collection of mean doses (including mean effective doses) is for the estimation of the global collective effective dose. **It is important to notice that the concept of the effective dose is applied for dose ranges only for diagnostic procedures and not for therapeutic procedures. Thus, it is requested to provide the activity and radiopharmaceutical used.** UNSCEAR is not looking for diagnostic reference levels (DRLs) per procedure as these would overestimate the population dose.
Depending on the modality, different dose quantities are requested. This section provides information about the physical dose quantities used in this survey and about effective dose calculation.

Dose quantities for nuclear medicine

Dose estimations in nuclear medicine are based on the methods of internal dosimetry. The International Commission on Radiological Protection (ICRP) and the Medical Internal Radiation Dose (MIRD) methodologies are the most commonly used internal dosimetry models **[I2, I3]**. In those models, pharmacokinetics determine the effective elimination/clearance rates of the different pharmaceuticals and nuclides from the various organs and systems of the human body. Pharmacokinetic studies determine which organs act as sources of irradiation in the body and which act as targets. A specific organ may be both a source and a target. Finally, source organs are assigned the calculated effective/cumulative activities and Monte Carlo studies are performed on anthropomorphic phantoms, in order to deduce procedure/anatomy specific multiplying factors (conversion coefficients) for organ doses, for the various radiopharmaceuticals and nuclides. Effective dose conversion coefficients in mSv/MBq are available and will be presented in the section dealing with effective dose calculation. **Effective dose conversion coefficients are intended for diagnostic nuclear medicine and not for therapeutic applications.**

NUCLEAR MEDICINE

Dose

The main dose quantities used for CT dosimetry (in hybrid systems) are the volume computed tomography dose index ($CTDI_{vol}$) and the dose length product (DLP). The $CTDI_{vol}$ provides an assessment of the average dose to the scanned volume of the standard acrylic CT phantom independently from the specific pitch value. This quantity is important because, multiplied by the scan length, it yields the DLP which in turn leads to the calculation of effective dose by use of anatomy specific conversion factors. These factors will also be presented in the section dealing with effective dose calculation.

Patient dose resulting from CT in hybrid systems is not negligible as compared to the dose arising from the radionuclide injection. **Thus, CT dose needs to be taken into account when calculating the total dose from a hybrid nuclear medicine procedure.** CT imaging which comprises more than one phase/scan should reflect this in the total DLP to determine the appropriate effective dose per procedure (figure 18).

Table 10 summarizes information on radiation dose quantities in nuclear medicine and PET.

Sample size	Mean activity [MBq]	Variation [SD]	Radiopharmaceutical				CT Dose					Mean effective dose [mSv]	Variation [SD]
			Most common	NM Ratio [%]	NM Dose [mSv]	Variation [SD]	DLP [Gy cm]	Variation [SD]	Ratio of CT [%]	CT Dose [mSv]	Variation [SD]		

Figure 18. Screenshot of dosimetry quantities for nuclear medicine procedures

Table 10. Information on nuclear medicine dose quantities used in the UNSCEAR Global Survey

Radiation dose quantity	*Description/definition*	*Information and remarks*
Effective dose	Effective dose E (Unit: sievert), is defined as the weighted sum of the mean radiation doses to a number of radiosensitive tissues or organs in the body **[I5, I8]**.	Mean effective dose values per procedure. The variation in terms of standard deviation. In the "comments" field, please provide information on the method used to determine the effective dose (e.g. ICRP weighting factors). Please leave the field empty if no effective doses were calculated for the national survey.
Mean activity	Mean activity of the administered nuclide. Unit: MBq	Average administered activity values per procedure. The variation in terms of standard deviation.
Quantities used in computed tomography and cone beam computed tomography		
Volume computed tomography dose index ($CTDI_{vol}$)	The volume CTDI ($CTDI_{vol}$) is equal to the value of $CTDI_{w}$ divided by the CT pitch factor. It provides an assessment of the average dose to the scanned volume of the standard acrylic CT phantom independently from the specific pitch value. Unit: mGy	Average $CTDI_{vol}$ values per procedure. The variation in terms of standard deviation.
Dose length product (DLP)	DLP equals $CTDI_{vol}$ multiplied by the scan length. DLP may be used along with computationally derived factors for the assessment of effective dose in CT scans. Unit: mGy × cm	Average DLP values per procedure. The variation in terms of standard deviation.

NUCLEAR MEDICINE

Dose

Sample size

The sample size (number of measurements) is used for the estimation of the mean dosimetry value per procedure. If information on effective doses is provided, the sample size could reflect the number of measurements that were the base of each calculation.

