The ATCM Model — A Simplified Introduction

Digital Workshop 20 October 2026

Reference Organ Absorbed and Effective Dose Coefficients for Computed Tomographic Examinations

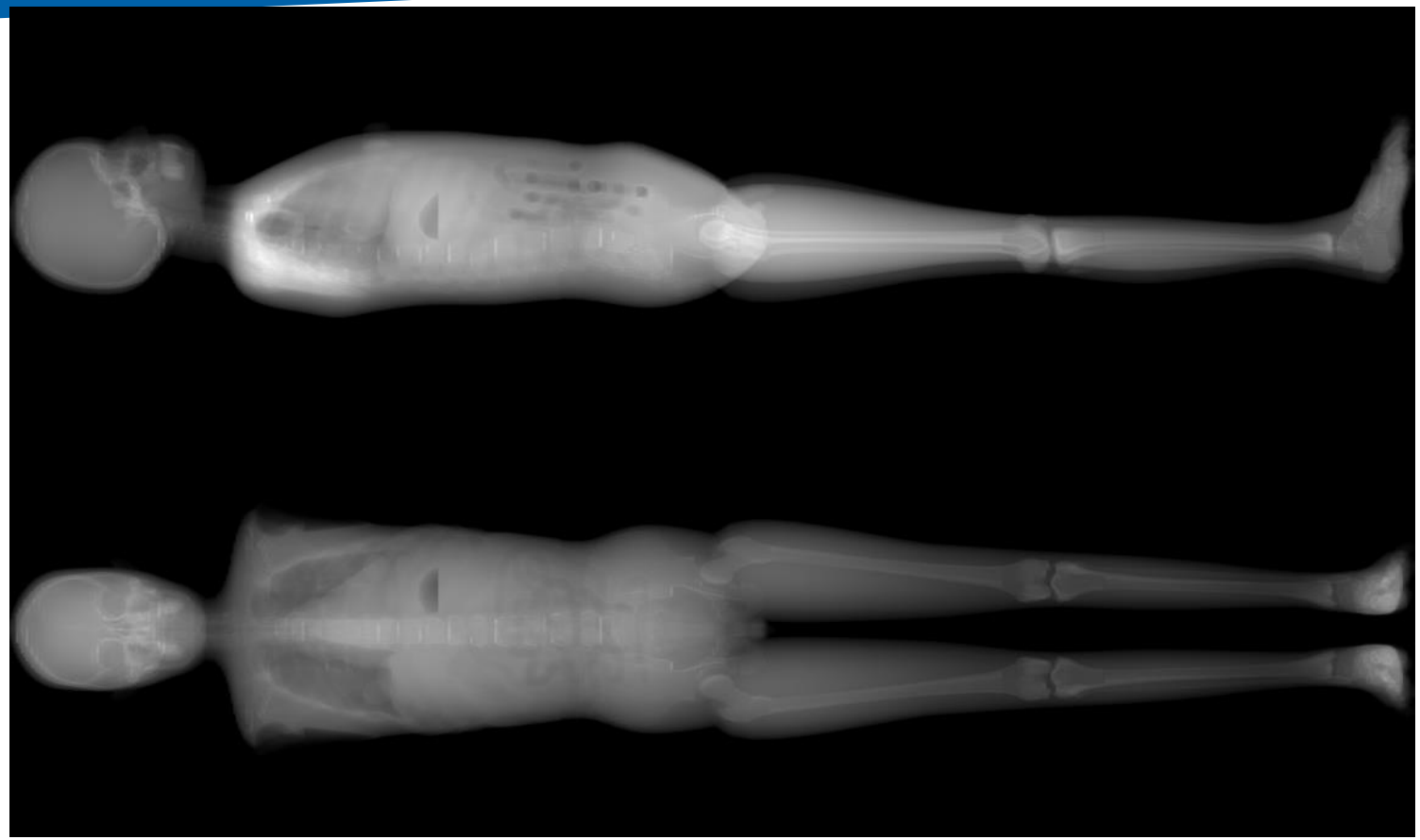


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ICRP

What is automatic tube current modulation (ATCM)?

