# RADIATION EXPOSURE OF THE GERMAN POPULATION FROM X-RAY DIAGNOSTIC PROCEDURES

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## INTRODUCTION

The following provides an overview of the frequency of X-ray diagnostic procedures in Germany, the effective dose per examination type, the collective and per caput effective doses, trends in frequency and effective dose and the risk evaluation, based on age-dependent risk coefficients.

## FREQUENCY OF X-RAY DIAGNOSTIC PROCEDURES

During the years 1990 to 1992, an average of nearly 100 million X-ray examinations per year were carried out in West Germany with 65 million inhabitants, resulting in an average of 1,500 examinations per 1,000 inhabitants per year. The most frequent X-ray examinations were those of the extremities (302/1000), followed by chest radiography (275/1000) and dental examinations (270/1000) (1). All numbers represent complete examinations, i.e., partially consisting of several single radiographs.

More than half of the X-ray examinations are performed by practicing physicians on out-patients. Nearly 25 % of all X-ray examinations are performed by dentists and only about 20 % of all examinations on in-patients in hospitals (2).

At present no relevant data are available from the new federal states (former GDR).

## DOSE ASSESSMENT AND EVALUATION

### *Mean doses per examination type*

In order to determine the average radiation exposure of the patient for the various examination types in diagnostic radiology, more than 5000 measurements of the dose-area-product (DAP) have been performed in the years 1992-1994 by our institute and medical phycisists in other parts of Germany (3). Large variations of the DAP up to 2 orders of magnitude have been found for the same examination type due to the great variability of the patients (age, size, weight etc.) and the equipment and technique used (number of exposures, fluoroscopy time, film/screen combination, grid, kV, filter etc.).

From these data mean values of DAP were calculated for more than 30 examination types. Mean values of effective dose E were determined by using examination type-specific conversion factors obtained from Monte-Carlo simulation of the relevant examination with anthropomorphic phantoms (4). Effective doses for computed tomography (CT), mammography, dental examinations and examinations of the extremities were estimated seperately. The mean value of E vary between 0.01 mSv for dental examinations and nearly 30 mSv for CT of the abdomen.

### *Collective effective dose*

The annual collective effective dose from X-ray diagnosis for West Germany (1992) of approximately 114000 manSv was obtained by multiplication of the estimated mean E per examination type with the corresponding annual frequency and summation over all types of examination. This rather high value, equivalent to an annual per-caput value of ca. 1.8 mSv, is mainly caused by the rapid increase of angiography including interventional radiology (ca. 9% of the collective effective dose) and even more of CT, which alone is responsible for about 35% of the collective effective dose.

## TRENDS

In spite of the introduction of alternative examination techniques such as sonography, mainly for parenchymal organs, and endoscopy, mainly for esophagus, stomach and large intestine, the number of X-ray examinations has altogether increased, namely by about 10 % between 1988 and 1992. The frequency of some types of X-ray examinations is very strongly increasing, i.e computed tomography by +80 %, angiography by +54 % and mammographie by +42 %. Other examination types are markedly decreasing, i.e. mainly those of the GI-tract by -32 % (2).

Since dose intensive examinations such as CT and angiography, including in particular interventional radiology, significantly increased and their absolute number is larger than that of GI-tract examinations of decreasing frequency, the collective effective dose increased between 1988 and 1992 by about 14,000 manSv or 14 % from 100,000 manSv in 1992. The annual per caput effective dose increased by only 8.5 % during this period, since the population also increased from about 61.5 Million 1988 to 65 Million 1992.

However, the per caput value is purely computational, since it includes also those fractions of the population where no X-ray diagnosis was performed. The per caput dose may not be used for calculating individual risks. The value is only suitable for comparison of countries with different medical care systems.

## QUALITY ASSURANCE AND QUALITY CONTROL

The legal provisions concerning diagnostic radiology prescribe that all radiological equipment must be thoroughly inspected by the manufacturer and an expert prior to starting up and afterwards every 5 years (5).

