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LETTER TO THE EDITOR

Response to 'Patient dose measurements in radiological practices'

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Abstract
A lack of suitable dosimetric quantities for application in diagnostic radiology is noted by Dr Moores. It is concluded by Dr Moores that it is not possible to adhere to the basic principles of the International Commission on Radiation Units and Measurements (ICRU) regarding patient dosimetry in diagnostic radiology due to the extremely wide variety of quantities and units employed. The conclusion of the ICRU on similar observations, however, was that there is a need for harmonization of quantities and terminology for dosimetry in diagnostic and interventional radiology and they established a Report Committee with the aim of formulating an ICRU report on 'dosimetric procedures in diagnostic radiology'. The report produced by this committee entitled 'Patient dosimetry for x rays used in medical imaging' was accepted for publication in December 2005 and is currently at press, and may serve to improve the current situation with regard to patient dose measurement in diagnostic and interventional radiology.

I read with interest the 'letter to the editor' submitted by Dr Moores (see above) concerning patient dose measurements in radiological practices.

In the introductory part of the letter a lack of suitable dosimetric quantities for application in diagnostic radiology is addressed. It is further noted that diagnostic radiology is the largest single source of population exposure and that consequently this topic may still be relevant and of some importance to the medical physics community.

Following these statements, the International Commission on Radiation Units and Measurements (ICRU) is introduced. The role of the ICRU with respect to quantities and units for radiation and radioactivity, measurement procedures and definitions of terms and concepts is indicated. The basic principle, which underpins these (ICRU) objectives, is formulated in the letter submitted by Dr Moores as to be concerned with the establishment of common, universally accepted, standards of dose measurement, so that values may be inter-compared for all areas of medical application as well as with non-medical areas.

It is concluded in the letter submitted by Dr Moores that it is not possible to adhere to this basic principle and to perform commonly accepted dose measurements in diagnostic

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radiology due to the extreme wide variety of quantities and units employed in patient dose measurements.

Approximately 10 years ago the ICRU established a Report Committee with the aim of formulating an ICRU report on 'dosimetric procedures in diagnostic radiology'. The report produced by this committee entitled 'Patient dosimetry for x rays used in medical imaging' was accepted for publication in December 2005 and is currently at press.

The observation of a wide variety of dosimetric quantities in radiology is shared by the ICRU Report Committee and formulated as follows: 'Various quantities and terminologies have been used for the specification of dose on the central beam axis at the point where the x-ray beam enters the patient (or a phantom representing the patient). These include the exposure at skin entrance (ESE), the input radiation exposure, the entrance surface air kerma (ESAK), the entrance air kerma, the air kerma (AK), the entrance surface dose (ESD), the entrance skin dose (ESD), and the integral skin dose (ISH and EC, 1998).' The conclusion of the ICRU Report Committee, however, was that there is a need for harmonization of quantities and terminology for dosimetry in diagnostic and interventional radiology.

In the letter of Dr Moores it is stated that there appear two fundamental reasons for undertaking patient dose measurements in radiological practices, namely:

- To assess/quantify the risk of radiation 'damage' to both healthy and unhealthy (diseased) tissues.
- To establish a 'calibration' mechanism for the assessment and comparison of outcomes/performance for particular applications.

The ICRU Report Committee formulated the two purposes of patient dosimetry as follows. In medical x-ray imaging there are two fundamental reasons for measuring or estimating patient dose. Firstly, measurements provide a means for setting and checking standards of good practice, as an aid to the optimization of the radiation protection of the patient and of image quality. Secondly, estimates of the absorbed dose to tissues and organs in the patient are needed to assess radiation detriment so that radiological techniques can be justified and cases of accidental overexposure investigated.

Although the reasons for patient dosimetry formulated in the letter submitted by Dr Moores seem not too different from those formulated by the ICRU, the conclusions drawn are quite different. The ICRU defines application specific quantities for radiography, fluoroscopy and computed tomography. For radiology and fluoroscopy dosimetric quantities are defined in terms of air kerma and a clear distinction in names is made in the case of absence or presence of backscatter. For computed tomography the definitions follow those of the IEC and the EC, except that air kerma is replacing absorbed dose in air. It is already foreseen that new quantities need to be defined for CT, for instance in relation to technical developments such as multiple detector rows of increasing dimensions.

Risk-related quantities are absorbed dose in relation to deterministic effects, the mean absorbed dose in the localized region of tissue of interest, usually the skin also referred to as peak skin dose (Miller *et al* 2002). The mean absorbed dose in organs is the dosimetric quantity related to stochastic effects. Effective dose is not considered a suitable quantity in relation to stochastic effects in patients for radiology, for instance because of potential differences in health status, gender and age between a particular group of patients and the reference population for whom the International Commission of Radiological Protection (ICRP) derived the risk coefficients.

Dose-conversion coefficients for assessment of organ and tissue doses play a major role in risk assessment as well as for setting and checking standards of good practice. A 'dose conversion coefficient', c, relates a dosimetric quantity to some other quantity, i.e., the normalization quantity, which can be readily measured or calculated in the clinical situation.

In general

$$c = \frac{\text{specified dosimetric quantity}}{\text{normalization quantity}}.$$

For stochastic effects, the specified dosimetric quantity is either the mean absorbed dose in an organ, D_T, or in a specialized tissue of interest, such as glandular tissue in the breast. For deterministic effects, the specified dosimetric quantity is the absorbed dose to the more heavily irradiated regions of tissues at the surface of the body; the tissue of interest is usually the localized region of skin that lies in the primary x-ray beam and receives the highest absorbed dose for an interventional procedure. In all cases, the subscript T, for the general case, may be replaced with the specific tissue or organ of interest when it is deemed helpful, for example, D_{stomach} for the specific organ, D_G for glandular tissue in the breast, and $D_{\text{skin,local}}$ for the skin region in the primary beam receiving the highest absorbed dose. For general radiology of adults and children, the specified dosimetric quantity is the organ dose, D_T. The incident air kerma, $K_{a,i}$, the entrance surface air kerma, $K_{a,e}$, or the air kerma-area product, P_{KA}, is used as a normalization quantity.

The ICRP (1996) introduced the concept of diagnostic reference levels (DRLs) for patients. DRLs are aimed at the management of patient doses consistent with the clinical imaging information that is required. This means that in individual cases, the exceeding of DRLs may be justified in terms of a clinical requirement, for example, need for additional diagnostic information, or the unexpected difficulty of a procedure. Local performance can be checked against DRLs by periodic measurement as part of a quality assurance programme. The dosimetric quantities used for DRLs are presented in the ICRU report. In interventional radiology, a combination of various quantities is considered useful, for example, fluoroscopy time, total number of images and air kerma-area product.

A separate section of the ICRU report is devoted to measurement methods, including sections on measurement and quality assurance of dosimeters, measurement methods for specific dosimetric quantities, features of measurements on patients and measurements with physical phantoms and skin dose determination.

Methods for determining organ and tissue doses include dose measurements in physical phantoms and Monte Carlo radiation transport calculations, and are presented in a separate section.

Appendices are devoted to backscatter factors, various sources of dose conversion coefficients obtained by Monte Carlo radiation transport calculation and a PC based Monte Carlo code for calculating patient doses in medical x-ray examinations.

The ICRU report on ‘Patient dosimetry for x rays used in medical imaging’ may serve to improve the current situation with regard to patient dose measurement in diagnostic and interventional radiology.

References

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