Mean activity

Administered activity is the most important contributing factor influencing individual patient dose. Thus, indicate the average administered activity by type of NM procedure.

Variation

All dose or administered activity values should be provided as average values per procedure or as mean effective dose per procedure. For uncertainty calculation, it is important to know the variation of these mean values in terms of standard deviation. Standard deviations should be provided separately in the appropriate column for each dose quantity.

Radiopharmaceutical

In nuclear medicine it is important to have full information about the combination of the nuclide and the radio-pharmaceutical used as pharmacokinetic properties of different radiopharmaceuticals may vary widely and impact patient dose very much. For this reason, it is very important to provide details on the specific radiopharmaceuticals commonly used in each procedure.

NM Ratio (percentage)

Data on the most common radiopharmaceutical need to be complemented by the percentage of its use compared to the total of all radiopharmaceuticals used. Practically, this would be the ratio of the number of procedures of a specific category performed with the most common radiopharmaceutical to the total number of such procedures performed with any radiopharmaceutical. Further information on radio-pharmaceuticals other than the most common one can be added in the comments, especially if it is estimated that another pharmaceutical makes an important contribution to the mean effective dose per examination.

CT Ratio (percentage)

The ratio of NM procedures that also have a CT component. This ratio is important to be able to determine which part of the effective dose arises from the radiopharmaceutical and which from the CT scan.

Effective dose

For the UNSCEAR Global Survey, users are encouraged to calculate the mean effective dose for the different procedures reported. **However, this does not include doses from therapeutic procedures. In therapy with radionuclides, organ doses are so high that the effective dose concept cannot be applied.** The dose quantities requested in this section (DLP, mean activity) could be used for these calculations.

NUCLEAR MEDICINE

Dose

Activity and DLP may be multiplied by appropriate factors in order to estimate the effective dose. The calculation methods may vary. In some cases, multiplication factors may not even be readily available. **Thus, additional information about the method used should be included in the "comments" field of the dosimetry section (sheet).**

There are two kinds of factors that may be multiplied with mean activity:

1. **Organ absorbed doses per unit administered activity (in mGy/MBq):** These factors, when multiplied by activity, provide the organ doses. The doses may then be multiplied with appropriate tissue weighting factors published by ICRP to yield effective dose. This is a two-step process. Organ dose calculations can be performed in the case of therapeutic NM procedures for which the effective dose does not apply. However, factors for organ dose calculations are not provided in this handbook. Due to the relatively recent update of the ICRP effective dose weighting factors, users are kindly requested to use the latest factors **[I8]** whenever possible. **If the old ICRP factors are used [I5], please state this in the spreadsheet comment field.**
2. **Effective doses per unit administered activity (in mSv/MBq):** These factors may be multiplied by activity values to yield effective dose values directly.

Pharmacokinetic data and relevant dose coefficients were made available by ICRP in publication 53 **[I4]**. This publication contains calculations of absorbed organ doses and the effective dose equivalent per unit activity administered for about 120 radiopharmaceuticals. The first addendum to Publication 53 was included in Publication 62 **[I6]**. It contains data for 6 additional substances and a table of effective doses per unit administered activity re-calculated with the tissue weighting factors of ICRP Publication 60 **[I5]**. The second addendum contains calculations of absorbed organ doses per unit activity administered for 9 radiopharmaceuticals and recalculations for 19 substances **[I7]**. The third amendment **[I9]**, provides data for 33 radiopharmaceuticals. The fourth amendment **[I10]**, provides biokinetic models, absorbed doses, and effective doses per unit activity for radiopharmaceuticals mainly based on 18F. A compendium of current information relating to radiation dose to patients, including biokinetic models, biokinetic data, dose coefficients for organ and tissue absorbed doses and effective dose for major radiopharmaceuticals, is currently in press under the name of ICRP Publication 128. These data are mainly compiled from ICRP Publications 53 **[I4]**, 80 **[I7]**, 106 **[I9]** and related amendments and corrections. This report also includes new information for ^{82}Rb-chloride and ^{123}I-, ^{124}I-, ^{125}I- and ^{131}I-iodide.

Due to the bulk and complexity of the available data, users are highly encouraged to provide details about the data used for any dose calculations in the "comments" field of the dosimetry section (sheet).

Table 11. Effective doses per unit administered activity (adapted from **[E2]**)

Table 11 contains effective doses per unit administered activity for the most common nuclear medicine procedures **[I4, I6, I7, I9, I10]**.

