ESTIMATING POPULATION DOSES FROM MEDICAL RADIOLOGY


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Abstract. An EU-funded project called DOSE DATAMED has been set up to develop mutually acceptable methods for future surveys of population exposure from medical x-rays, including issuing guidance on suitable patient dose quantities and dosimetry methods. The second report from the project group deals with guidance on how to conduct population dose surveys for medical exposures to improve the comparability of results from various countries. In order to assess population exposures from medical radiology in terms of the collective or per caput effective dose, it is necessary to estimate representative mean effective doses for each type of x-ray examination that makes a significant contribution to the collective dose in a country. Suitable practical dose quantities are entrance surface dose or the dose-area product for simple radiography, the total dose-area product for examinations including fluoroscopy, and the computed tomography dose index and the dose-length product for CT examinations. Factors for converting these practical dose quantities into effective doses are provided in the report. Guidance on assessing the frequency of x-ray examinations includes the definition of 225 specific x-ray examinations and 70 broader categories of examinations, and the identification of those 20 examinations most contributing to the collective effective dose. Information on the age and sex distribution of the patients undergoing these 20 important examinations is provided to assist in relating the collective doses to the collective detriment. Simple approaches for those countries that do not have resources to make comprehensive frequency or dose surveys are provided. The uncertainties involved in various survey methods are addressed. New approaches using dose data stored in the DICOM header and information in the radiological information system (RIS) are also discussed.

KEYWORDS: Diagnostic x-rays, patient dose, dosimetry, population exposure

1. Introduction

The European Commission (EC), on advice from the Article 31 Group Working Party on Medical Exposures, instigated a study at the end of 2004 to review the current situation in Member States regarding the implementation of Article 12 of the Medical Exposure Directive of 1997 and to develop appropriate guidance [1]. Article 12, entitled ‘Estimates of population doses’, requires Member States to ensure that the distribution of individual dose estimates from medical exposure is determined for the population and for relevant reference groups of the population, as may be deemed necessary by the Member State. The Commission was concerned that there were no internationally accepted protocols for evaluating patient exposures from medical x-ray imaging procedures and that reported estimates of population doses varied widely between European countries with similar levels of healthcare. It was thought that some of this variation might be due to differences in the methodology adopted to assess
population doses between Member States and to large inherent uncertainties in these assessments that had not been fully evaluated.

A multinational project (called DOSE DATAMED) involving ten European countries was set up to carry out this study. All project partners and the institutes that they work for have long experience of conducting national surveys of population exposure from medical radiology. The project has built upon this experience to review the existing national arrangements and strategies for carrying out these surveys in each country. It has looked at the different healthcare systems operating in each country to see if they could account for some of the differences observed in the population doses. It has studied and compared the methods and results of the most recent population dose surveys in each country and evaluated the uncertainties. The first report from the group (DD Report 1) presents the results and conclusions from this review of recent national surveys of population exposure from medical x-rays in Europe. A supplementary report - DD Report 1(a) - provides a brief review of the methods and results of recent national surveys of population exposure from diagnostic nuclear medicine procedures in eight of the DOSE DATAMED countries. The second report from the group (DD Report 2) provides recommendations for the development of a harmonised system for assessing patient doses and the level of provision of diagnostic radiology services in Member States, in order to improve the comparability of national population dose estimates in the future. In view of the relatively low contribution of nuclear medicine to population exposure compared to medical x-rays (4-14% in the various DOSE DATAMED countries), and the more straightforward and well-established methods for assessing patient doses for nuclear medicine examinations (see DD Report 1(a)), this guidance concentrates on population dose assessments for the x-ray imaging procedures used in diagnostic and interventional radiology. Nonetheless, much of the guidance given on the assessment of the frequency of x-ray procedures can be equally applied to nuclear medicine examinations.


2. Summary of recommendations

2.1 Purposes of population dose estimates, desired frequency and resources required

- The objectives of the study need to be clearly stated in any report on population doses from medical radiology. These might include all or only some of the following objectives:
  1. To observe trends in the annual collective dose (or the annual average per caput dose) from medical x-rays in a country with time.
  2. To determine the contributions of different imaging modalities and types of examination to the total collective dose from all medical x-rays.
  3. To determine the relationship between the frequencies of different types of x-ray examination, the typical radiation doses given to patients and their contribution to the total collective dose.
  4. To determine whether there are any regional variations within a country in the frequency or collective doses from particular types of x-ray examination.
  5. To compare the frequencies and the annual per caput doses from medical x-rays between countries.
  6. To compare the contribution from medical x-rays with those from other natural and man-made sources of population exposure in a country.
  7. To determine the age and sex distribution of the patients undergoing specific types of x-ray examination, particularly those making a major contribution to the total collective dose.

- If objective 6 or any additional objectives that involve comparisons of the radiation risks from medical radiology with those from other sources of population exposure are being considered, the
serious limitations of collective effective dose in this regard should be declared and objective 7 becomes particularly important.

