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How to measure the dose in CT

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1. Introduction

The advent of multi-detector computed tomography scanners, offering fast image acquisition and improved image quality, has led to a significant increase in the use of CT. However, radiation dose associated with CT examinations and the risk of developing cancer due to radiation is an issue of great concern for patients, especially for children, adolescents and pregnant patients. Estimating patient radiation dose and associated risk is among the main responsibilities of medical physicists and radiologists working in CT units.

2. Methods to estimate dose from CT examinations

The amount of radiation a patient receives from CT depends upon many parameters, including scanner design and acquisition protocol. Several methods have been described in the literature on the assessment of effective and organ dose from CT examinations.

Dose Length Product (DLP)

It is known that DLP=$CTDI_v$ x (scanning length) where $CTDI_v$ is an index that quantifies the intensity of the CT radiation x-ray beam. $CTDI_v$ is measured using a 100 mm pencil ionization chamber and standard cylindrical acrylic phantoms (Figure 1). To measure $CTDI_v$ for body examinations, a phantom diameter of 32 cm is used. To measure $CTDI_v$ for head examinations, a phantom diameter of 16 cm is used. When automatic exposure control is used, CTDI estimation should be based on the average value of tube current used throughout the CT scan. DLP can be used for the estimation of the patient effective dose using body region-specific coefficients. These coefficients are published values of (Effective Dose)/DLP that can be used to convert calculated values of DAP into patient effective dose (1). Although this method is simple and quick, it provides only a rough estimation of the effective dose. Thus, if the CT scan differs from the typical scan, for example starts or finishes at different anatomical levels than a typical scan, uncertainties are introduced. Moreover, the DLP method is not scanner specific i.e. it uses a single value of for all CT scanners.

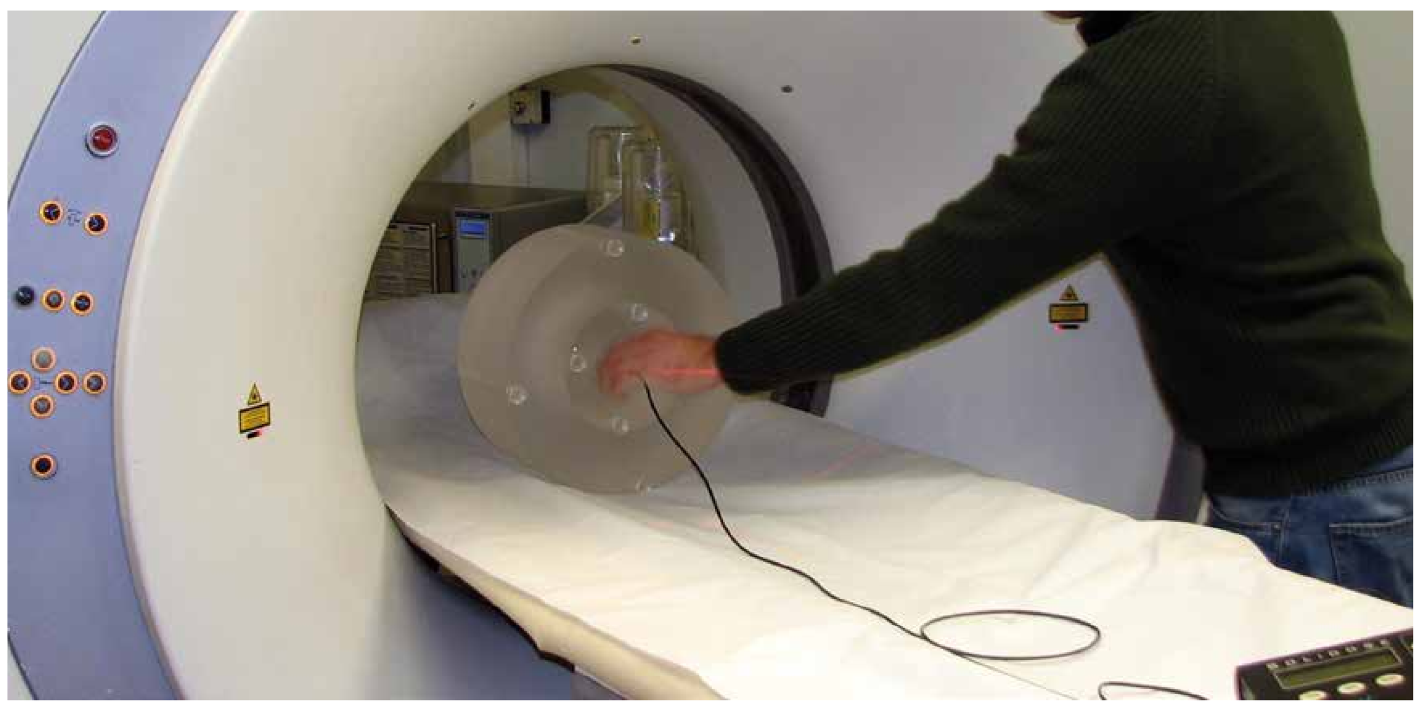

Fig. 1: CTDI measurement using a phantom and a pencil ionization chamber.

