

Radiation Quantities and Units

כולנו מתעסקים יום יום עם אמצעי דימות שונים החושפים את הנבדק לקרינה מייננת.

בשנים האחרונות השימוש ב-CT עולה באופן חד ביותר בבתי החולים ובקהילה. מה אנחנו באמת

יודעים לגבי נזקי הקרינה של מכשיר זה? להלן מספר עובדות למחשבה...

בברכה,

ד"ר אלי קונן

The unique radiation exposure conditions that exist in [computed tomography \(CT\)](#), during which thin slices of the patient are irradiated by a narrow, fan-shaped beam of x rays emitted from the x-ray tube during its rotation around the patient, have required the use of special dosimetry techniques to characterize the radiation doses to patients and to monitor CT system performance. This section describes the basic dosimetry quantities used to indicate patient doses during CT.

Absorbed dose - The fundamental quantity for describing the effects of radiation in a tissue or organ is the absorbed dose. Absorbed dose is the energy deposited in a small volume of matter (tissue) by the radiation beam passing through the matter divided by the mass of the matter. Absorbed dose is thus measured in terms of energy deposited per unit mass of material. Absorbed dose is measured in joules/kilogram, and a quantity of 1 joule/kilogram has the special unit of gray (Gy) in the International System of quantities and units. (In terms of the older system of radiation quantities and units previously used,

1 Gy equals 100 rad, or 1mGy equals 0.1 rad

Equivalent dose - The biological effects of an absorbed dose of a given magnitude are dependent on the type of radiation delivering the energy (i.e., whether the radiation is from x rays, gamma rays, electrons (beta rays), alpha particles, neutrons, or other particulate radiation) and the amount of radiation absorbed. This variation in effect is due to the differences in the manner in which the different types of radiation interact with tissue.

The variation in the magnitude of the biological effects due to different types of radiation is described by the "radiation weighting factor" for the specific radiation type. The radiation weighting factor is a dimensionless constant, the value of which depends on the type of radiation. Thus the absorbed dose (in Gy) averaged over an entire organ and multiplied by a dimensionless factor, the radiation weighting factor, gives the equivalent dose. The unit for the quantity equivalent dose is the sievert (Sv). Thus, the relation is

equivalent dose (in Sv) = absorbed dose (in Gy) x radiation weighting factor

In the older system of units, equivalent dose was described by the unit rem and 1 Sv equals 100 rem or 1 mSv equals 0.1 rem.

For x rays of the energy encountered in CT, the radiation weighting factor is equal to 1.0.

Thus, for CT, the absorbed dose in a tissue, in Gy, is equal to the equivalent dose in Sv.

Effective dose - The risk of cancer induction from an equivalent dose depends on the organ receiving the dose. A method is required to permit comparison of the risks when different organs are irradiated. The quantity "effective dose" is used for this purpose. The effective dose is calculated by determining the equivalent dose to each organ irradiated and then multiplying this equivalent dose by a tissue-specific weighting factor for each organ or tissue type. This tissue- or organ-specific weighting factor accounts for the variations in the

risk of cancer induction or other adverse effects for the specific organ. These products of equivalent dose and tissue weighting factor are then summed over all the irradiated organs to calculate the "effective dose." (Note that effective dose is a calculated, not measured quantity.) The effective dose is, by definition, an estimate of the uniform, whole-body equivalent dose that would produce the same level of risk for adverse effects that results from the non-uniform partial body irradiation. The unit for the effective dose is also the sievert (Sv).

What are the Radiation Risks from CT?

Risk Estimates

In the field of radiation protection, it is commonly assumed that the risk for adverse health effects from cancer is proportional to the amount of radiation dose absorbed and the amount of dose depends on the [type of x-ray examination](#). A CT examination with an effective dose of [10 millisieverts](#) (abbreviated mSv; 1 mSv = 1 mGy in the case of x rays.) may be associated with an increase in the possibility of fatal cancer of approximately 1 chance in 2000. This increase in the possibility of a fatal cancer from radiation can be compared to the natural incidence of fatal cancer in the U.S. population, about 1 chance in 5. In other words, for any one person the risk of radiation-induced cancer is much smaller than the natural risk of cancer. Nevertheless, this small increase in radiation-associated cancer risk for an individual can become a public health concern if large numbers of the population undergo increased numbers of CT screening procedures of uncertain benefit.

It must be noted that there is uncertainty regarding the risk estimates for low levels of radiation exposure as commonly experienced in diagnostic radiology procedures. There are some that question whether there is adequate evidence for a risk of cancer induction at low doses. However, this position has not been adopted by most authoritative bodies in the radiation protection and medical arenas.

Radiation Dose

The effective doses from diagnostic CT procedures are typically estimated to be in the range of 1 to 10 mSv. This range is not much less than the lowest doses of 5 to 20 mSv received by some of the Japanese survivors of the atomic bombs. These survivors, who are estimated to have experienced doses only slightly larger than those encountered in CT, have

demonstrated a small but increased radiation-related excess relative risk for [cancer mortality](#).

Radiation dose from CT procedures varies from patient to patient. A particular radiation dose will depend on the size of the body part examined, the type of procedure, and the type of CT equipment and its operation. Typical values cited for radiation dose should be considered as estimates that cannot be precisely associated with any individual patient, examination, or type of CT system. The actual dose from a procedure could be two or three times larger or smaller than the estimates. Facilities performing "screening" procedures may adjust the radiation dose used to levels less (by factors such as 1/2 to 1/5 for so called "low dose CT scans") than those typically used for diagnostic CT procedures. However, no comprehensive data is available to permit estimation of the extent of this practice and reducing the dose can have an adverse impact on the image quality produced. Such reduced image quality may be acceptable in certain imaging applications.

The quantity most relevant for assessing the risk of cancer detriment from a CT procedure is the ["effective dose"](#) . Effective dose is evaluated in units of millisieverts (abbreviated mSv; 1 mSv = 1 mGy in the case of x rays.) Using the concept of effective dose allows comparison of the risk estimates associated with partial or whole-body radiation exposures. This quantity also incorporates the different radiation sensitivities of the various organs in the body.

Estimates of the effective dose from a diagnostic CT procedure can vary by a factor of 10 or more depending on the type of CT procedure, patient size and the CT system and its operating technique. A list of representative diagnostic procedures and associated doses are given in Table 1 that is adapted from a report of the [European Commission](#).

Table I. - Radiation Dose Comparison

| Diagnostic Procedure | Typical Effective Dose (mSv)¹ | Number of Chest X rays (PA film) for Equivalent Effective Dose² | Time Period for Equivalent Effective Dose from Natural Background Radiation³ |
|------------------------------|---|---|--|
| Chest x ray (PA film) | 0.02 | 1 | 2.4 days |
| Skull x ray | 0.07 | 4 | 8.5 days |
| Lumbar spine | 1.3 | 65 | 158 days |
| I.V. urogram | 2.5 | 125 | 304 days |
| Upper G.I. exam | 3.0 | 150 | 1.0 year |
| Barium enema | 7.0 | 350 | 2.3 years |
| CT head | 2.0 | 100 | 243 days |
| CT abdomen | 10.0 | 500 | 3.3 years |

1. Effective dose in millisieverts (mSv).

2. Based on the assumption of an average "effective dose" from chest x ray (PA film) of 0.02 mSv.

3. Based on the assumption of an average "effective dose" from natural background radiation of 3 mSv per year in the United States



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