Modality category	*Procedure category*	*Specific procedures*	*Radio-nuclide*	*Effective dose per unit activity administered (mSv/MBq)*	*Ref.*
Diagnostic procedures using gamma cameras and SPECT or SPECT-CT*	Nervous system	Brain perfusion (HMPAO or ECD)	Tc-99m	– HMPAO: 0.0093 – ECD: 0.0077	**[I4, I7, I9]**
	Nervous system	Dopamine transporter imaging (parkinsonism)(β-CIT)	I-123	0.05	**[I9]**
	Skeletal	Bone scan	Tc-99m	0.0057	**[I4, I7]**
	Cardiovascular	Myocardial perfusion imaging	Tl-201 Chloride	0.14	**[I9]**
	Cardiovascular	Myocardial perfusion – Imaging, rest (Tetrofosmin, MIBI) – Radionuclide ventriculography (MUGA)	Tc-99m	– Tetrofosmin: 0.0069 – MIBI: 0.009 – MUGA: 0.007	**[I4, I7, I9]**
	Pulmonary	– Lung perfusion	Tc-99m	0.011	**[I4, I7]**
	Endocrine	Thyroid Tc-99m scan Parathyroid (MIBI)	Tc-99m	– Thyroid, oral administration, no blocking: 0.013 – Parathyroid, MIBI: 0.009	**[I4, I7]**
	Endocrine	Thyroid I-123 uptake 35%	I-123	0.22	**[I9]**
	Gastrointestinal	Hepatobiliary system			
		– IDA derivatives	Tc-99m	0.017	
		– Large colloids	Tc-99m	0.0094	
		– Labelled erythrocytes	Tc-99m	0.007	
		Gastrointestinal bleeding			
		– Labelled erythrocytes	Tc-99m	0.007	

* Procedures performed with other types of equipment (e.g. single channel spectrometers) should be added under "Other".

Table 11. Effective doses per unit administered activity (adapted from [E2])

Modality category	*Procedure category*	*Specific procedures*	*Radio-nuclide*	*Effective dose per unit activity administered (mSv/MBq)*	*Ref.*
Diagnostic procedures using gamma cameras and SPECT or SPECT-CT*	Genitourinary	Renal imaging	Tc-99m	– DMSA: 0.0088 – MAG3: 0.007 – DTPA: 0.0049	**[I4, I7]**
	Oncology	Gallium citrate scan In-111 Octreotide scan		– Ga-67: 0.1 – In-111: 0.054	**[I4, I7, I9]**
	Infection/ inflammation	Ga-67 scan for infections In-111 labelled monoclonal tumour-associated antibodies (intact antibodies) Tc-99m leukocyte study (infection or IBD)		– Ga-67: 0.1 – In-111: 0.22 – Tc-99m: 0.011	**[I4, I7, I9]**
	Oncology	Tumour imaging (FDG)	F-18	0.019	**[I9, I10]**
Diagnostic procedures using PET, PET-CT* and PET-MRI	Oncology (other than F-18				
	Nervous system				
	Skeletal	Bone scan Bone marrow scan	F-18		
	Cardiovascular	Myocardial perfusion (FDG)	F-18	0.019	**[I9]**
	Cardiovascular (other than F-18)	Cardiovascular (myocardial perfusion, PET-H2O)	O-15	0.0011	**[I9]**
	Infection/ inflammation				

* Procedures performed with other types of equipment (e.g. single channel spectrometers) should be added under "Other".

The DLP of the examination should be used along with computationally derived factors for the assessment of effective dose in CT imaging. Such generalized factors are presented in table 12.

Some CT image acquisition processes comprise more than one phase and multiple scans. In such cases, the **total DLP** should be reported so that estimation of the total effective dose per nuclear medicine procedure will be possible.

Table 12. Generalized E/DLP coefficients for CT image acquisition processes (adapted from **[E1]**)

Region of body scanned	*E/DLP (mSv/mGy cm)*
Head	0.0021
Neck	0.0059
Chest	0.014
Abdomen and pelvis	0.015
Pelvis	0.015
Trunk	0.015

RADIOTHERAPY

In this section, information is provided to facilitate the completion of the radiotherapy (RT) questionnaire. The information requested is organized according to the four main sections (sheets) of the questionnaire, namely:

- **General information:** for general information about the country, its population, the survey period and contact details of contributors.
- **Staff and devices:** for information on the staffing levels and the available equipment.
- **Frequency:** for data on frequency of treatments and “optional” data regarding the age and the sex distribution of the population undergoing these treatments.
- **Dose:** for information on mean doses from different treatments.

