Al-Mustaqbal University
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Radiological Techniques
Department

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Radiation Protection Course

Lecturer

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Chapter Nine

CT Dose Metrics and Calculation

Introduction: CT (computed tomography) dose metrics and calculations refer to the methods and values used to quantify and assess the amount of radiation exposure a patient receives during a CT scan. CT imaging involves the use of X-rays to create detailed cross-sectional images of the body. While CT scans are valuable for diagnostic purposes, it's important to manage and monitor the radiation dose to minimize potential risks to the patient.

CT Dose Index (CTDI): CTDI is a standard metric used to quantify the radiation dose delivered during a CT scan. It is expressed in units of milligray (mGy) and is calculated based on the average radiation dose in a specific region of the body, and is typically measured in two ways: (CTDIvol) and (CTDIw) .

Volume CTDI (CTDIvol): CTDIvol is an extension of CTDI that accounts for the entire volume of tissue irradiated during the scan. It takes into consideration the thickness of the imaging slices and provides a more comprehensive assessment of dose.

CTDIvol represents the average radiation dose in a defined phantom (a standardized model that simulates the human body) and is measured over a specific length of the body or section of the scan. This measurement takes into account both the intensity and duration of the radiation exposure during the CT scan.

The CTDIvol is calculated using the following formula:

$$CTDIvol = \frac{1}{n}\sum_{i=1}^{n} CTDI_{air,i}$$

Where:

n is the number of measurement points along the scan length.

$CTDI_{air,i}$ is the CTDI measured at each point in a cylindrical phantom filled with air.

CTDIw (Weighted CTDI): CTDIw takes into account the different tissue densities encountered in the body. It uses a weighted average of the CTDI values in different regions of the phantom, reflecting the attenuation characteristics of various tissues.

The formula for CTDIw is as follows:

$$CTDIw = \frac{1}{3} CTDI_{head} + \frac{2}{3} CTDI_{body}$$

Where:
$CTDI_{head}$ is the CTDI measured in the head region of the phantom.
$CTDI_{body}$ is the CTDI measured in the body region of the phantom.

$$CTDI_{w} = CTDI_{vol} \times \sum WTi$$

Where the sum is taken over all tissues I that are irradiated during the scan.

Assume we have a CT scan with the following parameters:

1. **CTDIvol (Volumetric CTDI):** 15 mGy
2. **Tissue Weighting Factors (*WTi*):** Let's consider two tissues - soft tissue (WTsoft) with a weighting factor of 0.012 and lung tissue (WTlung) with a weighting factor of 0.002.

The formula for CTDIw is $CTDIw = CTDIvol \times \sum(WTi)$, where $\sum(WTi)$ is the sum of the tissue weighting factors.
Let's calculate the Weighted CTDI:
$CTDIw = CTDIvol \times \sum(WTi)$ =15 mGy× $CTDIw$=15mGy×($WTsoft+WTlung$)
=15 mGy×(0.012+0.002)$CTDIw$=15mGy×(0.012+0.002)
=15 mGy×0.014$CTDIw$=15mGy×0.014
=0.21 mGy$CTDIw$=0.21mGy

The Dose-Length Product (DLP): is a radiological quantity used in computed tomography (CT) imaging to quantify the total radiation exposure a patient receives during a CT examination. It takes into account both the radiation dose (measured in milligrays, mGy) and the length of the irradiated volume (measured in centimeters, cm). DLP is a valuable parameter for estimating the overall radiation risk associated with a CT scan.

Calculation of DLP:

- The formula for calculating DLP is given by: ***DLP=CTDIvol*×Scan Length** where *CTDIvol* is the Computed Tomography Dose Index for the specific section of the patient or phantom, and Scan Length is the length of the irradiated volume along the z-axis (in centimeters).
- **Effective Dose (ED)**: The effective dose is a calculated estimate of the overall radiation risk associated with a particular CT scan. It is expressed in units of millisieverts (mSv). The concept of effective dose takes into account not only the dose to a specific organ or tissue but also the varying sensitivities of different tissues to radiation.

The effective dose is calculated using a conversion factor known as the tissue weighting factor (WT). This factor reflects the relative radiosensitivity of different tissues and organs.