- It is recommended that, if possible:
  - Frequency surveys should be repeated every 5 years
  - Patient dose surveys should be repeated every 5 years
  - Both types of survey should be as close in time as possible

although it is recognised that the resources required to perform these surveys are considerable and not every country may be able to meet this ideal.

- At least two senior scientists, should be responsible for co-ordinating the whole project and to assure the scientific quality of the results

- The team conducting the survey should have expertise (internally or by external consultancy) in radiology, dosimetry, public health, statistics and project management.

- National public health and the radiation protection authorities should be involved in the project.

- Collaboration with the professional bodies associated with medical radiology is essential from the first stage of the survey.

2.2 Suitable dose quantities

- The annual collective and per caput effective doses for the totality of all x-ray examinations conducted in a country and for those specific examinations making major contributions to the total should be estimated, to meet objectives 1-5.

- In addition, information on the age and sex distribution of the patients undergoing the types of x-ray examination making a major contribution to the total collective dose will be valuable for relating the collective doses to the collective detriment (important for objective 6).

- Effective dose estimates for medical exposures should not be used for assessing radiation risks to patients by simple application of ICRP’s nominal probability coefficients for radiation-induced cancer.

2.3 Guidance on assessing frequency of x-ray examinations

- An x-ray examination or interventional procedure should be 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’.

- The most reliable and accurate approach is to collect frequency data (and estimate typical effective doses) for every specific type of examination.

- The second best approach is to collect frequencies (and estimate doses) for broad categories of examinations.

- The third best approach is to give priority to the examination types and categories that contribute most to the collective effective dose in the country, covering at least 75% of the total. If a country does not have the resources to investigate and identify the procedures that are currently responsible for 75% of the collective dose, the ‘Top 20 Exams’ listed in Table 1 (and described in detail in Appendix 1 in the report) can be used.
Table 1: The twenty examination types identified to be the highest contributors to the collective effective dose in Europe

<table>
<thead>
<tr>
<th>Plain film radiography (no contrast medium)</th>
<th>Radiography/fluoroscopy (usually with contrast)</th>
<th>Computed tomography</th>
<th>Interventional radiology</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. Thoracic spine</td>
<td>10. Barium follow</td>
<td>15. CT chest</td>
<td></td>
</tr>
<tr>
<td>4. Lumbar spine</td>
<td>11. IVU</td>
<td>16. CT spine</td>
<td></td>
</tr>
<tr>
<td>5. Mammography</td>
<td>12. Cardiac angiography</td>
<td>17. CT abdomen</td>
<td></td>
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<tr>
<td>6. Abdomen</td>
<td></td>
<td>18. CT pelvis</td>
<td></td>
</tr>
<tr>
<td>7. Pelvis and hips</td>
<td></td>
<td>19. CTentire trunk</td>
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</table>

- Annual numbers of examinations can be obtained directly from a sample of hospitals, clinics or practices and then scaled up to cover the whole country; or from central statistics held by government departments or insurance companies for all (or at least a large proportion) of radiology practice in the country.

- Information on the annual numbers of x-ray examinations should be available from the computerised Radiology Information Systems (RIS) that are now widely in place in most hospitals throughout Europe.

- If frequency data are derived from a relatively small sample of hospitals or practices, steps should be taken to ensure that the sample is as representative of national radiology practice as possible.

- It is important to make clear whether dental radiology conducted by dentists in ‘Dental Practices’ and/or Nuclear Medicine examinations are included in the population dose assessments or not.

- Major sources of error in the frequency estimates should be identified and the uncertainties evaluated. Important sources of uncertainty include:
  - Problems in relating the information stored in terms of examination codes into actual numbers of examinations
  - Bias in the sample and invalid assumptions made when scaling up sample data to derive frequencies for the whole country
  - Lack of frequency data from some important providers of radiology services
  - Mistakes in the data recorded or collected

2.4 Guidance on assessing patient doses

- Medical physicists with particular expertise in diagnostic radiology dosimetry should be directly involved in the assessment of patient doses.

- In order to assess population exposures from medical radiology in terms of the collective or per caput effective dose it is necessary to estimate representative mean effective doses \( E \) \([2, 3]\), for each type of x-ray examination that makes a significant contribution to the collective dose in a country.

- The most reliable and accurate approach is to conduct extensive patient dose surveys to measure or calculate practical dose quantities at as representative a sample of hospitals in a country as possible.

- The practical dose quantities that are commonly measured include the entrance surface dose (ESD) or the dose-area product (DAP) for simple radiography, the incident air kerma \( (K_{ai}) \) for
mammography, the dose-area product (DAP) for radiographic/fluoroscopic examinations, and the computed tomography dose index (CTDI) and the dose-length product (DLP) for CT examinations.

- The number of hospitals and clinics included in the survey must be large enough to reflect all variations in clinical practice in the country.

- The number of rooms included from each hospital and the selection of hospitals must be such that they reflect all types of x-ray equipment used for a certain examination type in the country.