RADIOTHERAPY General information

In this section, contributors are requested to fill in their contact details and general information about their country such as:

- **Year:** Indicate the year (or period) to which the data refer.
- **Population (inhabitants):** Indicate the total population size in number of inhabitants of the country for the year to which the data refer.
- **Population (survey base):**): Indicate the size of population in number of inhabitants if the data collected are for a particular region, city or hospital only. Provide the total population size of the country if the information provided is for the whole country. When a smaller fraction of the population is used as a basis for assessing the situation in the whole country, an estimation of how representative the data are with regard to the entire country should be provided for each treatment separately. Such information is requested in the frequency sheet of the questionnaire.
- **Contact information:** The data submitted should be signed off by the national contact person (NCP), registered on the UNSCEAR online platform, including name, institution and contact details (e-mail/phone) to facilitate any feedback. Please, indicate contact details of any other persons who have provided information and who should be acknowledged in the final report. **Contact details for at least one person are required as this information will be transferred to the UNSCEAR database.**

The country code is provided automatically, and the date of submission will be generated during upload of the file.

RADIOTHERAPY

Staff and devices

Collected information on staffing and equipment may be correlated with frequency and dose information and provide useful insights on the effect of equipment and staffing levels on population doses from medical radiation.

Staff

Information about the number and type of professionals working in radiotherapy should be provided in this sheet. The numbers should reflect the situation in the entire country as accurately as possible and could be based on data originating from national registries or professional associations. Data should reflect the situation regarding professionals working in both hospital and private practice. Please note that:

- Only practising professionals should be included and their actual occupancy time should be taken roughly into account. For example, two part-time physicians, each working 50% of the normal working hours, count as one full-time professional.
- Persons working in two areas or more should be counted according to their main activity.
- Some data about professionals not working in radiotherapy are also requested. For example the number of general practitioners.

The number of individuals working in radiotherapy in the following categories are requested:

- **Physicians:** All physicians in the country irrespective of their medical specialization.
- **General practitioners:** Medical doctors usually acting as primary care providers at an early stage of a disease's onset. In some countries they are called family doctors.
- **Radiation oncologists:** Only medical doctors specialized in radiation oncology.
- **Other doctors using radiotherapy:** All other physicians using radiotherapy. For example urologists (prostate brachytherapy), surgeons (intraoperative radiotherapy).
- **Medical physicists in radiotherapy:** Medical physicists licensed or authorized to practise in radiotherapy.
- **Dosimetrists:** Dosimetrists licensed or authorized to practise in radiotherapy. Dosimetrists are professionals who perform calculations for treatment planning in radiotherapy. In some countries there are no licensed dosimetrists and medical physicists undertake their duties.
- **Radiation technologists in radiotherapy:** Radiation technologists licensed or authorized to perform treatments in radiotherapy.
- **Nurses in radiotherapy:** Nurses practising in radiotherapy or working as radiation technologists.

RADIOTHERAPY Staff and devices

Devices

A wide range of different radiological devices are used in radiotherapy. Some general information and guidelines on how to list the different devices is provided here:

- Only data on the numbers of **actually operating equipment** are required.
- Systems with multiple X-ray tubes are counted as one device.

Note that the equipment listed in the radiotherapy questionnaire includes imaging devices. These may be different from the ones used in radiology departments and may be for exclusive use for radiotherapy purposes. If this is not the case and the same machine (e.g. CT) is also used in diagnostic radiology, then they should be only listed once in the radiology section of the questionnaire. Patient doses resulting from CT uses for radiotherapy planning are not taken into account in the UNSCEAR survey.

Table 13 describes the different types of equipment used in radiotherapy.

Table 13. Radiotherapy devices listed in the RT questionnaire

Descriptions and images are provided in order to help recognize and categorize the different devices

Radiotherapy systems

Low-energy X-ray (<250 keV)	Radiotherapy machines that produce relatively low-energy X-rays. They might look similar to imaging machines because they use X-ray tubes for the production of X-rays. These machines are used for treatment of superficial tumours.	
Cobalt-60	Radiotherapy machines containing a high activity cobalt source for delivering therapy. The source produces gamma radiation of 1.25 MeV average energy. Their relatively low-energy beam makes them more suitable for shallow seated tumours. They are less bulky than a linear accelerator but they have heavy shielding around the cobalt source.	
Stereotactic (with gamma source)	Device consisting of a heavily shielded head comprising about 200 cobalt sources. These systems may very accurately target tumours and achieve very accurate dose distributions. The patient wears specialized equipment so that the target remains fixed to the geometry of the device and only moves controllably.	

