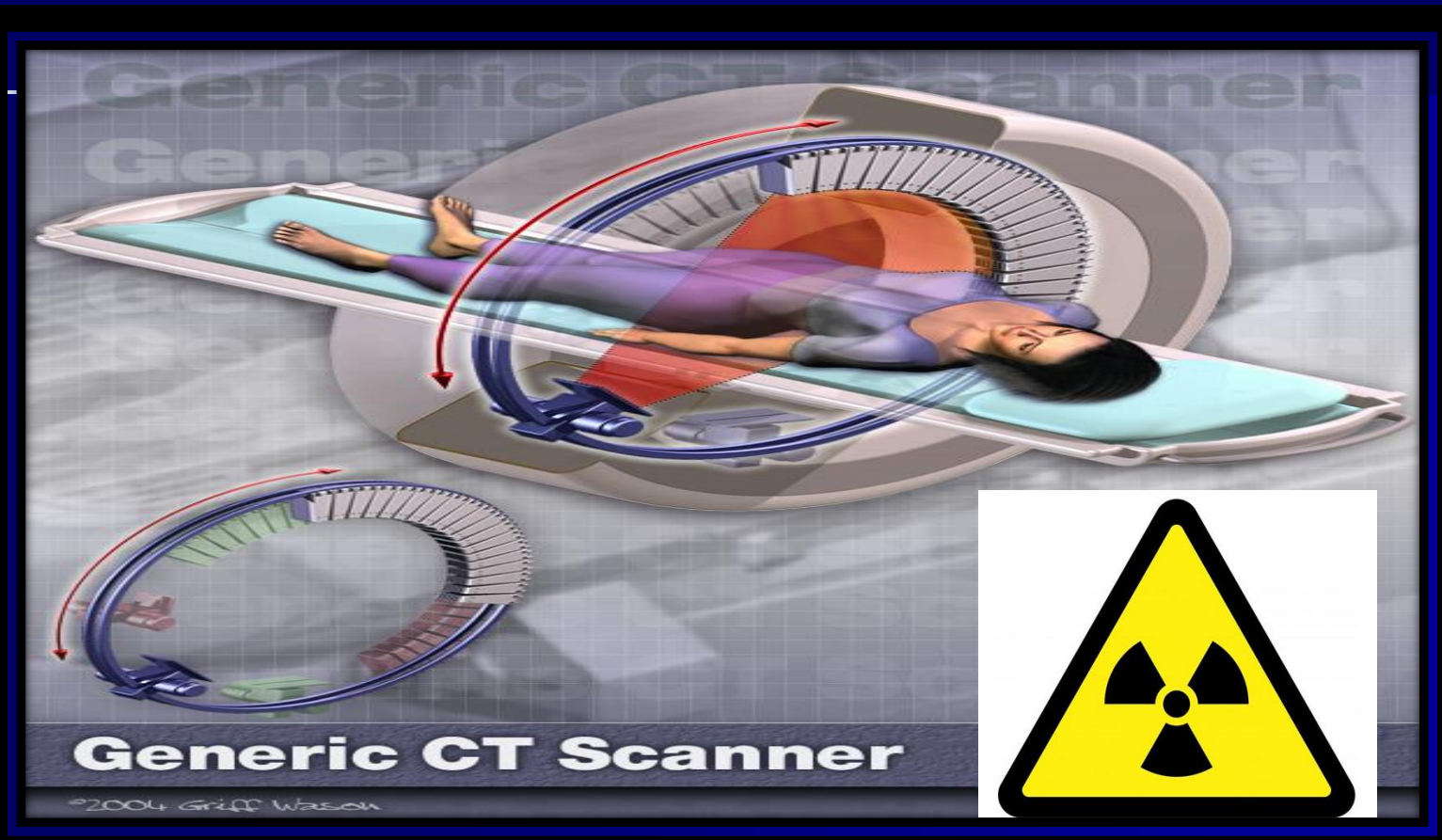
بسم الله الرحمن الرحيم

Radiation Protection in CT Scan



Presentation: **Mohammad Akbarnejad**
(M.Sc., Radiobiology & Radiation protection)

Facts About CT…

- Facts about CT…
  - 69 million CT examinations per year for all ages in USA in 2007.
  - Approximately 10% growth rate per year
  - 7 million CT examinations per year in children
  - 40-50 % increase in paediatric CT from 2005/06.
  - Up to 31% of paediatric body CT examinations are multiphase in some reports

Facts About CT…

- The frequency of CT examinations is evenly distributed at all ages:
  - 33% are performed in children under age of 10

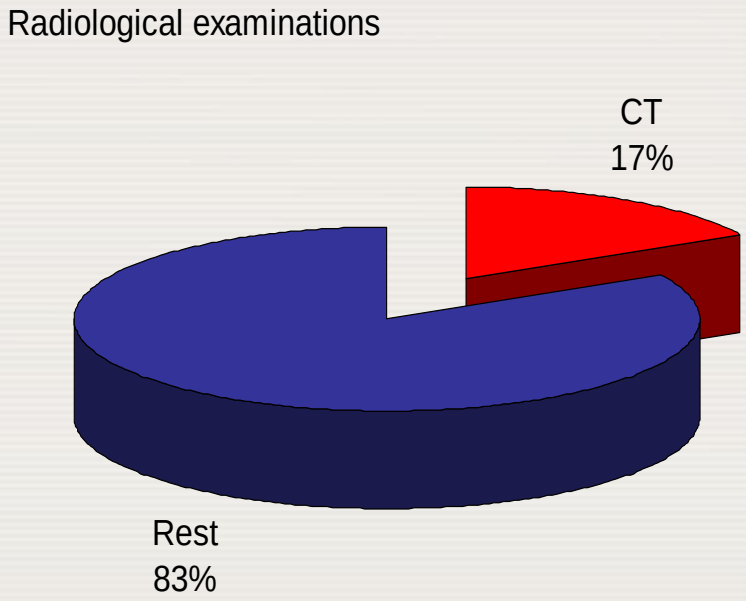
- Repeated examination:
  - 30% of adults and children have three or more CT scans

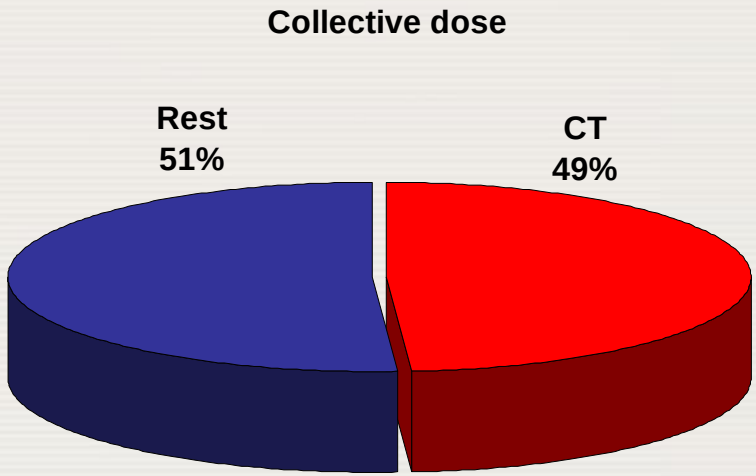
METTLER, F.A., et al., J. Radiol. Prot. ***20*** *4 (2000) 353-359*

CT as a Dose Contributor

CT examinations:

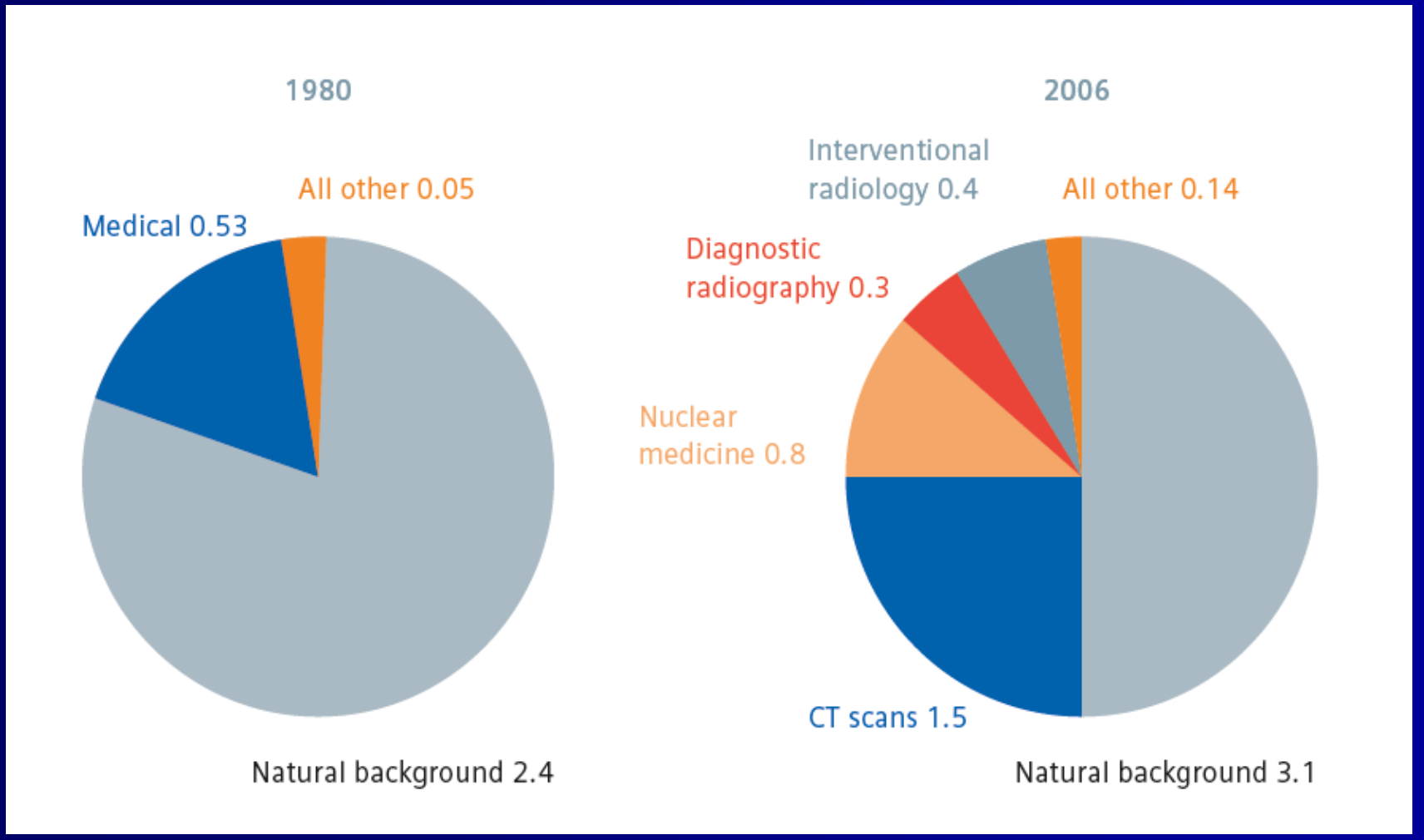
- *comprise only 17% of all radiological examinations, but...*
- *contributes to 49% of the effective dose all radiological examinations*





