# OPTIMISATION OF MEDICAL EXPOSURES IN COMPUTED TOMOGRAPHY

The Computed Tomography (CT) equipment has become a ubiquitous diagnostic modality in a hospital, owing to its versatility and practicality. CT combines a series of X-ray images taken around the body and uses computer processing to create cross-sectional images (slices) of the human body. 3D image creation in CT is based on variable absorption of X-rays by different tissues and the principle of working is similar to creation of 2D image in radiography but X-ray images taken around the human body in CT are responsible for more radiation dose to patient as compared to radiography. Today, many CT systems are capable of imaging multiple slices simultaneously. Such advances allow relatively larger volume of anatomy to be imaged in relatively less time. Over the years, there has been great advancements in the CT technology such as improvements in speed and image quality. The image reconstruction techniques have contributed significantly in reduction of radiation dose to the patient as compared to erstwhile CT scanners.

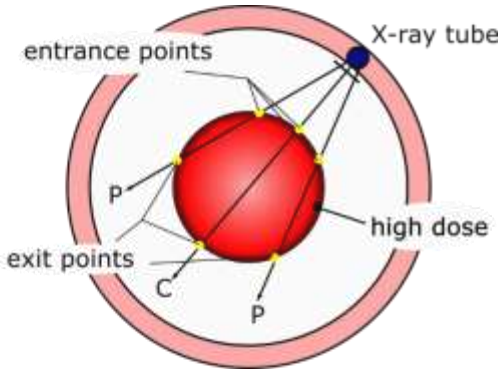
Radiation exposure to patient (i.e. medical exposure) while undergoing CT examination is intentional and for the direct benefit of the patient. For such medical exposure, specific dose limits are not applicable but it is governed by principles of radiation protection, i.e. Justification for medical procedure and Optimisation of protection in medical exposure. The responsibility for the justification of the use of a particular procedure lies with the relevant Radiological Medical Practitioners (e.g. radiologist, interventional cardiologist, etc.). Optimisation of medical exposure to patient does not necessarily imply low radiation exposures, rather exposures concomitant with precise diagnostic value. Patient receiving lower medical exposure could lead to compromise in image quality and jeopardize the purpose of imaging. On the other hand, higher exposures only for the sake of sharp images with no additional diagnostic value should be discouraged.

## DOSE OPTIMISATION PARAMETERS

CT scan protocols for dose optimisation are often created with imaging parameters set to minimize imaging dose with acceptable image quality for diagnostic purpose. Optimisation of dose to the patient undergoing medical diagnostic CT depends on patient alignment and many other physical parameters such as scanning mode (axial/helical), tube current, tube voltage, AEC, table feed/speed, gantry rotation, scan length, detector configuration, reconstruction techniques, etc. For establishing optimisation process, basic understanding of these parameter and their subsequent implementation plays paramount role and therefore an attempt is made in this article to elaborate parameters contributing for dose optimisation.

1) **PATIENT CENTERING:** One of the important attributes for dose optimisation is patient centering. If body of patient miscentered in CT gantry, increase in the surface dose and image noise is observed. In order to understand reasons for the above, one need to understand the physics of bow tie filter and Automatic Exposure Control (AEC) of CT scanners.

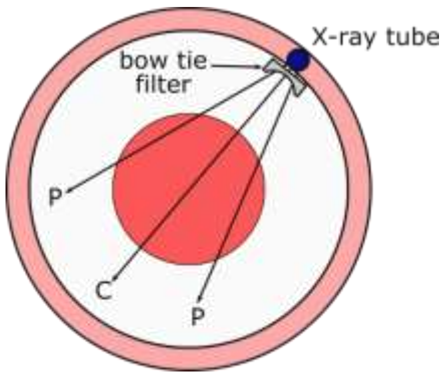
**Bow tie filter:** CT uses fan beam of X-rays. Consider the below image, the uniform distribution of X-ray beam would cause radiation hot spot near entrance points and exit points or at the patient's body periphery during entire CT scan. However, the distribution needs to be uniform with respect to circular/elliptical shape of the patient in order to get good image quality with radiation dose reduction to the patient. The intensity at periphery of the beam need to be compensated using filter.