Another quality assurance measure concerns the qualification of the staff. Only physicians with a special qualification in both the medical field and radiological protection are permitted to use X-rays and are eligible for establishing the indication. All other physicians as well as radiographers and auxiliary medical staff are allowed to take action only upon instruction and under supervision. However, they must also possess medical knowledge and are obliged to attend a course in radiological protection, albeit on a lower level.

Quality control of all X-ray machines is achieved with so called " constancy tests" performing phantom exposures once a month. The performance of the film-processing machines has to be controlled daily.

Important institutional panels for acceptance auditing are committees which request X-ray films of patients subjected to all types of diagnostic procedures from all physicians and hospitals and are offering advice on the improvement of image quality (1).

The Federal Medical Board of Germany has published guidelines for quality assurance describing medical and technical requirements how to conduct standard examinations of conventional radiology and computed tomography (6-7).

By all these measures it is intended to optimize the radiation exposure of the patient in diagnostic radiology.

## ASSESSMENT OF RISK AND BENEFIT

It is shown in annex C of ICRP 60 (8) that the lifetime probability of radiation induced fatal cancer varies with sex and predominantly with the age at the time of exposure. For the multiplicative risk projection model, which is prefered at present by the ICRP, the lifetime mortality risk decreases with increasing age at exposure.

If the collective risk from diagnostic radiology needs to be assessed, one must use an adequate average risk coefficient for patients to be applied to the collective dose. Since the age distribution of patients is generally very different from that of the whole population, the ICRP average risk coefficient of 5.2 % per Sv (8, Annex C) is not applicable to patients.

Based on a representative trial in West-German hospitals of 1990 the age distribution of in-patients representing about 20% of all patients was determined for all X-ray diagnostic procedures and classified for 7 types of examinations, making about 86 % of the collective effective dose of in-patients. About 45% of all in-patient examinations are performed on patients older than 65 years, further 30% on patients aged between 41 and 64 years. From the age distribution per examination type mean risk modifying factors for in-patients per examination type were derived. For the 7 examination types the risk modifying factors vary between 0.38 and 0.51. The weighted mean, finally gives a mean risk modifying factor for in-patients of 0.47. In other words: the stochastic radiation risk of in-patients is only about half of that of the population. The mean risk modifying factor for out-patients (ca. 75 % of all X-ray examinations) surely must be higher due to their younger mean age. Therfore a risk modifying factor of 0.6-0.7 for all patients of diagnostic radiology seems to be quite reasonable.

These factors take into account only the different age structure between patients and population, but no other possible differences in risk related to the different health status of patients. The mean life-expectancy of patients with severe diseases is shorter than for the average of the population in the respective age class and also shorter than the latency period. Since a considerable part of the collective dose is used in the diagnostics of such patients the overall radiation risk coefficient is reduced.

However, assessments of the radiation risk in diagnostic radiology are of no value if the risk is considered separately from disease and therapy related risks and if the benefit for the patient from the radiological examination is not taken into account. The difficulty is, of course, to quantify the benefit because it is not easily definable. The benefit could, for example, be measured in years of prolonged life expectancy, which again are difficult to assess. According to other conceptions, the benefit is identified by those portions of radiological diagnoses that lead to - positive or negative - therapeutic decisions because they are the only ones of importance for the patient. Therefore the most important question before performing an examination should be: Will I get an information which really influences the therapy of the primary disease?

When ionizing radiation is applied in medicine, the benefit to the patient should always be the main priority. This benefit is an integral part of the risk-benefit-evaluation together with the individual radiation risk for the patient and other individual risks from the examination. For the assessment of the individual radiation risk from a specific examination, the age-dependent cancer mortality risk coefficient of that patient may be used together with the average effective dose of the respective examination type. Additionally must be taken into account that the age-dependency of cancer mortality varies for different tumors and also that a very different individual presdisposition exists for the development and survival of a cancer disease, which, in part, could be of genetic origin. Added to this, for the exposure of young patients, the genetic risk must be considered which can largely be disregarded for older patients.

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