Mettler et al. Helath Phys 2008, 95:502-7

Distribution and development of annual per capita dose in the population from 1980 to 2006 in the USA as an mSv to development in industrialized countries example for the



Amount of Radiation Resulting From CT

Examination	Effective Dose (mSv)	Chest X-ray Equivalents
3-view ankle radiography	0.0015	0.07
2-view chest radiography	0.02	1
Radionuclide cystogram	0.18	9
Flouroscopic cystogram	~0.33	~16
Radionuclide bone scan	~5	~250
Brain CT	2	100
Chest CT	up to 3	up to 150
Abdominal CT	up to 5	up to 250

Frush D, et al, CT and Radiation Safety: Content for Community Radiologists
www.imagegently.org

اصول فیزیکی وتکنیکی CT

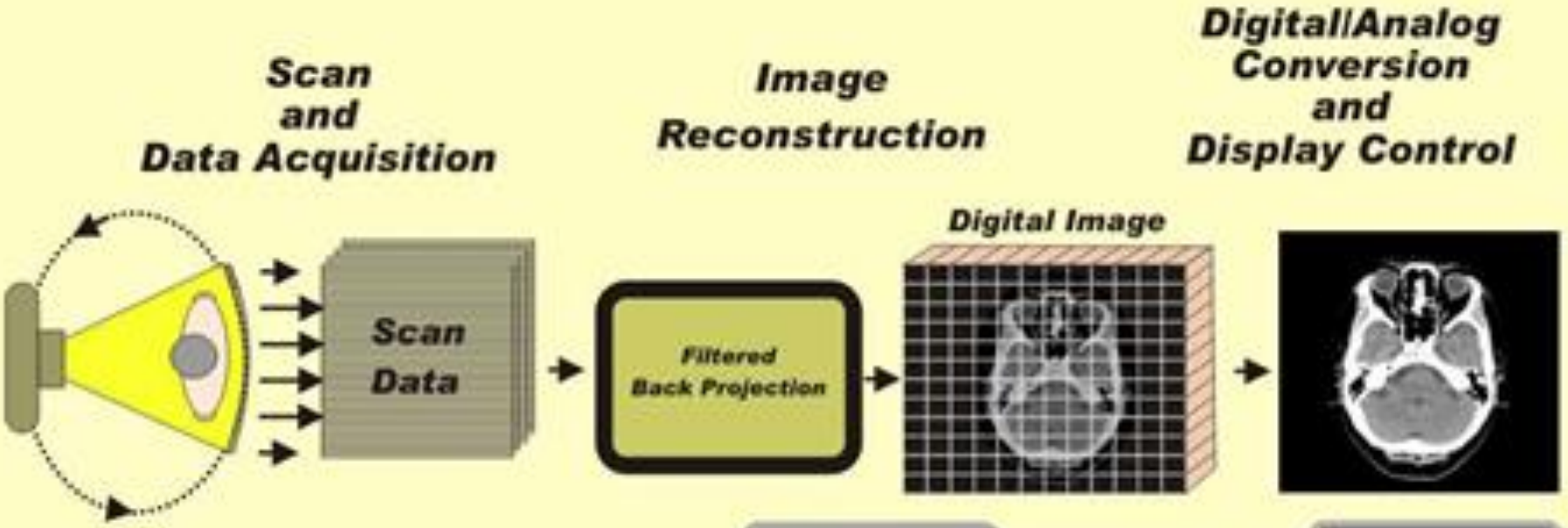
❖ **براساس ۳ اصل استوار است:**

۱- سبک خاص جمع آوری اطلاعات (Data acquisition)

۲- سبک خاص پردازش اطلاعات (Data processing)

۳- سبک خاص نمایش/ذخیره سازی/ مستند سازی تصاویر(Display /storage/ document)

The Three Phases of CT Image Formation



KV

MA

Time

Pitch

Beam Wid.

Slice Th.