X-ray fan beam with flat distribution

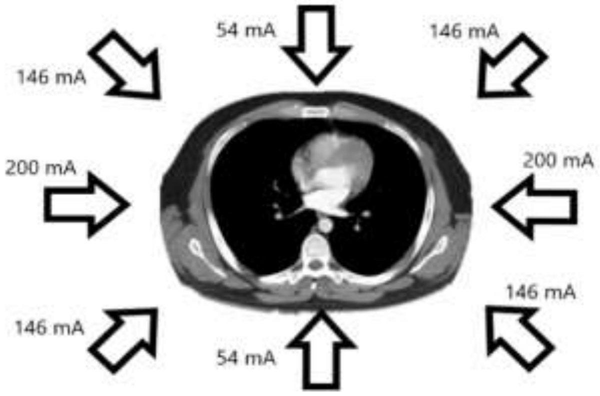
In CT scanners, a bow tie shaped filter is used to shape and reduces the intensity of the incident X-ray beam in the periphery of the X-ray field where the attenuation path through the patient is generally thinner. This tends to equalize or flatten the X-ray intensity that reaches the detector array.

Bow tie filter presumes that the centre of the body region being scanned coincides or approximates with the gantry isocentre. Off centering of patient disturbs up beam bow tie filter function and lead to asymmetric distribution of noise and artifacts.



X-ray fan beam distribution with bow tie filter

**Automatic Exposure Control (AEC):** Consider below scan CT slice, the lateral and oblique X-ray beam need higher current due to thicker body part as compared to AP/PA beam. Uniform current value throughout the patient body scan would not provide constant image contrast. Therefore, the X-ray tube current value need to be modulated based on the size and attenuation characteristics of the body part to be scanned. Such technique is called Automatic Exposure Control (AEC). AEC technique employs tube current based on beam attenuation data obtained from the localizer radiographs and/or 'on the fly' during initial tube rotation around the patient. If the patient set at elevated couch, CT assumes patient is larger and uses higher exposure parameters. Patient receives higher dose and image quality also decreases. Similarly, if patient is set too low in gantry, CT assumes patient is smaller and calculate insufficient exposure parameters and gets poor image quality. Both the cases jeopardize the intent of optimisation.

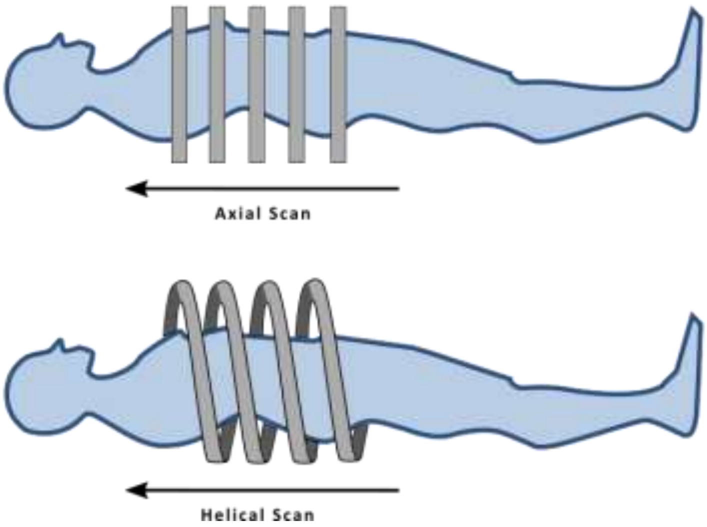


Tube current modulation

The technologist and radiologist should be aware about the impacts due to miscentering of patient. There are situations wherein patient centering is not feasible due to certain patient related factors such as:

- Patient who cannot lie flat.
- Those who cannot elevate their arms sufficient above their heads (such patients are more likely to be centered below the gantry isocentre).
- Those who have spinal curvature abnormalities or need to elevate their head or chest relative to caudal portion of their body.
- Patients on life support systems or those referred for emergent clinical indications may also be difficult to centre optimally.

2) **SCANNING MODE:** Axial (or sequential) and helical (or spiral) are commonly available scan modes with the CT scanners. Axial or sequential mode, as name suggest performs series of axial or sequential CT scans results in a number of circular X-ray tube trajectories around the patient, requiring the X-ray tube to be turned OFF between each axial scan. Whereas in helical or spiral mode, X-ray tube is continuously ON while table moves at constant speed. The speed of CT image acquisition increases with the introduction of helical scanning in the late 1980s, and another large increase in scanner speed occurred when multi-slice CT scanners became available in the late 1990s. Most of the body examinations are performed with helical scanning mode while axial mode is still used commonly for Head CT, diffused lung diseases



(for expiratory/prone images) and CT guided procedures used to confirm needle position. Axial scan of head with gantry tilt has been a remarkable technique to reduce radiation dose to eye.