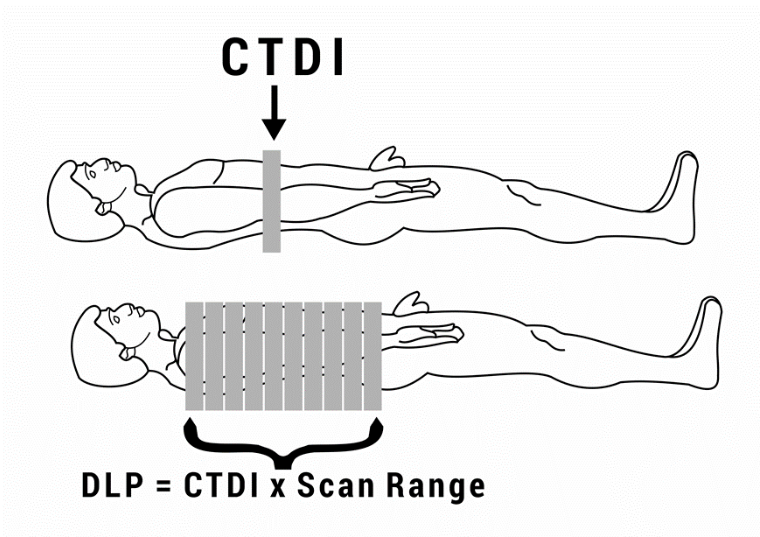
- The formula for calculating the effective dose (ED) is given by: $ED = DLP \times \sum_i W_{Ti}$
- where:

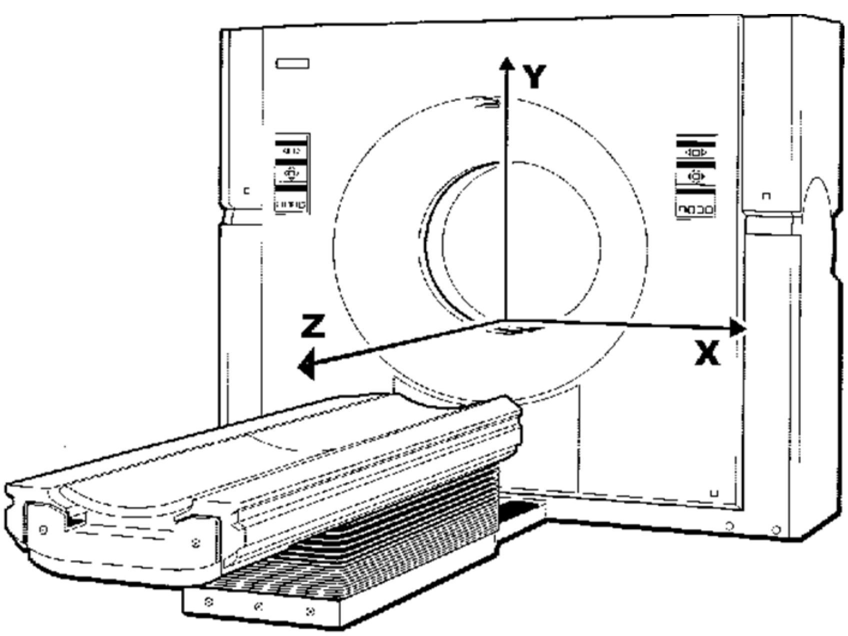
ED is the effective dose (in mSv).

DLP is the dose-length product (in mGy·cm).

WTi is the tissue weighting factor for each specific organ or tissue.

- The sum in the formula includes contributions from all organs or tissues irradiated during the CT scan.





Factors affecting dose in CT

Several factors can affect the radiation dose delivered during a Computed Tomography (CT) scan. It's important to note that efforts are continually made in the field of radiology to minimize radiation exposure while maintaining diagnostic image quality. Here are some key factors influencing the dose in CT:

Patient Size and Anatomy:

Larger patients generally require higher radiation doses to penetrate through the increased tissue thickness and obtain diagnostic images.

Patient anatomy also plays a role; for example, imaging body parts with more bone may require higher doses.

Scan Protocol:

The specific imaging protocol chosen by the radiologist or technician can significantly impact the dose. Protocols may vary depending on the clinical question and body part being imaged.

Adjustments in tube current (mA), tube voltage (kVp), and scan time affect dose.

Scan Length:

The extent of the body part being scanned affects the dose. Longer scan lengths result in higher doses.

Tube Current Modulation:

Automatic exposure control adjusts the tube current based on the thickness and density of the scanned anatomy, optimizing dose for each region.

Scan Frequency:

The number and frequency of CT scans a patient undergoes over time can contribute to the cumulative radiation dose. Clinicians aim to minimize unnecessary repeat scans.

Radiation Shielding:

Proper use of lead aprons and other shielding devices can protect areas of the body that are not being imaged from unnecessary radiation exposure.

Pediatric Considerations:

Children are more sensitive to radiation, so specific pediatric protocols are often used to reduce doses while maintaining diagnostic image quality.

Radiation Dose Monitoring and Reporting:

Healthcare facilities implement dose monitoring programs to track and optimize radiation doses. This helps ensure that doses are kept as low as reasonably achievable (ALARA) without compromising diagnostic accuracy.