FOV

Matrix

Filter

Window
Width

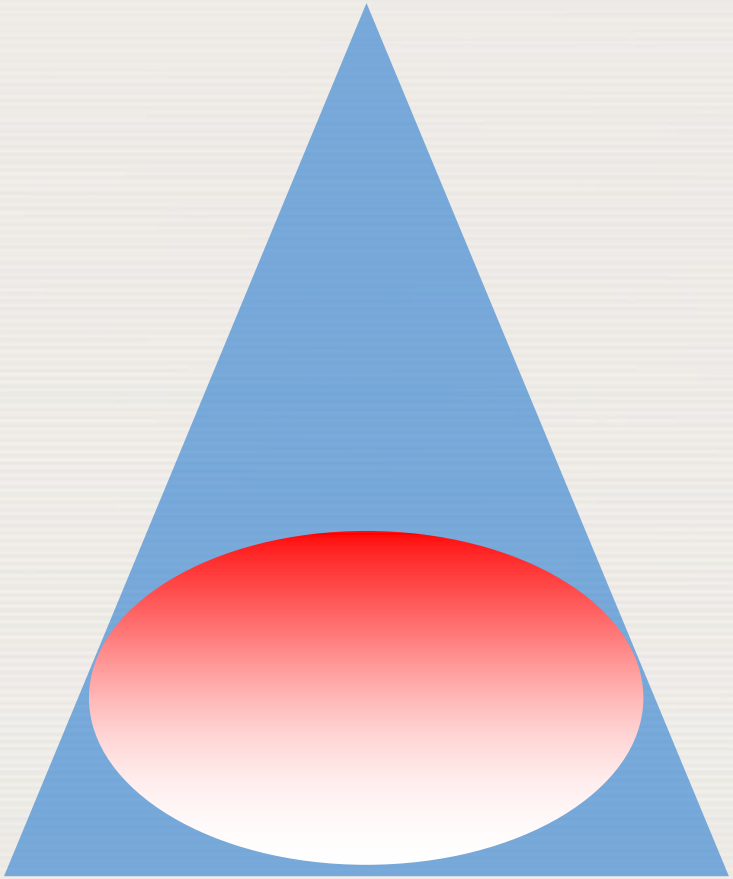
Window
Level

Zoom

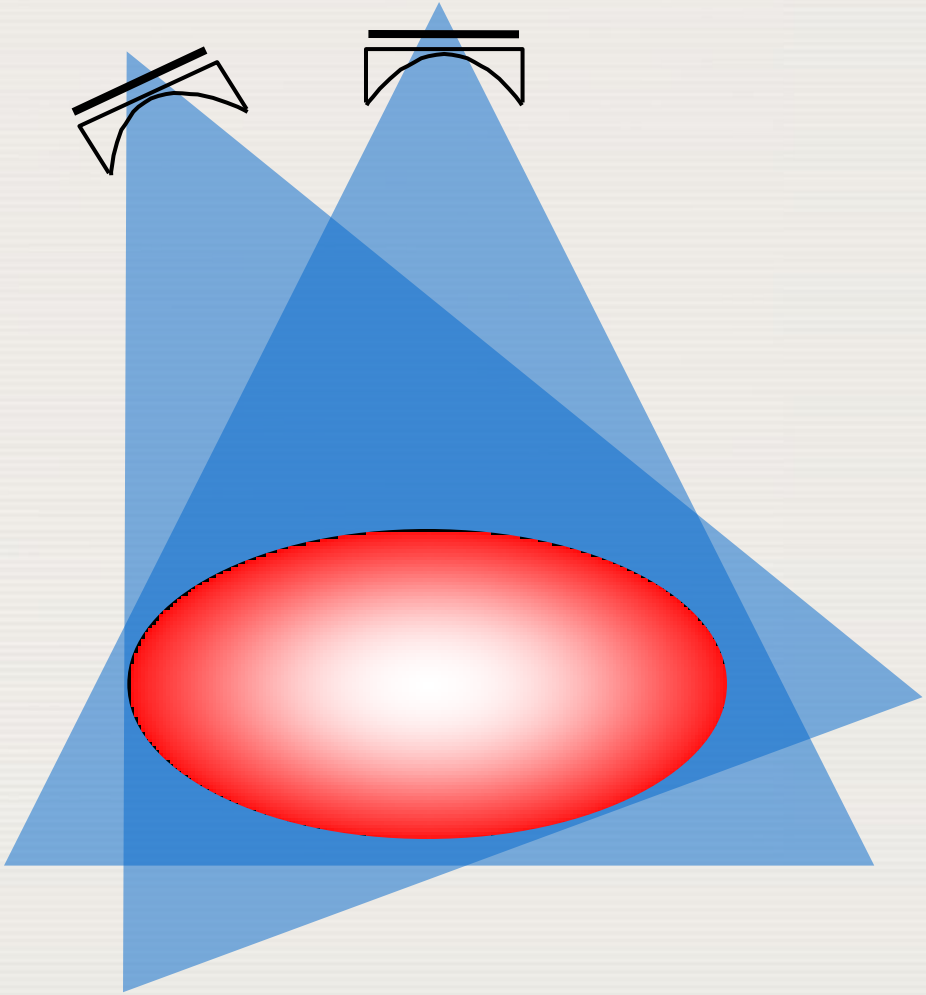
Major Protocol Factors

Why is this so?

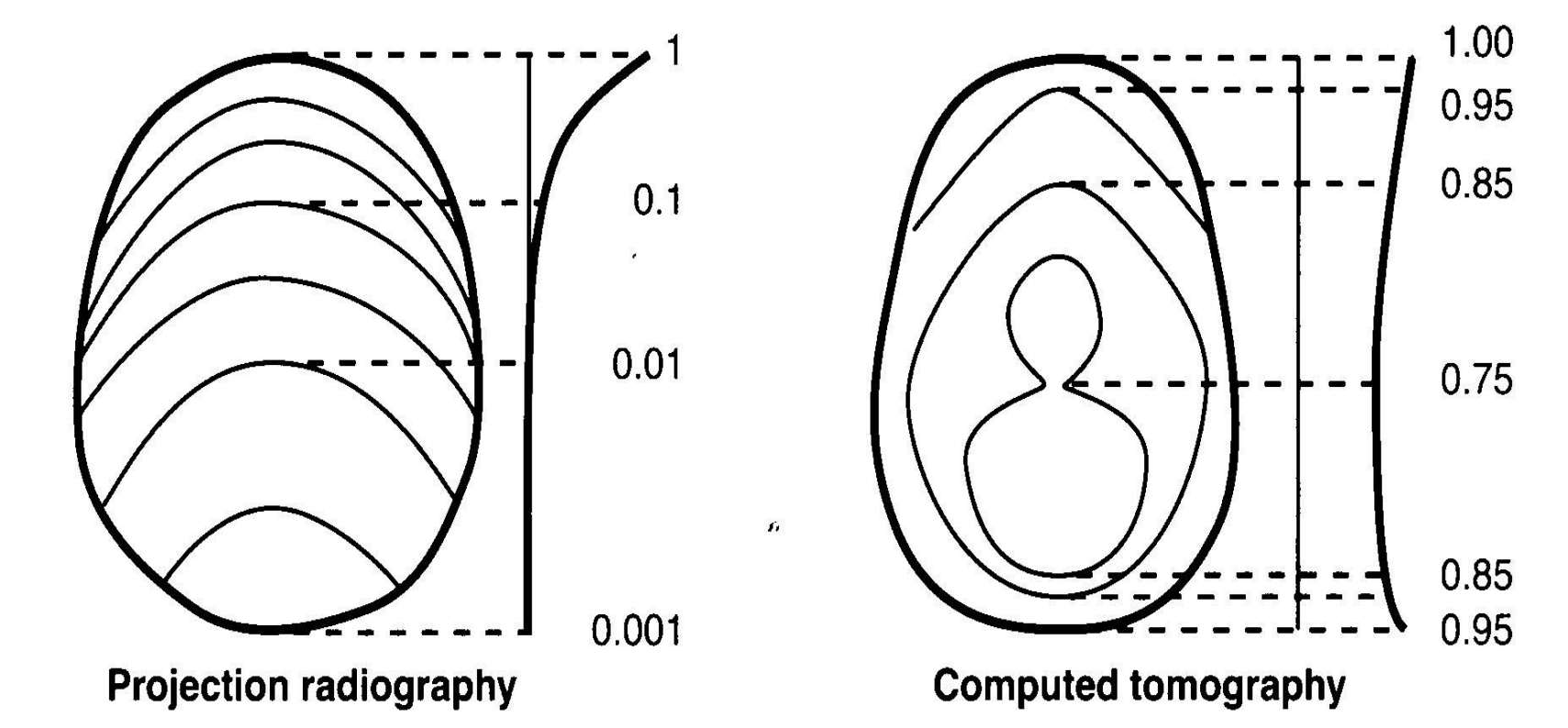
Radiography



CT



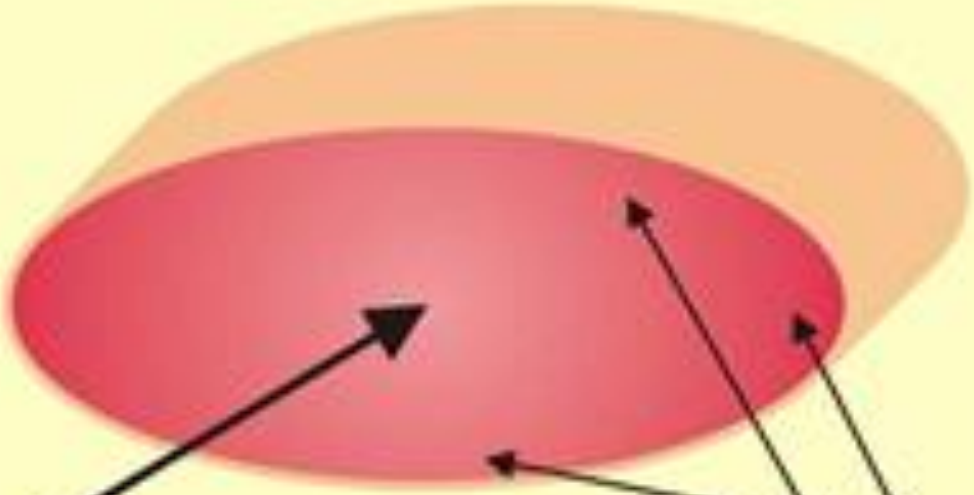
Why is this so?