3) **TUBE CURRENT:** Tube current represents number of electrons flowing through the X-ray tube per unit time. It is measured in milliampere (mA). The quantity of X-rays is directly proportional to the product of tube current and exposure time (mAs). Dose to the patient is directly proportional to tube current. For example, 50% mA reduction results in 50% dose reduction. Tube current is most commonly adjusted scan parameter to increase or decrease the radiation dose. In most of the CT scanners, the tube current is adjusted using AEC techniques. AEC technique enable automatic adjustment of tube current according to the size and attenuation characteristics of the body part being scanned and achieve constant CT image quality with lower radiation dose.

4) **TUBE POTENTIAL:** It represent potential difference between cathode and anode, which drives electron across the X-ray tube. The unit of tube potential is kilo voltage (kV). The dose changes by nearly the square of kV change, provided all other scan parameters are held constant. Most CT scanners require user to specify a fixed kV value for CT protocol. Generally, smaller patients (particularly children) should be scanned at low kV (70-100 kV). Similarly, CT angiography or contrast enhanced CT can be performed at low kV (80-100 kV). The kV reduction improves image contrast while reducing the radiation dose but avoid low kV in large size patients or patient with large shoulders undergoing neck CT or CT angiography, which will result in poor image quality. One need to bear in mind that inappropriate reduction in kV increases image noise.

5) **GANTRY ROTATION TIME:** It represents the time needed for X-ray tube and detector array to complete one rotation. Faster gantry rotation implies faster scanning. Faster gantry rotation is preferred for children, moving or non-cooperative patients and moving organs.

6) **SCAN LENGTH:** After taking the scout image, the scan length must be restricted to what is essentially prescribed to image. Dose to the patient increases with increase in scan length. It is commonly observed that CT abdomen have extra images acquired beyond the area of interest. Limit scan to intended anatomical area can cut dose by significant amount. It is imperative to minimise overlap when scanning of two contiguous body regions. Radiologist may discuss with technologist for establishing scan length protocols for the optimisation of dose.

7) **SLICE THICKNESS & INTERVAL:** Slice thickness (mm) represents nominal width of reconstructed image in the longitudinal axis. Slice interval (mm) represents distance between two consecutive reconstructed images. Choice of slice thickness depends on the clinical indications and body region being scanned. Thin slice implies higher noise, higher contrast and less partial volume artifacts. Thin slice scan is suitable for high contrast and subtle abnormalities. Whereas thicker slice implies less noise and more artifacts. Thick slice scan is suitable for low contrast and large patients.

8) **RECONSTRUCTION KERNEL:** It represents a feature of the scanner which influences the smoothness and sharpness of images in transverse plane. Analytical image reconstruction (such as FBP- filtered back projection) and iterative image reconstruction are generally available reconstruction kernels with most of CT scanners. FBP technique is fast way to reconstruct CT image. Its image reconstruction algorithm back project the sinogram to the 2D image domain. However, at low doses, the image reconstruction is more prone to increase noise and artifacts. Iterative image reconstructions are newer techniques. It incorporates better mathematical CT model and iterates to reduce inconsistencies in the image reconstruction. Even at low doses, it can reconstruct lower noise and low artifacts images. Since it is iterative process, it is generally slower than FBP. It is important to note

that iterative technique do not reduce dose by itself but rather allow user to reduce dose compared to FBP.

**WAY AHEAD:**

Knowledge of scan parameters can help in designing appropriate and optimal CT protocols for implementation. At the beginning, the protocol is set into two age groups viz. children and adult. Children should be scanned at lower doses than adult. In second step, the protocol is passed to body region specific sections viz. chest CT can be done at lower doses compared to abdomen CT. The third step follows the clinical indications e.g., kidney stones can be imaged with low dose.


Indication groups to establish optimised CT protocols

For establishing optimised CT protocols, radiological medical practitioner (radiologist, interventional cardiologist, etc.), medical radiological technologist and medical physicist of institute should discuss jointly and apply judiciously the protocols and all built-in radiation protection features that the CT machine provides.

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