Monte Carlo Simulation

Several Monte Carlo codes have been successfully employed to assess radiation dose from CT examinations. Mathematical phantoms are used to represent the average patients during simulations. Over the last years, a shift has been observed from simple mathematical phantoms to tomographic patient models. Patient-specific and scanner-specific Monte Carlo simulations have been used to accurately estimate radiation dose from CT examinations (2). Monte Carlo software packages can be used to a) develop voxelised models based on image data from patients who underwent MDCT examinations and b) calculate patient-specific radiation doses (Figure 2). Each pixel in the image represents a radiation dose value. Black indicates the lowest dose, whereas white indicates the highest dose. Uncertainties associated with MC methods include errors related to modelling, for example the effect of patient table attenuation should be taken into consideration otherwise errors in effective dose of about 5% will result. Monte Carlo simulation is a powerful tool that allows accurate estimation of patient dose. However, it is time consuming and operators must have the required information to simulate CT scanners and expertise to perform the experiments.

To calculate patient effective and organ doses, normalised dose data based on simulation measurements published in the literature can also be used (3,4). Moreover, commercially available software packages have been developed to calculate organ and effective dose based on pretabulated data derived from simulated CT exposure on phantoms.

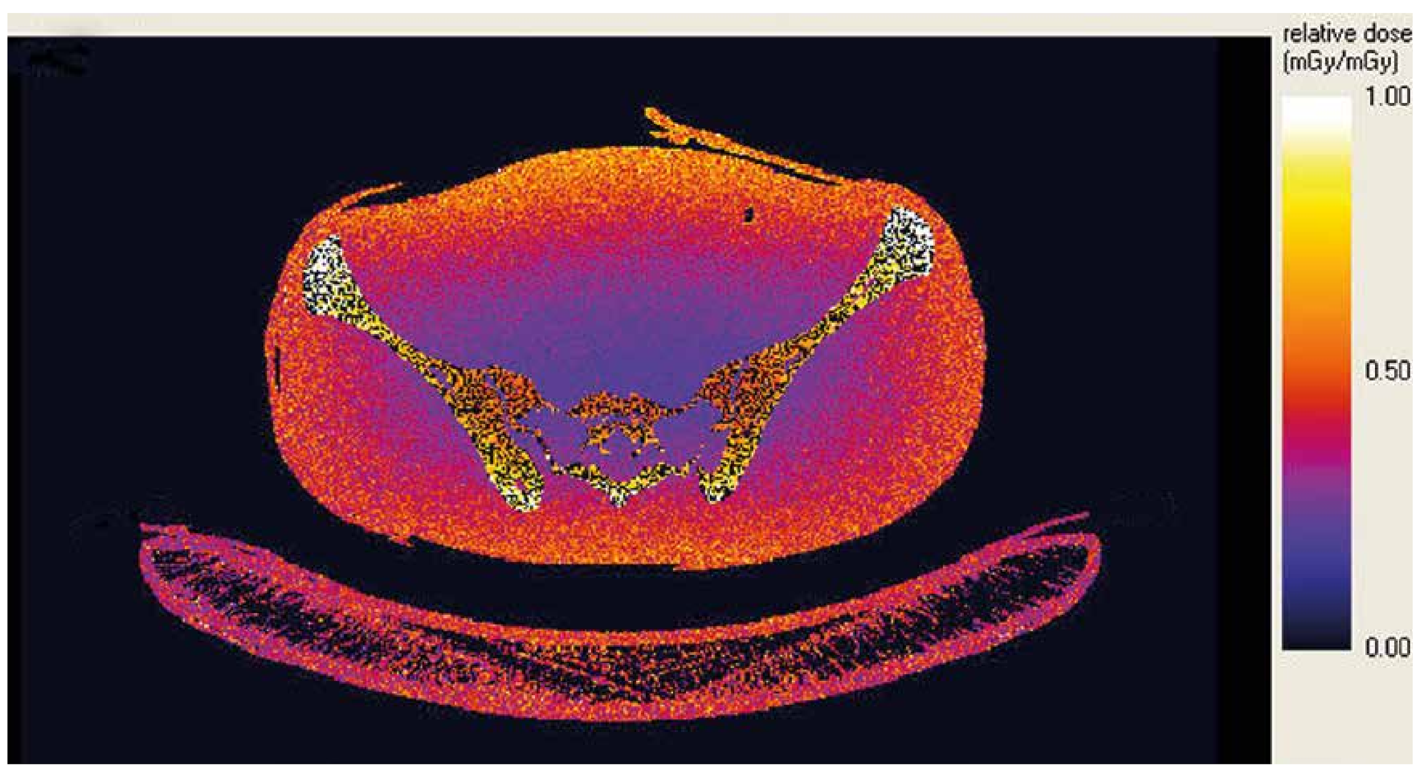

Fig. 2: User interface of a Monte Carlo software package that can be used to calculate patient-specific radiation doses. Each pixel in the image represents a radiation dose value. Black indicates the lowest dose, whereas white indicates the highest dose.

Physical anthropomorphic phantoms and thermoluminescence dosimetry

Physical anthropomorphic phantoms representing adult male and female patients or paediatric patients and thermoluminescent dosimeters (TLDs) have been used to measure patient doses from CT. These phantoms are usually cut into sections, which contain holes for the position of dosimeters. Accurate calibration of TLDs is very important before dose measurements. Instrumentation of thermoluminescence dosimetry includes an annealing oven to anneal all crystals before use and a TLD reader system to read the dosimeters. Verification of Monte Carlo simulation results is usually performed using physical anthropomorphic phantoms and TLDs.

References

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