- For the purpose of making population dose estimates, it is reasonable to assume that children receive the same mean effective dose as adults from the same type of examination.

- When measuring doses directly on patients, the sample of patients in each room/facility should be representative regarding their size (weight) and the clinical indication. Ideally doses should be measured or calculated for at least 10 and preferably 20 close-to-average size adult patients (e.g. with weights between 60–80 kg). No complication leading to higher than usual doses or no premature termination of the examination should have occurred.

- When doses are measured or calculated for a standard examination protocol, the protocol should be representative for the average “typical” procedure used in each room/facility for average sized adult patients.

- When selecting coefficients for converting practical dose measurements into effective doses, those which most closely match the exposure conditions and examination techniques for the examinations in question should be used.

- If it is not possible to derive conversion coefficients matched specifically to the exposure factors and examination techniques used in a particular country, generalised coefficients may be used.

- For those countries currently without the resources to make extensive national patient dose surveys, three sets of ‘typical’ effective doses for the ‘Top 20 Exams’ are provided in the full report. Such countries should choose the set that is derived from the DOSE DATAMED countries in which the healthcare setting most closely matches their own.

- Major sources of error in the typical effective dose estimates should be identified and the uncertainties evaluated. Important sources of uncertainty include:
  - Uncertainties in the basic dose measurements
  - Uncertainties due to variations in patient doses between hospitals and the limited sample size
  - Uncertainties in the coefficients used to convert the measured dose quantities into typical effective doses

- The new tissue weighting factors recommended in the 2007 recommendations of the ICRP [3] are likely to result in significant increases in effective doses calculated for x-ray examinations of the head and breast and significant reductions for examinations of the pelvis. Consequently, care must be taken when comparing new and old effective dose estimates, not to confuse changes due to the use of different tissue weighting factors with changes due to differences in radiology practice.

- In the future when voxel phantoms are used to derive improved organ and effective dose conversion coefficients for diagnostic medical exposures, care must be taken when comparing new and old effective dose estimates, not to confuse changes due to the use of different phantoms with changes due to differences in radiology practice.
2.5 Guidance on assessing age/sex distributions of x-ray patients

- When the objectives of making a population dose estimate include comparisons of the contribution from medical x-rays with those from other natural and man-made sources of population exposure in a country, it is important to determine the age and sex distribution of the patients undergoing important types of x-ray examination.

- Ideally, the age and sex distribution of patients undergoing those types of x-ray examination making a major contribution to collective dose should be determined in each country by a representative survey of national practice.

- Ideally, the data for each type of examination should be presented in five year age bins for each sex.

- If specific national data are unavailable, typical European age/sex data for the ‘Top 20 Exams’ and for ‘All CT, ‘All angiography’ and ‘All interventional’ procedures, based on the average distributions seen in five DOSE DATAMED countries, can be used. These are shown in Appendix 3 in the report.

2.6 Guidance on presenting the results of population dose estimates

- Clearly state the objectives of the study, the period over which data was collected and whether it covers all significant types of radiology practice in the country or not.

- Essential information to report:
  - Total annual collective effective dose from all medical x-ray imaging procedures
  - Total annual average per caput effective dose from all medical x-ray imaging procedures
  - Total annual numbers of all medical x-ray imaging procedures
  - Total annual numbers of all medical x-ray imaging procedures per 1000 population
  - Mean effective dose per procedure (averaged over all medical x-ray imaging procedures)

- Same data as above but broken down into:
  o All CT examinations
  o All angiographic examinations
  o All interventional procedures
  o All radiographic and fluoroscopic diagnostic x-ray examinations not included in above 3 categories

- List those types of examination or procedure responsible for at least 75% of the collective dose.
- Give percentage contribution to the total frequency and the total collective dose and the mean effective dose estimated for each of these examinations/procedures.

- Desirable information to report:
  - Same data as above but 4th category further divided into:
    o Radiography of the teeth
    o Radiography of the chest
    o Radiography of the limbs
    o Radiography of the spine
    o Mammography
    o Radiography/fluoroscopy of the gastro-intestinal tract
    o Radiography/fluoroscopy of the urinary tract
    o Other radiography/fluoroscopy
- Ideally, the age/sex distributions of the patients undergoing the major contributors to the collective dose should be determined from a representative sample of patients in the country.
- If this is not possible, the typical European age/sex distributions shown in Appendix 3 of the report, and based on the average distributions seen in the DOSE DATAMED countries can be referred to.

2.7 Use of electronic information stored in modern medical imaging and radiology information systems

- The need for compliance with the latest standards of the International Electrotechnical Commission (IEC) and profiles from Integrating the healthcare Enterprise (IHE) for radiation dose reporting in radiology should be included in purchasing specifications for new x-ray equipment or new radiological information systems (RIS) or Picture Archiving Systems (PACS).

- In the future the national authorities responsible for population dose surveys may gather the electronic information on patient doses from RIS/PACS systems around the country as input to any national dose databases for the establishment of diagnostic reference levels and/or for future population dose estimates.

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REFERENCES

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