Dose distribution*

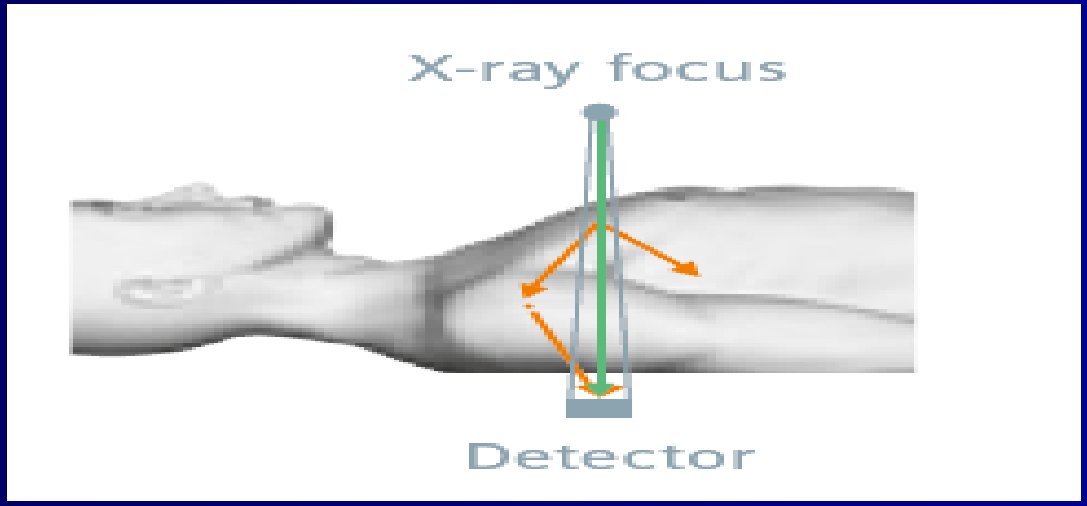
*in relative units

Distribution of Radiation Dose Within the Image Slice



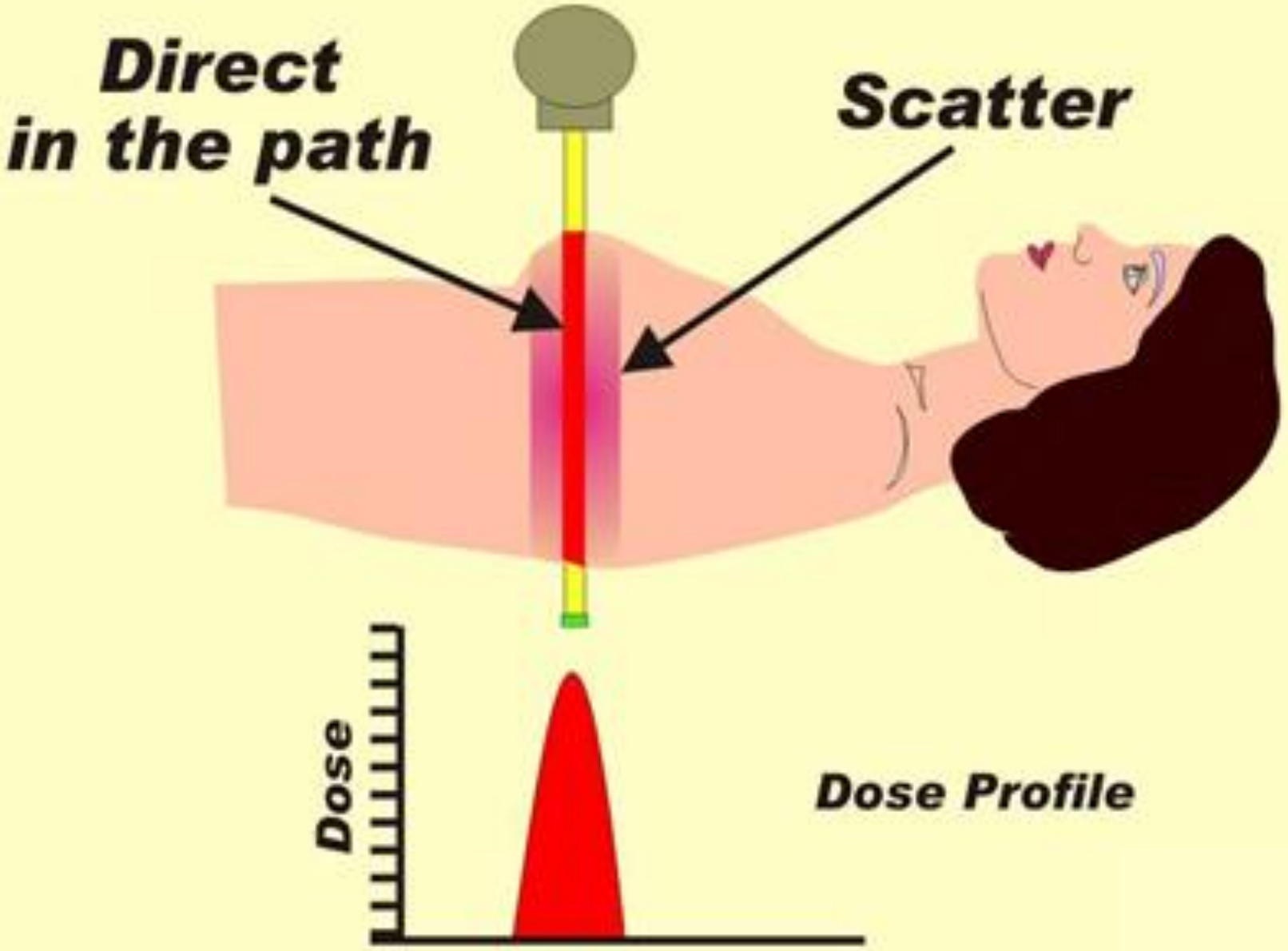
Generally lower dose at the center.

Dose in other areas will vary with body dimensions, composition, and MA modulation.