- Attenuation of human body is not uniform
- Strongest attenuation leads to highest detector noise and thus is determining tube current for desired image quality
- Unnecessary high dose at regions with low attenuation

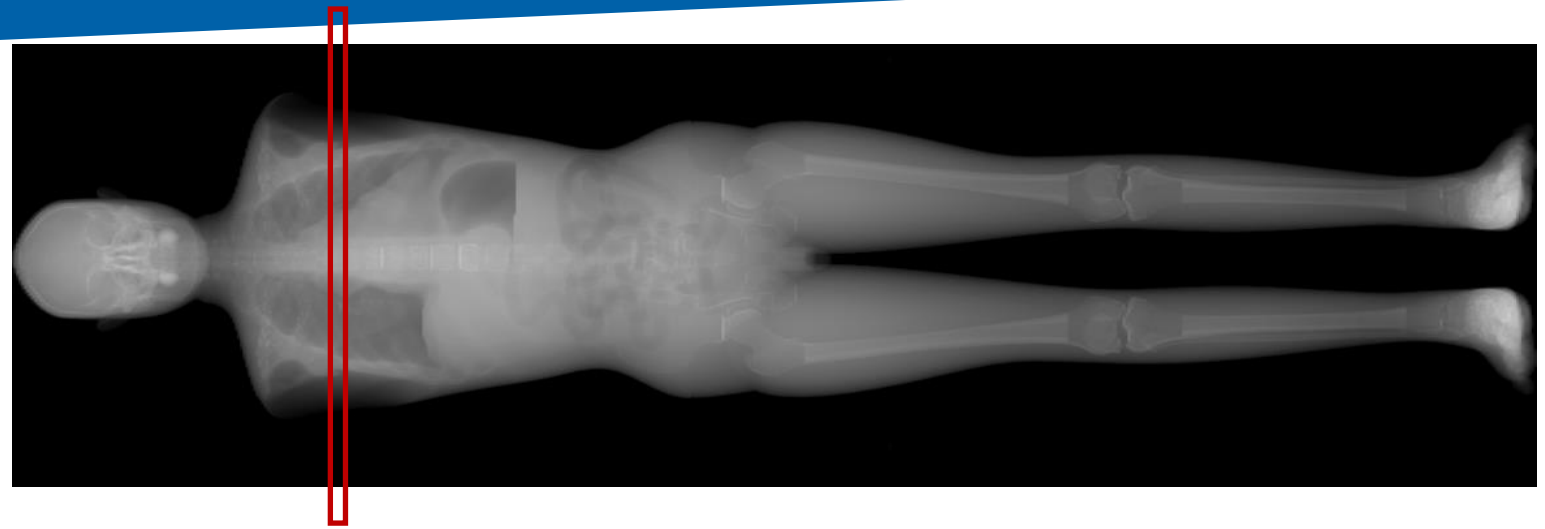


⇨ Modulation of tube current during scan

Types of ATCM

- **Longitudinal or z-modulation**
  Variation of tube current along body main axis
- **Angular modulation**
  Variation of tube current in transverse plane
- **Angular + longitudinal modulation**
  Supported (and standard) by most modern CT-scanner
- **Organ-based modulation**
  Additional reduction of exposure particularly for superficial organs like breast or eyes

General ATCM concept



- **Determine a representative attenuation $A(\varphi, z)$ for each tube position**
- **Tube current $I(\varphi, z)$ is then given by: $I(\varphi, z) \propto A^q(\varphi, z)$**
- **q: modulation strength**
  - q = 1: constant noise in all directions
  - q = 0.5: minimal overall noise

Challenges

Actual implementation of manufacturers is not only more sophisticated, but also proprietary. Some examples:

- **Upper and lower limits of tube current**
- **Upper and lower limits on gradient of tube current**
- **Different modulation strengths for different protocols/patient sizes**
- **Different modulation strengths for angular and longitudinal modulation**

ICRP concept

- **Provided CT dose coefficients should be independent of CT manufacturers and model**
- **Preferentially physics-based approach**