Table 13. Radiotherapy devices listed in the RT questionnaire

Radiotherapy systems

Linear accelerators	Linear accelerators have been replacing the cobalt sources in radiotherapy practice. These machines produce high energy beams (4-25 MV) through radiofrequency acceleration of electrons. The high energy electrons hit a heavy metal target in order to produce the therapeutic X-ray beam. Such photon beams are suitable for more deeply seated tumours. The electron beam produced may be used directly for the irradiation of surface meoplasms if the heavy metal target is removed.	
Robotic radiosurgery	Systems comprising a robotic arm sporting a compact linear accelerator at the end of it. In conjunction with patient immobilization systems, these robotic devices may be used for very accurate delivery of dose to the target volume.	
Helical radiotherapy (tomotherapy)	Helical radiotherapy machines built on a gantry like CTs. The difference is that instead of an X-ray tube they comprise a linear accelerator which revolves around the patient. The radiation dose is delivered slice by slice to the target volume.	
Brachytherapy devices HDR/LDR)	A type of internal radiotherapy with sealed sources. The sources are stored in the shielding of the device when the device is idle. During therapy, the sources may move through appropriate catheters to reach the area of disease. Catheters usually need to be placed surgically. High dose rate (HDR) devices can treat patients in a matter of minutes in contrast to low dose rate (LDR), in which treatments may last days. Brachytherapy may be carried out with permanently implantable sources. These sources are surgically implanted into the tumour and usually emit electrons to avoid high dose to healthy tissues.	

RADIOTHERAPY Frequency

This questionnaire sheet is for information collection on the frequency of various radiotherapy treatments performed on patients. The information is important in order to scale the growth of radiotherapy worldwide. The treatment types have been categorized under external beam radiotherapy and internal brachytherapy as well as by anatomical region or condition (e.g. benign diseases). In the following sections, the categorization of treatments will be described in more detail.

Categorization of examinations

The categorization of treatments in this survey follows the two types of radiotherapy:

- External beam radiotherapy
- Brachytherapy

Further, the categorization of radiotherapy treatments considers the anatomical regions that might have been exposed and the condition to be treated. A single modality may also be used in different ways. For instance, a different number of fields or different field sizes may be used for a specific external beam radiotherapy treatment. Such differences in clinical practice make it difficult to define all treatments clearly. For this survey, **a radiotherapy treatment is defined as one or a series of irradiations of one anatomical region/organ/organ system, using a single treatment modality (i.e. linear accelerator or brachytherapy system), needed to treat a specific condition, during one or more visits to the radiotherapy department, hospital or clinic.** More than one visit to the radiotherapy centre is required if the dose to the tumour is delivered in fractions.

Table 14 shows the types of treatments included in this survey and the treatment categories in which specific treatments are to be listed.

Table 14. Categorization of specific radiotherapy treatments used in the UNSCEAR Global Survey

Modality category	*Treatment category*
External beam therapy systems	Total body irradiation (TBI) Lymphoma/Hodgkin Lymphoma/Non-Hodgkin Eye Breast Lung/thorax (including oesophagus) Gynaecological tumour Head/neck Primary brain Brain metastases Skin (local therapy) Skin (total skin electron beam irradiation, e.g. Kaposi's sarcoma) Bladder Prostate Kidney (including Wilms' tumour) Testis Other urological tumours Colon and rectum Other digestive tumours (e.g. stomach, liver) Bone and soft tissue sarcomas Bone metastases Neuroblastoma Other paediatric tumours Benign diseases (other than sites listed above)
Brachytherapy	Head/neck Eye Skin Brain Lung Colorectal Other GI (e.g. liquid brachytherapy for liver metastases) Breast Gynaecological Prostate Intravascular (e.g. for intimal hyperplasia)

RADIOTHERAPY Frequency

Number of patients

In contrast to diagnostic radiology and nuclear medicine, in radiotherapy the number of patients undergoing each treatment type for the reported year or period and NOT the number of treatments should be reported.

Representation (percentage)

The approximate percentage of representation or coverage of the data for the whole country is requested for each treatment type in order to accurately extrapolate data and reduce uncertainty. If you don't know this information, please make a rough estimate in order to make the UNSCEAR assessment as accurate as possible.

Age and sex distribution of patients

As demographic data differ from country to country, it is desirable to collect data on the age and sex distribution of patients undergoing radiotherapy treatments from as many countries as possible. **This part is optional; however, the information on age and sex distribution is very important for the evaluation, and even incomplete data might be useful for the survey.** Please consider collecting such data for future evaluations.

The number requested in the radiotherapy age and sex section should reflect the total number of patients and NOT the number of performed treatments.