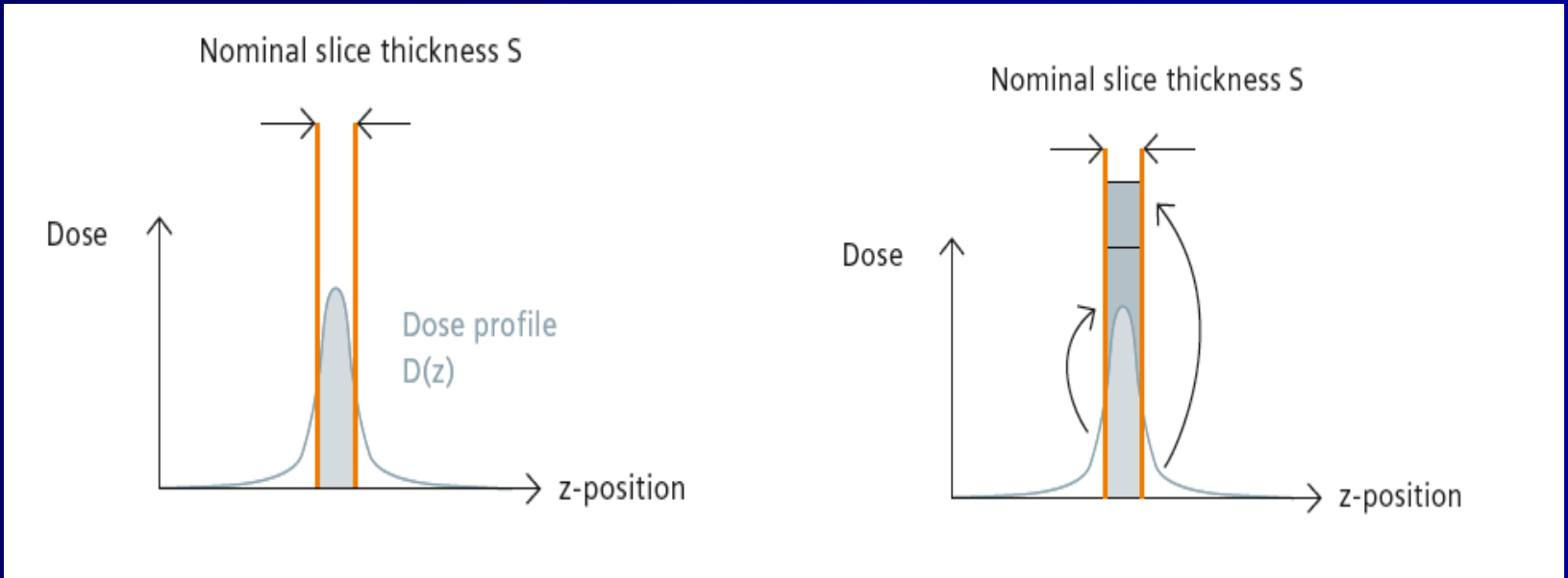


- **Contribution of direct and scattered radiation to an axial CT slice.**

Radiation Dose for Single Slice

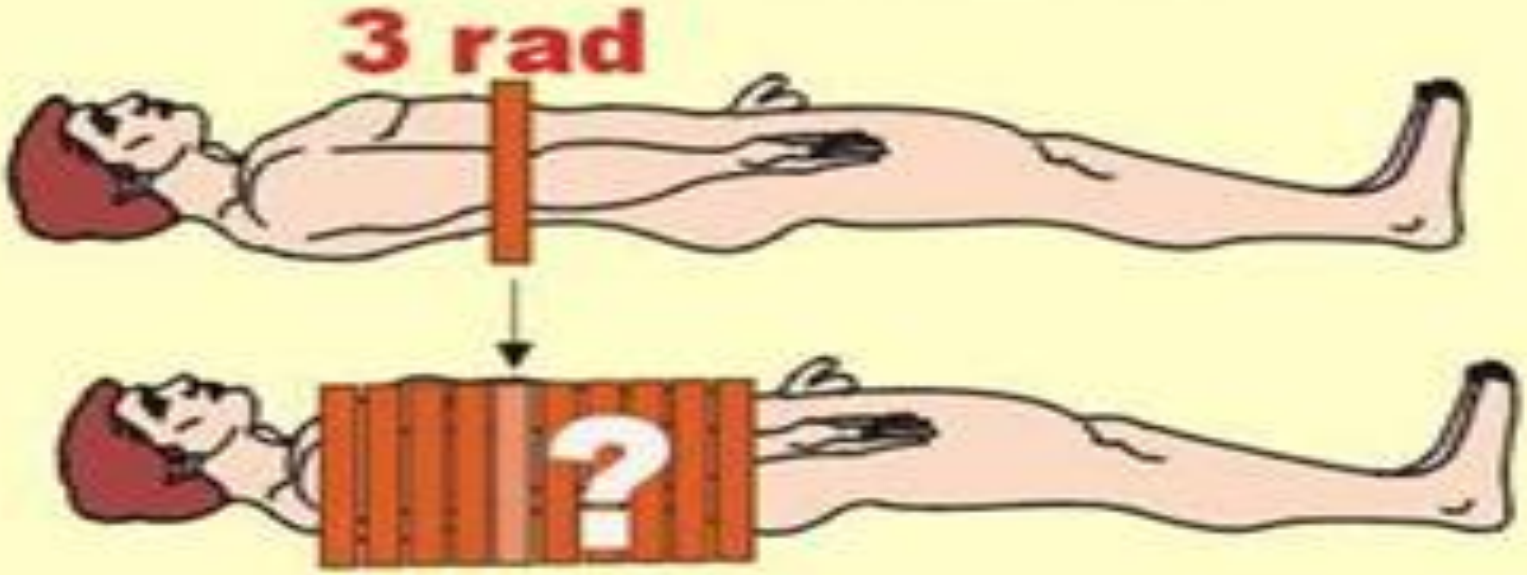


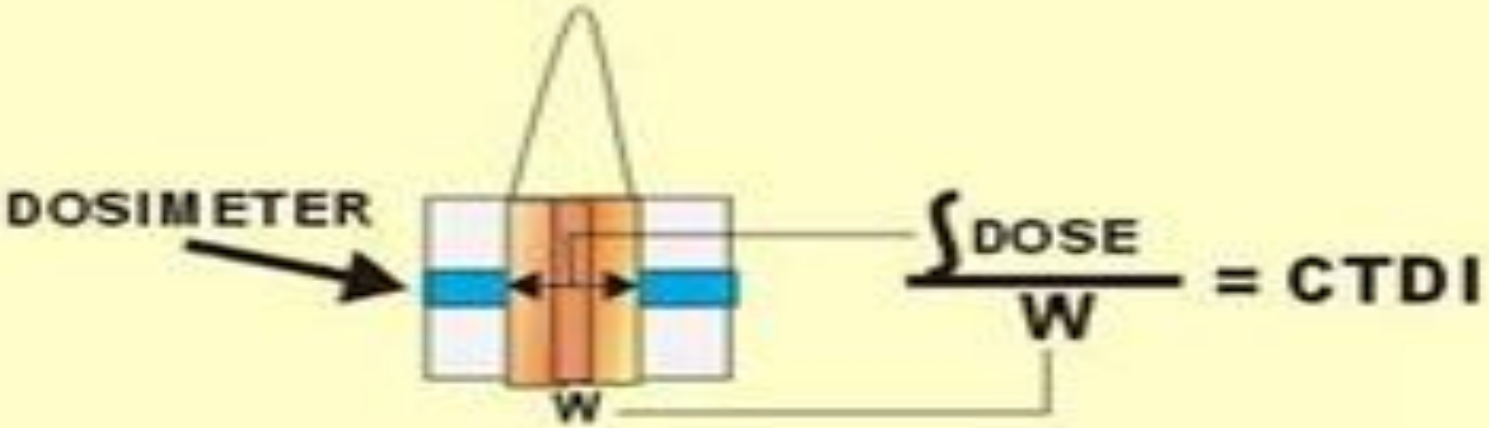
Computed Tomography Dose Index (CTDI)



- Absorbed dose in the slice
- Absorbed dose including scatter contributions from outside the slice (CTDI)

COMPUTED TOMOGRAPHY DOSE INDEX



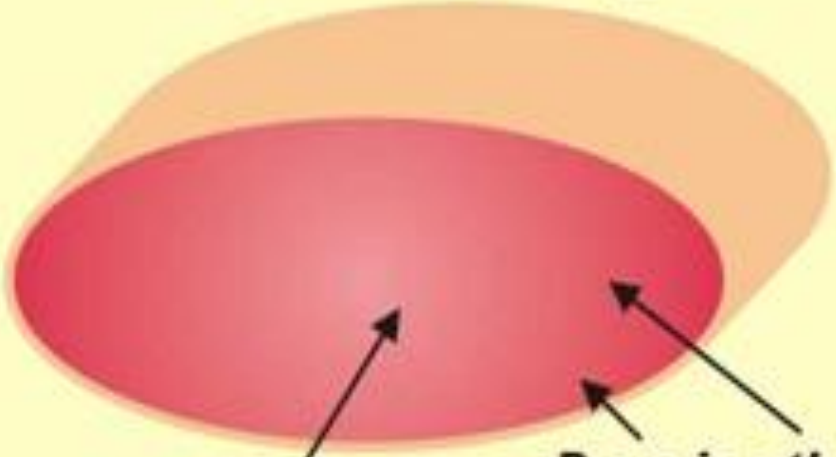


Weighted

Computed Tomography Dose Index

(Approximate Average Dose in Slice)

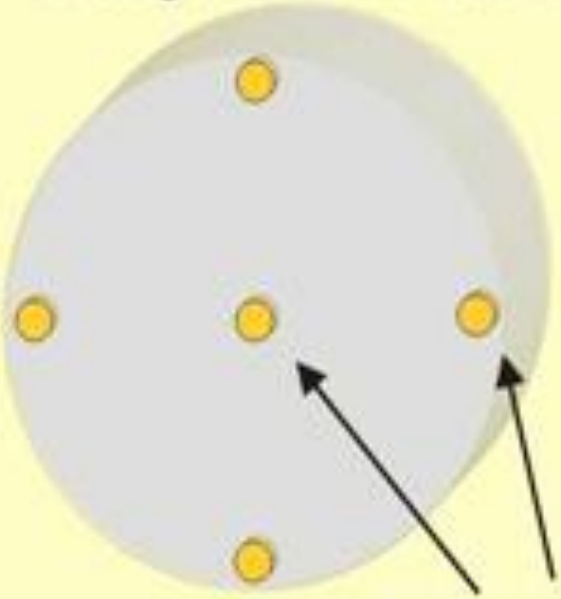
Patient Body



Generally lower dose at the center.

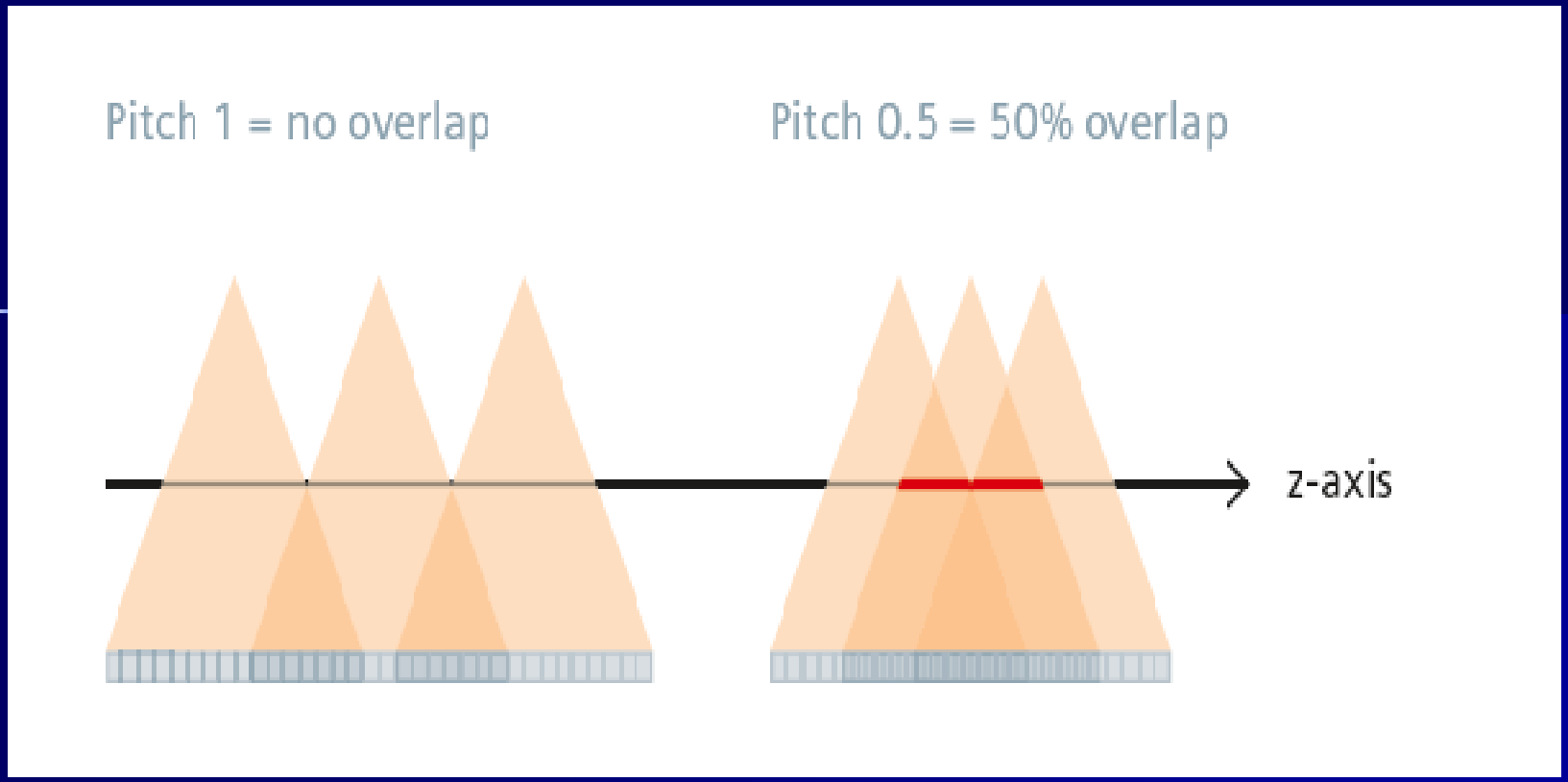
Dose in other areas will vary with body dimensions, composition, and MA modulation.