+ Sinusoidal angular tube current modulation

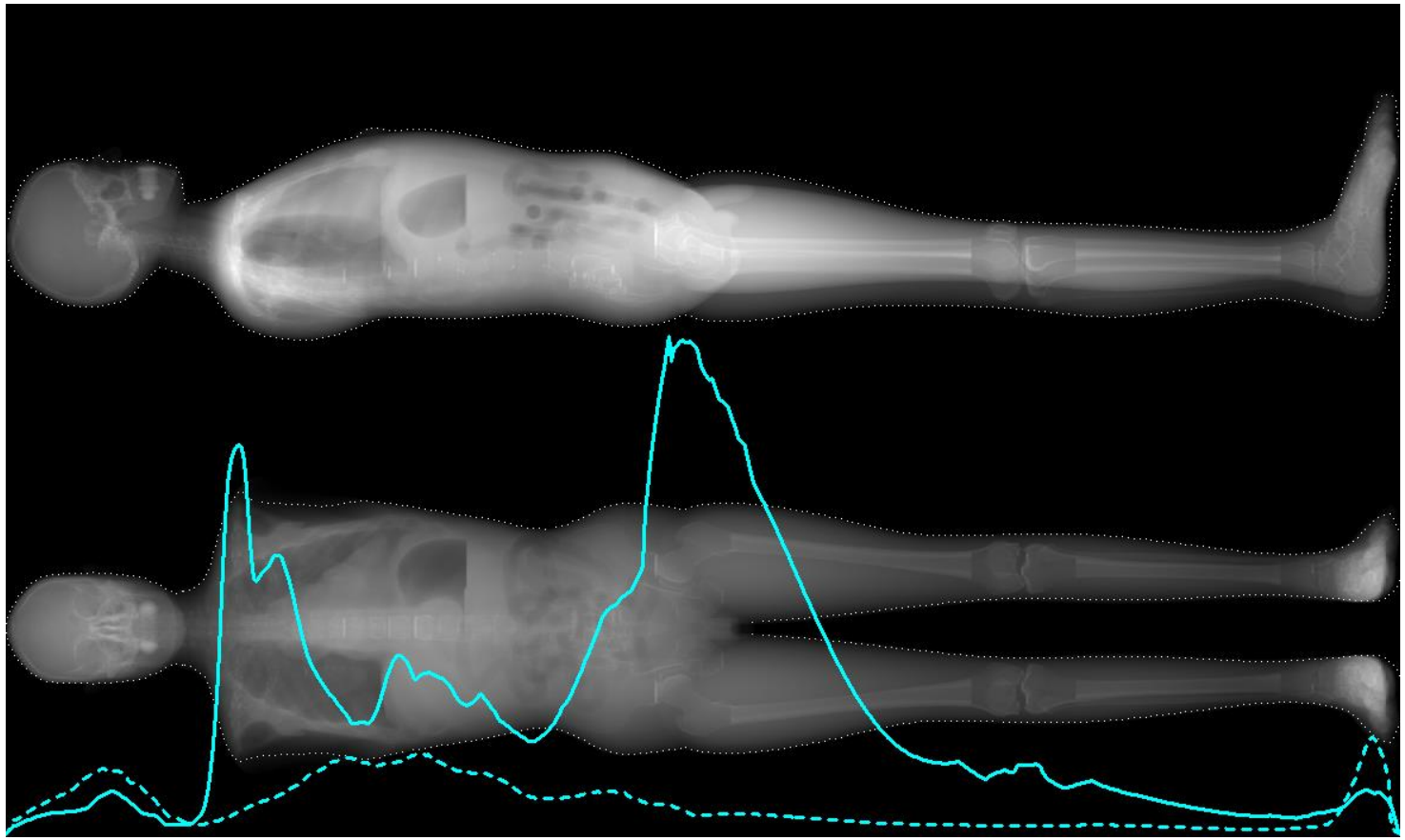
+ Based on localizer radiographs in AP and RLAT direction

+ Maximal attenuation along body profile used as representative attenuation

+ Modulation strength: $q = 0.75$

$$I_i(\varphi) \propto \left(A_i^{\mathrm{AP}}\right)^{0.75} + \frac{\left(A_i^{\mathrm{RLAT}}\right)^{0.75} - \left(A_i^{\mathrm{AP}}\right)^{0.75}}{2}(1 + \cos 2\varphi) \qquad (\varphi = 0: \mathrm{RLAT})$$

