

SOURCES OF ERROR IN THE DETERMINATION OF THE RADIATION
EXPOSURE OF A POPULATION DUE TO DIAGNOSTIC X-RAY EXAMINATIONS

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In the industrialized countries the great majority of the exposure of the population to "artificial" radiation stems from the use of X-ray in medical diagnosis. Because of the presence of scattered radiation during examinations, practically every organ is subjected to a certain radiation dose. Therefore, every X-ray examination potentially involves a genetic and a somatic risk. The first one can be assessed by determining the corresponding doses to the gonads. The estimation of the somatic burden is more difficult. The yardstick usually adopted is the mean dose in the active bone marrow. By means of sophisticated phantom measurements or by means of Monte Carlo calculations, it has now become possible to state the relevant dosage figures involved in many different types of X-ray examination (s. (1) as an example). Using these figures any physician considering a particular examination can form an idea of the corresponding radiation burden.

In order to judge the radiological activity of a country from the point of view of radiation protection it is necessary to deduce useful reference values. Beside the dosage figures mentioned above these have also to take into account the frequency of examination. Already in 1958 (2) concepts of "average annual genetically significant dose" (GSD) and "average annual bone marrow dose" (BMD) were introduced. Both values have the character of an index. A comparison of index values with earlier values, or with those in other countries, enables sometime important radiation-protective conclusions to be drawn.

In 1978 the Department of Medical Radiation Physics of the University of Berne established these indices for Switzerland for the second time. The results are given in Table 1

	1971	(mrad)	1978
GSD	19		23
BMD	63		63

Table 1 : Average annual genetically significant gonadal doses and average annual bone marrow doses for the Swiss population in 1971 and 1978

Since these values are basic figures to many discussions on radiation protection it seemed to us important to check their reliability. This depends on the accuracy of the measurements of the doses to the gonads and to the bone marrow and on the reliability of the estimated number of examinations per year.

Determination of the Resultant Gonadal and Bone Marrow Doses per Examinations.

For the phantom measurements mentioned above a sophisticated measuring technique employing TL detectors was developed. An accuracy of within $\pm 4\%$ was achieved. Therefore the real difficulty was not the measurements itself, but laid in the correct interpretation.

For 17 types of radiological examinations a "standard man" phantom was irradiated with X-ray unit parameter (KV, SSD, film size) corresponding to approximately the mean value to the parameter reported to us by some 200 swiss doctors. The bone marrow dose (BMD, in mrad) per skeletal region was derived by an often laborious method from the data obtained with 55 TLD placed in the different bones. The doses derived apply, as the "adult phantom", to the irradiation parameters set in our X-ray unit. A mean bone marrow dose per examination for the parameters to which the X-ray units are actually set by the swiss doctors was determined using a computer program.

The gonadal doses, which are derived in effect from dose measurement at one point, are much more subject to variation due to anatomical position or equipment settings than the corresponding bone marrow doses. The average location of the female gonads is not well-known. It is therefore not always clear whether these lay within the radiation field in case of an examination. The resulting gonadal doses can vary thereon by orders of magnitude. For this reason we always measured the ovaries dose in the three different locations well-known from reference works.

The Statistical Determination of the Frequency of Examination

As early as 1971 for the first enquiry, a large number of doctors were questioned about their X-ray work. A detailed analysis of this data showed that it would be possible in any future enquiry, without significantly impairing accuracy, to greatly reduce the number of examination types investigated and - due to a suitable division of the doctors interviewed into various sampling strata - also the number of enquiries themselves. Letters were sent out beforehand to about 200 doctors asking them to describe their examination procedures with particular emphasis on the field setting as well as on their equipment parameters. If one is prepared to accept a statistical uncertainty of 10 %, the time expenditure involved in such an enquiry can be kept down to a reasonable amount.

Summary and Conclusions

Although it was not possible to measure directly many influential factors, their effect on the variations in the resulting average annual GSDs and BMDs can be estimated.

	GSD	BMD
Accuracy of measurement	$\pm 4\%$	$\pm 2\%$
Simulation of the field and equipment setting	$\pm 12\%$	$\pm 8\%$
Localisation of the organs	$\pm 15\%$	$\pm 5\%$

Estimated average variation in the determination of gonadal and bone marrow doses per examination: as already mentioned, the above estimations show that the determination of the gonadal doses is liable to greater error than that of the BMDs. On the other hand, the highest extrapolation error for both calculations is about 10%.

When calculating the average annual GSDs and BMDs the average must be taken of all examination types of medical practice: the relevant resulting variation lies between $\pm 10\%$ and $\pm 20\%$. It can be concluded from this that the established doses per examination can be a satisfactory reference aid for medical practitioners. If it is intended to compare figures between regions or countries, the question of standardising the measurement procedures arises. The effort and expense involved to date in various countries in determining the relevant values is probably out of proportion to their meaningfulness; for this reason we would like to conclude by making an urgent request to those interested that they exert their influence in such a way that propositions on this topic be prepared in the near future.

Bibliography

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