Acrylic Phantom



Dosimeters

$$CTDI_{weighted} = 1/3\ CTDI_{center} + 2/3\ CTDI_{periphery}$$



- If the table moves fast (pitch = 1) the X-ray beam profiles do not overlap,
- if the table moves slowly (pitch = 0.5) the X-ray beam profiles overlap.
- Please note that the overlap is measured at the isocenter of the scanner (along the z-axis)

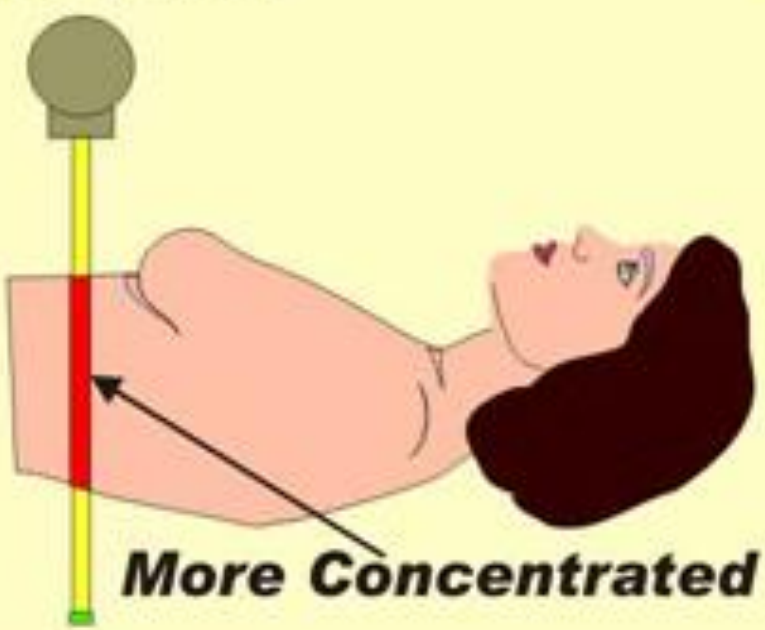
Volume

Computed Tomography Dose Index

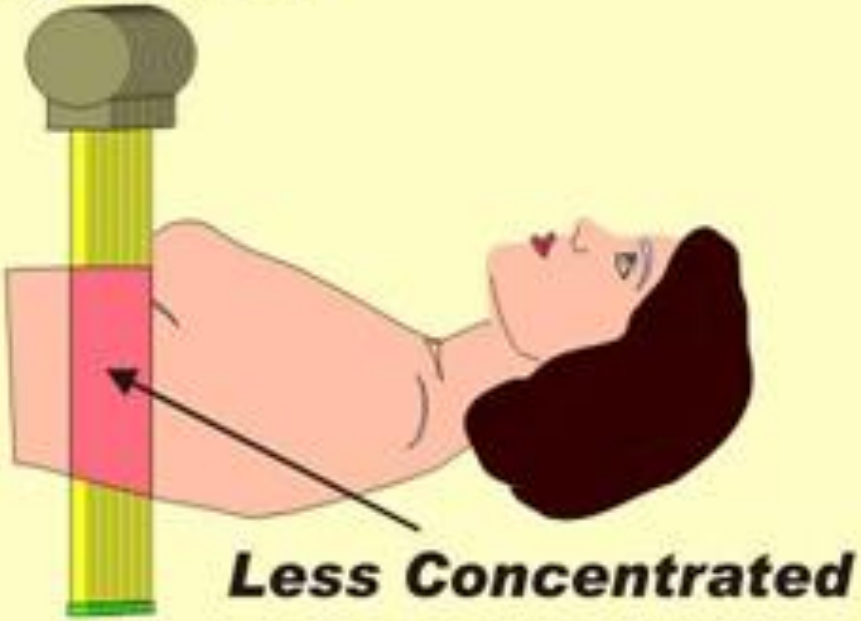
(Accounts for the Effect of Pitch on Dose)