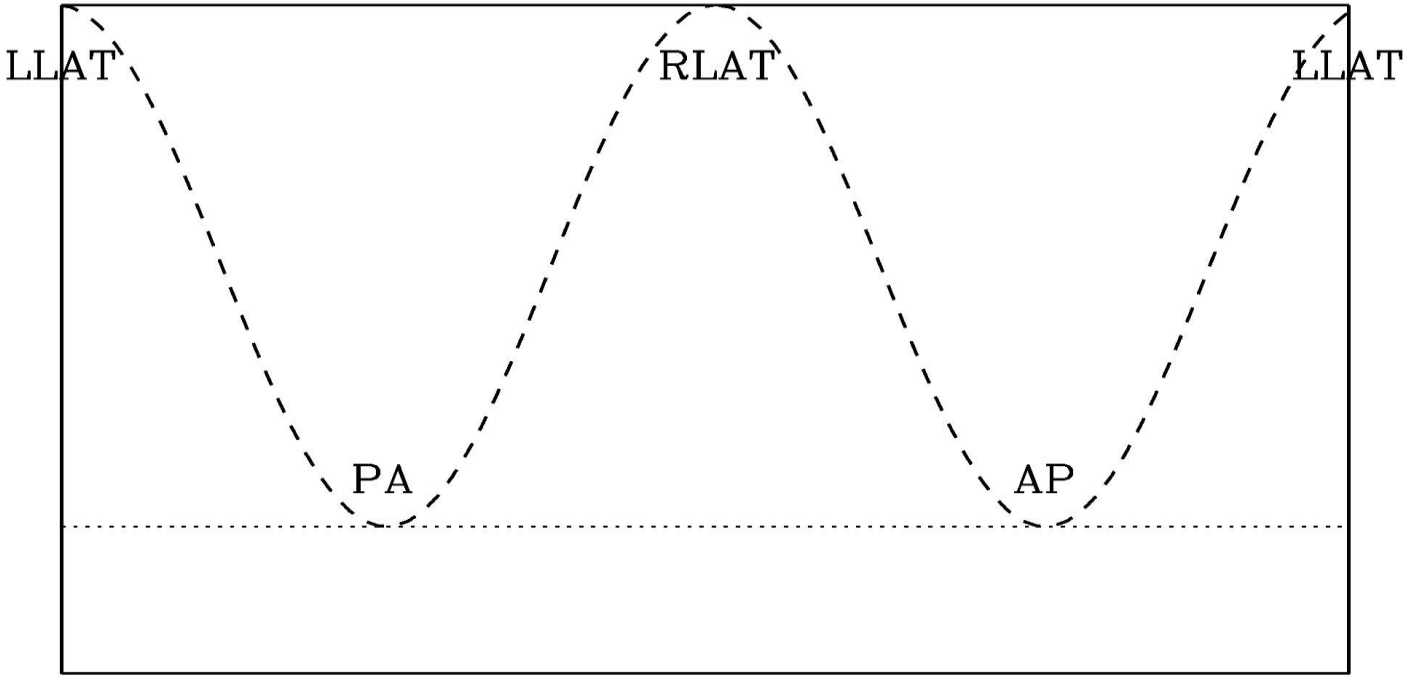
Localizer radiographs for 15-yr old male



Resulting tube current for RLAT (solid) and AP (dashed) directions

Computation of dose coefficients

- Simulating axial CT slices
- Division of calculations for sinusoidal ATCM in two components:
  - fixed tube current (0th order)
  - sinusoidal with zero current in AP/PA and maximum in lateral (1st order)



Combined dose coefficients for ATCM

- **Axial slice *i***

$$\left(D_{\mathrm{org}}/\mathrm{CTDI_w}\right)_i = \frac{\left(D_{\mathrm{org}}/\mathrm{CTDI_w}\right)_{i,0} + \zeta_i \left(D_{\mathrm{org}}/\mathrm{CTDI_w}\right)_{i,1}}{1+\zeta_i} \quad \textbf{with} \quad \zeta_i = \frac{1}{2}\left(\frac{\left(A_i^{\mathrm{RLAT}}\right)^q}{\left(A_i^{\mathrm{AP}}\right)^q} - 1\right)$$

- **Protocol (multiple slices)**

$$\left(D_{\mathrm{org}}/\mathrm{CTDI_{vol}}\right)_{P_A} = \frac{\sum_{i=n}^{m} \tau_i \left(D_{\mathrm{org}}/\mathrm{CTDI_w}\right)_i}{\sum_{i=n}^{m} \tau_i} (n-m+1) \quad \textbf{with} \quad \tau_i \sim \left(A_i^{\mathrm{AP}}\right)^q$$



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