The recent UNSCEAR classification has 20 age bands for each sex and provides more detailed information than the old UNSCEAR classification of just three broad age bands (0–15 years, 16–40 years and >40 years) for each sex. However, the old UNSCEAR classification can still be used (figure 19). **Use the new UNSCEAR classification, if possible, to provide detailed information, or the old UNSCEAR classification if detailed numbers are not available.**

0-1		2-4		<5		5-9		10-14		0-14		15-19		20-24		25-29		30-34		35-39		15-39		40-44		45-49		50-54	
male	female	male	female	male	female	male	female	male	female	male	female	male	female	male	female	male	female	male	female	male	female	male	female	male	female	male	female	male	female

Figure 19. Current and old UNSCEAR classification for age and sex distribution

RADIOTHERAPY Dose

This section of the questionnaire aims to collect dose related information for the major treatments in radiotherapy. The classification of treatment categories is similar to the one used in the frequency sheet and will not be repeated here. **The purpose of the collection of prescribed doses is for the estimation of the global status of radiotherapy practice and not for the collective effective dose estimation. Doses in radiotherapy are usually so high that the premise of effective dose cannot be applied for population cancer risk estimations.**

Dose quantities for radiotherapy treatments

Doses used in radiotherapy are typically in the range of several grays. The concept of effective dose does not apply to such high doses **[I5, I8, U1, U2]**. Thus, doses from radiotherapy treatments are not included in estimates of the global collective dose due to medical exposures. From this standpoint, the UNSCEAR Global Survey collects information on typically prescribed doses and general treatment techniques in order to gauge the global practice in radiotherapy. The type of radiotherapy technique, especially for external radiotherapy, is a key factor for the assessment of such practices (figure 20).

Beam energy [MV] / radionuclide	Prescribed dose to target volume [Gy]	Number of fractions/course	Most frequently used technique (Ex. 2D/3D/IMRT)

Figure 20. Screenshot of dosimetric information requested in the RT questionnaire

RADIOTHERAPY Dose

The most usually applied radiotherapy techniques are listed below:

- **Two-dimensional radiotherapy (2D):** This technique uses one or more rectangular fields in an appropriate configuration to increase tumour dose while sparing healthy tissues. This is generally a crude technique. Although beam modifying blocks may be used to match the irradiation field more to the target volume, the field does not conform very well to the shape of the target volume.
- **Three-dimensional conformal radiotherapy (3D CRT):** Additionally to the 2D technique, 3D CRT uses fields that conform to the shape of the target volume. This is possible through the use of multi-leaf collimators, which may accurately conform the beam to the shape of the target volume.
- **Intensity modulated radiotherapy (IMRT):** This technique builds on the premise of 3D CRT, adding beam intensity modulation in order to improve dose distribution, maximizing damage to the tumour while sparing more healthy tissue. A recent enhancement of IMRT is volumetric modulated radiation therapy (VMAT).
- **Stereotactic body radiation therapy (SBRT):** This technique uses precise three dimensional localization of the target volume. Use of the term “body” means that therapy is applied to non-brain tumours, in contrast to gamma radiosurgery.
- **Stereotactic radiotherapy with gamma source:** Sometimes called radiosurgery or stereotactic radiosurgery (SRS), stereotactic radiotherapy uses gamma sources, e.g. a gamma knife applying this technique.
- **Helical radiotherapy:** A technique in which a linear accelerator delivers radiotherapy to the patient while spinning around the patient’s body in a manner similar to that of a CT scanner.

In brachytherapy, two techniques are usually applied:

- **High dose rate brachytherapy (HDR):** Uses sources of high strength and may finish a treatment very quickly. The exposure of the patient is in the range of minutes.
- **Low dose rate brachytherapy (LDR):** Uses sources of low strength. The duration of treatment of the patient is in the range of days.

Table 15 summarizes information about radiation dose quantities and required information to be filled into the dosimetry section of the RT questionnaire.

Table 15. Information on radiation dose quantities used in the UNSCEAR Global Survey

Radiation dose quantity	*Description/definition*	*Information and remarks*
Prescribed dose to target volume	Prescribed target volume dose (Unit: gray), is defined as the dose that needs to be delivered to the target volume in order to treat the condition without damaging surrounding healthy tissues. The prescribed dose is decided by the radiation oncologist.	Usual prescribed dose delivered to the patients for the specific condition.
Beam energy	For X-ray beams produced by X-ray tubes or linear accelerators, the beam energy is in fact a spectrum of energies. For this reason, it is customary to describe the beam by the maximum electron accelerating voltage in kV or MV.	For X-rays: the maximum electron accelerating voltage in kV (low-energy beams) or MV (linear accelerators).
	For gamma photons emitted from a nuclide or a cobalt-60 unit, the energy can be specific and be expressed in MeV.	For gamma photon beams (cobalt-60, brachytherapy): Energy of emitted photons in MeV.
Radionuclide	If gamma photons are used for therapy (cobalt-60 unit or brachytherapy), knowing which radionuclide emits the photons is important in order to know the energy of the emitted photons.	Symbol of the radionuclide emitting the photons in each treatment category involving gamma photons (cobalt-60, brachytherapy).
Number of fractions per course	For medical reasons, some radiotherapy treatments must be performed in multiple sessions. In each session, a fraction of the total prescribed dose is delivered to the target volume.	The number of fractions typically needed to deliver the prescribed dose to the target volume for each treatment category.
Most frequently used technique	Radiotherapy techniques (listed above) have evolved and may now achieve better dose delivery to the tumour than the crude techniques of the past. Use of modern techniques is an indicator of the quality of radiotherapy practice.	The most frequently used technique for each treatment category.

APPENDIX
Examples of dose calculations

- Diagnostic and interventional radiology
- Nuclear medicine

This part aims to help users in using dose metrics and the corresponding coefficients presented herein for the estimation of the mean effective dose per examination or procedure.

APPENDIX: EXAMPLES OF DOSE CALCULATIONS

The examples correspond to the two major disciplines for which the effective dose is applied. **Mean values of the dosimetric quantities should be used in order to calculate mean effective doses representative of the practice in a country.**

Diagnostic and interventional radiology

From a dosimetry point of view, the major kinds of RD examinations fall into two categories: projectional imaging and cross-sectional imaging. The first category includes radiography, mammography and fluoroscopy thus including interventional procedures. Cross-sectional imaging includes CT and CBCT examinations.

Radiography

In many occasions mean effective dose from projection radiography examinations may be directly calculated. This is possible by multiplying the available mean DAP/KAP value by the anatomy specific, dose conversion coefficients tabulated on table 4. For example an abdomen X-ray with a mean DAP of 7 Gy·cm^2 would yield an effective dose of:

$$E = 7\ \text{Gy·cm}^2 \times 0.26\ \text{mSv·(Gy·cm}^2\text{)}^{-1} = 1.82\ \text{mSv} \quad (1)$$

In case a mean DAP/KAP value is not available for an examination, it can be calculated by using more elementary quantities such as the air kerma free in air (K_α). K_α is the dose absorbed to air, free in air (measured in mGy). This quantity is directly measured with an appropriate calibrated dosimeter at 1 m distance (radiography) or 50 cm distance (fluoroscopy). If it is normalized to the (tube current—exposure time product (mAs)), it is then called "dose yield" or "X-ray tube output" measured in mGy/mAs. Assuming reasonable uniformity of X-ray intensity throughout the whole field, it is possible to calculate the cumulative DAP/KAP by multiplying the dose yield with the total mAs and the field size at the distance in question. For example an X-ray output of 10 mGy/mAs for a 10 × 10 cm^2 X-ray field during a 10 mAs exposure will yield a DAP/KAP value as follows:

$$\text{DAP/KAP} = 10\ \text{mGy·mAs}^{-1} \times 10\ \text{cm} \times 10\ \text{cm} \times 10\ \text{mAs} = 10\ \text{Gy·cm}^2 \quad (2)$$

The following dose quantities could be available and could possibly be used to calculate the mean effective dose from specific examinations. The definitions and their connections to DAP/KAP and air kerma free in air are described so that the user may track back to the value required for mean effective dose estimation.

Incident air kerma ($K_{\alpha,i}$) is measured free in air on the central axis of the X-ray beam at the focus skin distance, (FSD). It is measured in mGy and it is related to air kerma free in air by the inverse square law, as follows:

$$K_{\alpha,i} = K(d)_\alpha \times (d/d_{FSD})^2 \quad (3)$$

where $K(d)_\alpha$ is the air kerma free in air at a distance d from the focus.

Entrance surface dose (ESD) or entrance surface air kerma (ESAK) ($K_{\alpha,e}$): This quantity is measured in mGy and equals the air kerma multiplied by a backscatter factor B.

$$K_{\alpha,e} = K_{\alpha,i} \times B \quad (4)$$

The ESD is useful as it can be calculated by using the tube output, the distance from the focus of the X-ray beam and the backscatter factor.

APPENDIX: EXAMPLES OF DOSE CALCULATIONS

Diagnostic and interventional radiology

Fluoroscopy and interventional procedures

In fluoroscopy and interventional procedures, DAP/KAP is the dose metric of interest. Most of the times it is displayed on the console of the fluoroscopy machine. In examinations/interventional procedures involving a lot of fluoroscopy time, average cumulative DAP/KAP should be used for mean effective dose calculations. Tables 4 and 5 provide anatomy and procedure specific dose conversion coefficients. The calculation of mean effective dose is performed by multiplying the average cumulative DAP/KAP with the appropriate coefficients found in tables 4 and 5. The calculation required is similar to the one presented in equation (1) above.

However, doses in interventional radiology are usually much higher than simple diagnostic radiography and need special attention. For example, a PTCA procedure (e.g for stent placement) with a cumulative mean DAP/KAP of 50 Gy·cm^2 results in 13 mSv by using the appropriate coefficient value for PTCA stent placement from table 5.

$$E = 50\ \text{Gy·cm}^2 \times 0.26\ \text{mSv·(Gy·cm}^2\text{)}^{-1} = 13\ \text{mSv} \qquad (5)$$

Mammography

In mammography, the mean effective dose may be derived by using the quantity of incident air kerma and a set of factors that connect incident air kerma and effective dose in mammography for typical mammography exposure conditions (table 6). In an exposure of both breasts with the following conditions:

- Breast thickness: 50 mm
- 28 kV
- Mo/Mo
- HVL = 0.32 mm Al
- $K_{\alpha,i}$ = 230 mGy,

would yield the following effective dose:

$$E = 230\ \text{mGy} \times 0.0087\ \text{mSv·mGy}^{-1} = 2\ \text{mSv} \qquad (6)$$

APPENDIX: EXAMPLES OF DOSE CALCULATIONS

Diagnostic and interventional radiology

Computed tomography

In CT, the quantity of interest is the dose length product (DLP). DLP values are usually displayed on the console of the CT scanner. These values may be multiplied by computationally derived coefficients for the assessment of effective dose in CT examinations. Such generalized coefficients are presented in table 7. As an example, calculation of the effective dose to the patient due to a chest CT scan with an average DLP of 700 mGy·cm would go as follows:

$$E = 700\ \text{mGy·cm} \times 0.014\ \text{mSv·(mGy·cm)}^{-1} = 9.8\ \text{mSv} \quad (7)$$

Sometimes the DLP value may not be available while the average $CTDI_{vol}$ is available. Since DLP is in fact equal to $CTDI_{vol}$ multiplied by the scan length, it is possible to estimate effective dose by multiplying the generalized coefficients with $CTDI_{vol}$ and the total estimated average scan length. **The total effective dose arising from a CT scan is calculated by using the total (cumulative) DLP**, especially for examinations involving several scans. In case the calculation is done by using $CTDI_{vol}$, the user should use the total estimated scan length for all phases of the examination.

APPENDIX: EXAMPLES OF DOSE CALCULATIONS

Nuclear medicine

The situation in nuclear medicine is quite simpler than in diagnostic and interventional radiology. Mean effective dose calculations involve just the act of multiplication but fortunately there is a coherent set of coefficients that may be found tabulated in just a few sources **[I4, I6, I7, I9, I10]**. A collection of important and often used dose conversion coefficients is presented on table 11. These coefficients connect effective dose with the administered activity of specific radiopharmaceuticals. For example, a ^{18}F-FDG brain scan with a mean administered activity of 740 MBq would yield the following effective dose:

$$E = 0.019\ mSv \cdot MBq^{-1} \times 740\ MBq = 14.06\ mSv \quad (8)$$

UNSCEAR is only interested in effective dose estimation from diagnostic nuclear medicine procedures. However, there are also tabulated coefficients that may be used for specific organ dose estimations **[I4, I6, I7, I9, I10]**.

Some NM procedures may additionally involve the use of CT (e.g. in PET-CT, SPECT-CT). In order to assess the total mean effective dose from such procedures it is important to know the estimated percentage of procedures that involve CT scans in any category (see paragraph **"CT Ratio [percentage]"** in section B). The total mean effective dose from such procedures will then be the dose arising from both the radionuclide and the CT scan. For example consider an infection/inflammation procedure with ^{67}Ga (Citrate) in the chest area. Also consider that the CT ratio is 40%. This means that only 40% of the total number of procedures have a CT component. For a mean administered activity of 300 MBq and an average DLP of 140 mGy·cm, the total effective dose will be:

$$E = 60\% \times (\text{mean effective dose from the radiopharmaceutical}) + 40\% \times (\text{mean effective dose from the chest CT scan}) = 0.6 \times (0.1\ mSv \cdot MBq^{-1} \times 300\ MBq) + 0.4 \times (140\ mGy \cdot cm \times 0.014\ mSv \cdot (mGy \cdot cm)^{-1}) = 18\ mSv + 0.8\ mSv = 18.8\ mSv \quad (9)$$

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