$$CTDI_{volume} = CTDI_{weighted} / Pitch$$

Low Pitch

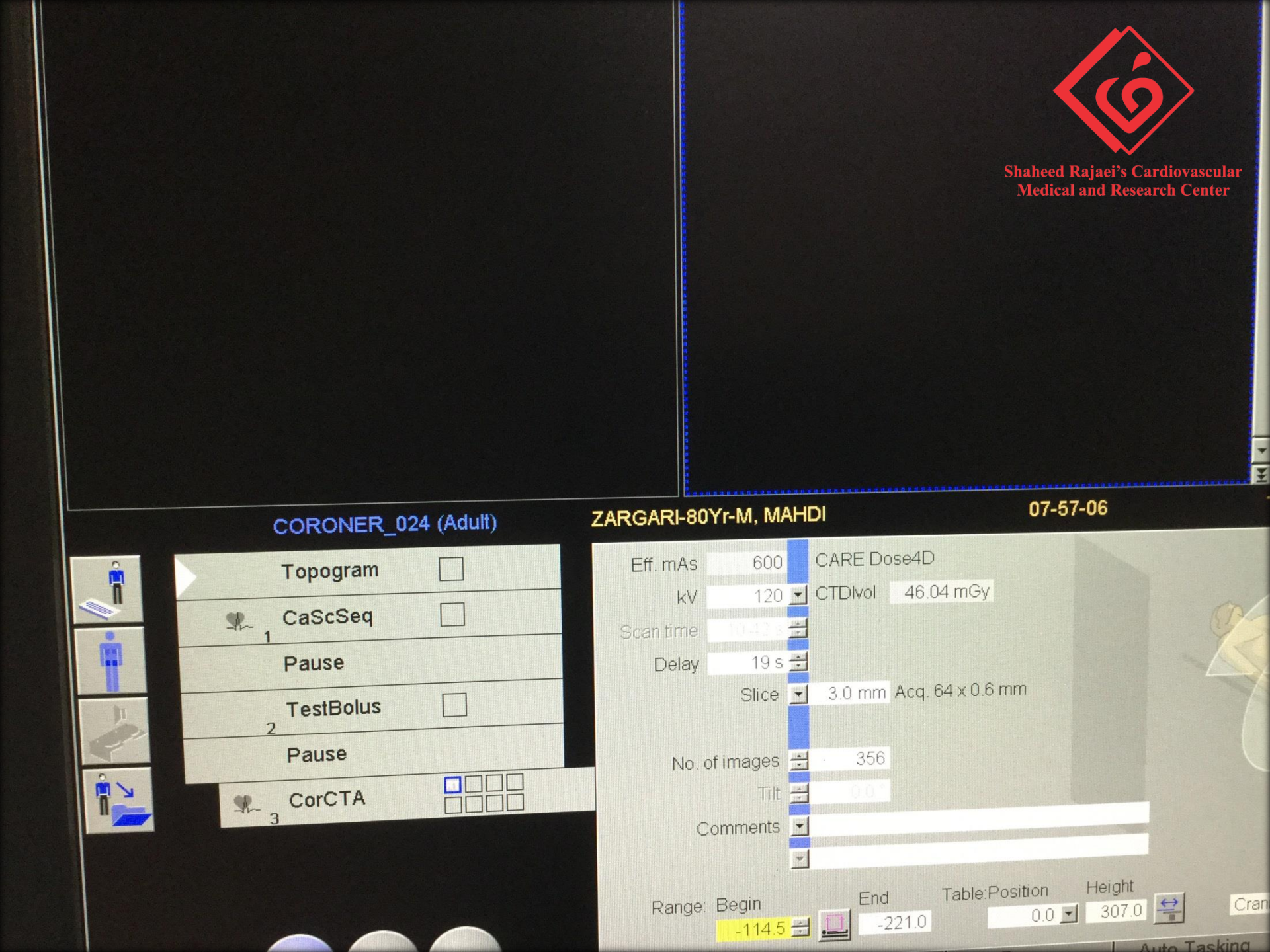


High Pitch



Higher Dose

Lower Dose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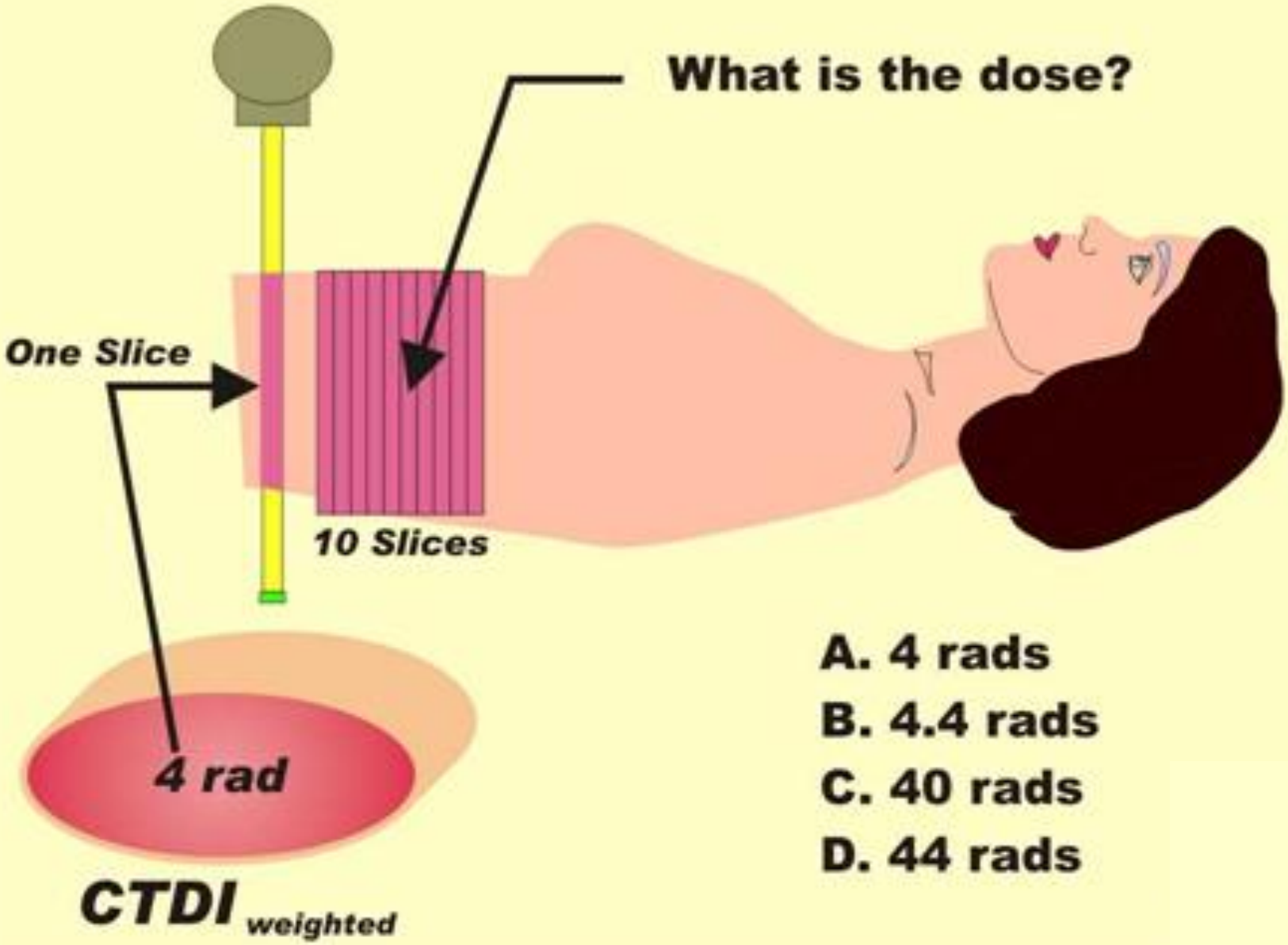
CORONER_024 (Adult)
ZARGARI-80Yr-M, MAHDI
07-57-06
Topogram
CaScSeq
1
Pause
TestBolus
2
Pause
CorCTA
3
Eff. mAs
600
CARE Dose4D
kV
120
CTDIvol
46.04 mGy
Scan time
Delay
19 s
Slice
3.0 mm
Acq. 64 x 0.6 mm
No. of images
356
Tilt
Comments
Range: Begin
-114.5
End
-221.0
Table:Position
0.0
Height
307.0

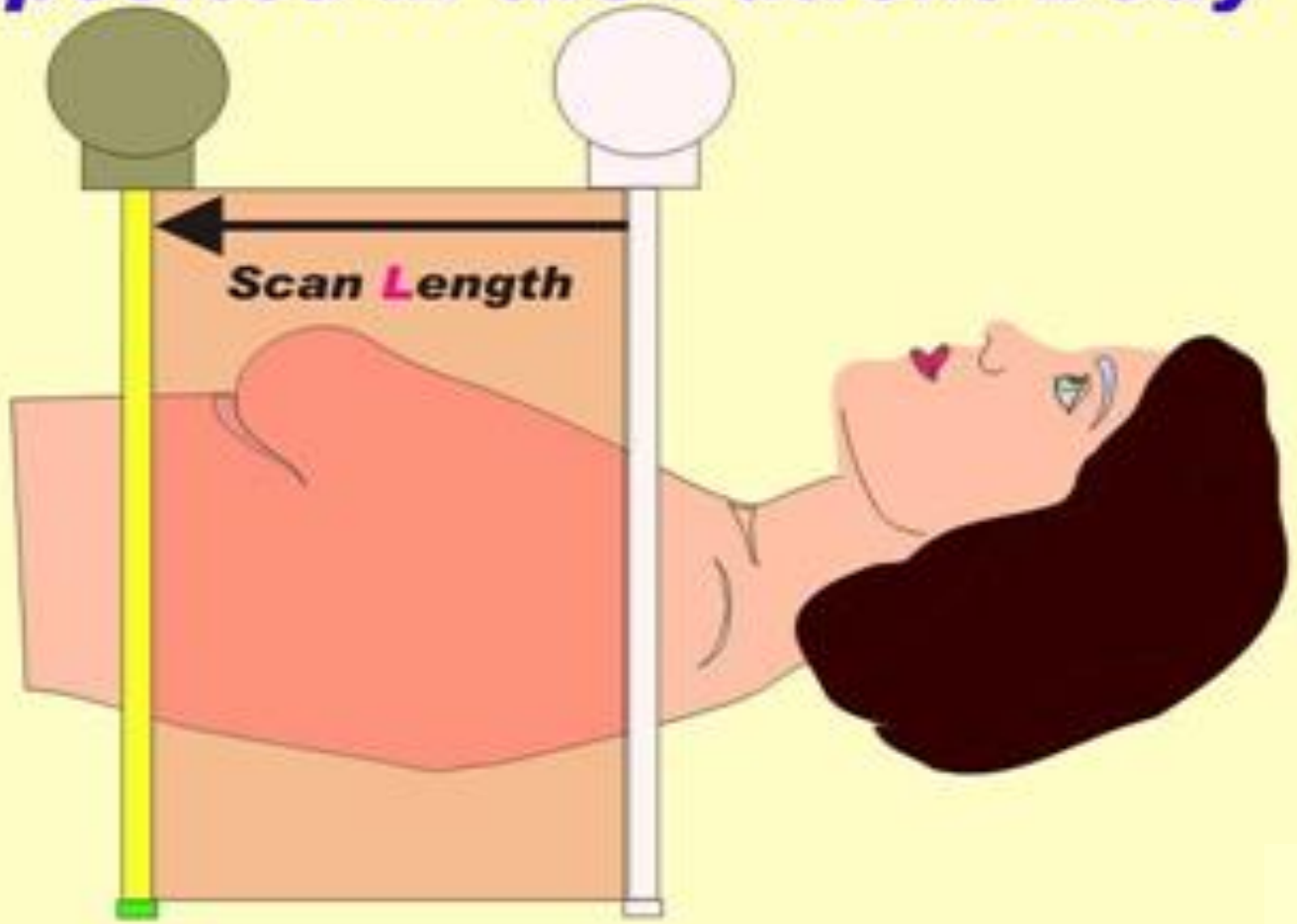
Radiation Dose for Multiple Slices



A. 4 rads
B. 4.4 rads
C. 40 rads
D. 44 rads

Dose Length Product

Represents Total Radiation Energy Deposited in the Patient Body



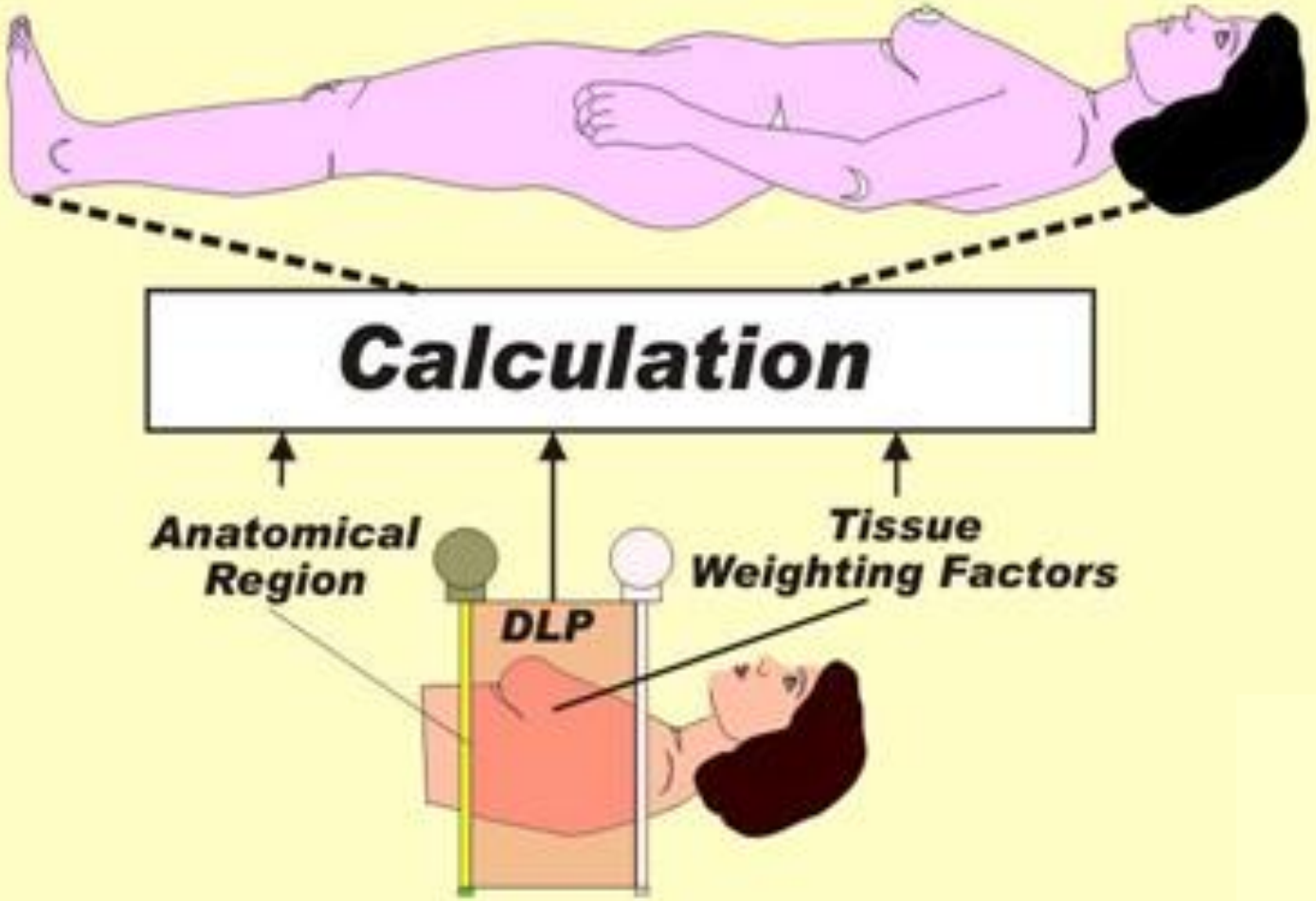
$$DLP = CTDI_{vol} \times Length$$

Effective Dose

"Equivalent Whole Body Dose"

used for

Estimation of Risks



Effective dose:

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For different scan ranges, the effective dose E can be calculated approximately from the DLP :

$$E = DLP \cdot f$$

where f is a mean weighting factor (average between male and female models) for different regions of the human body:

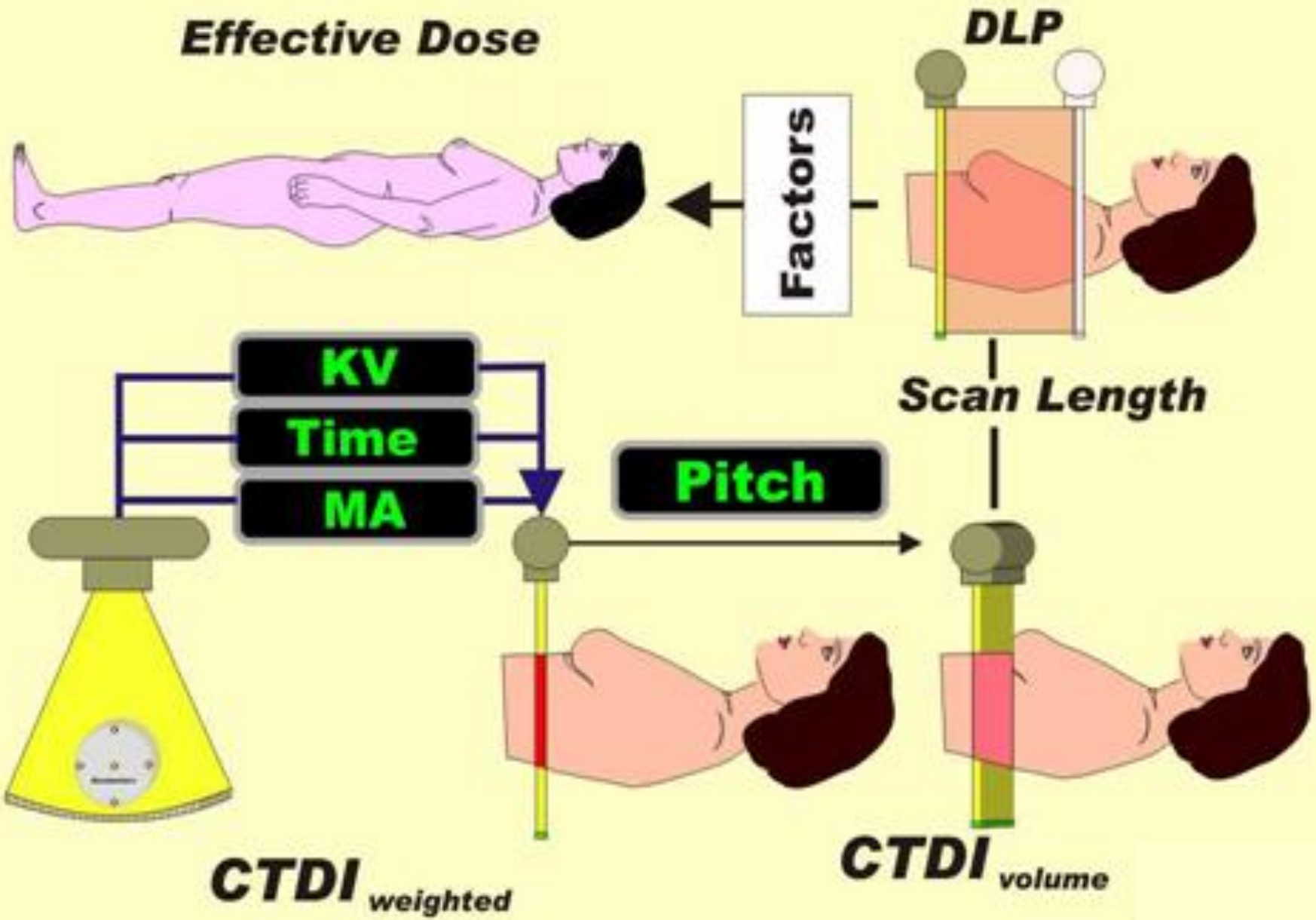
Head: f = 0.0021 mSv/(mGy · cm)

Neck: f = 0.0059 mSv/(mGy · cm)

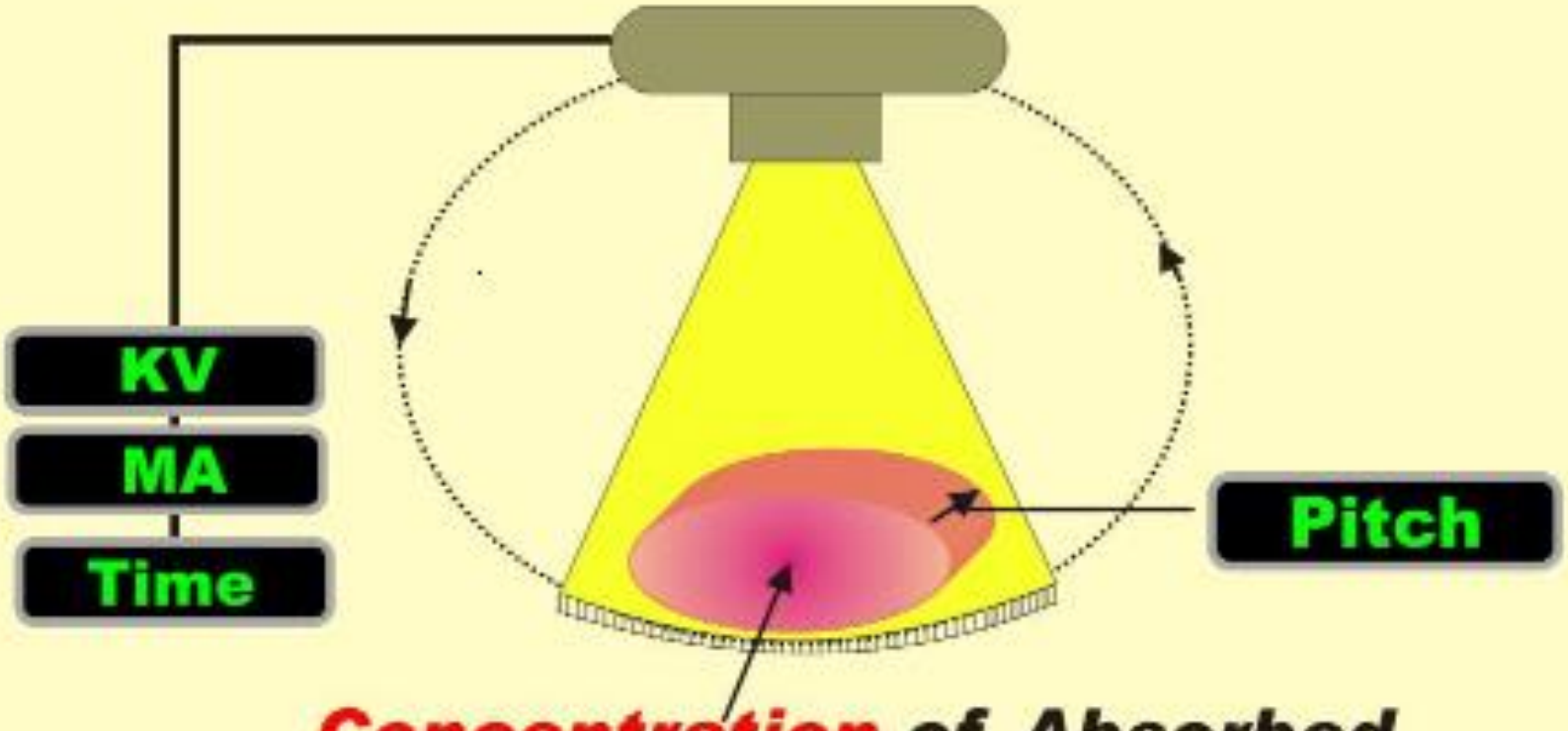
Thorax: f = 0.014 mSv/(mGy · cm)

Abdomen and pelvis: f = 0.015 mSv/(mGy · cm)

CT Dose Quantities

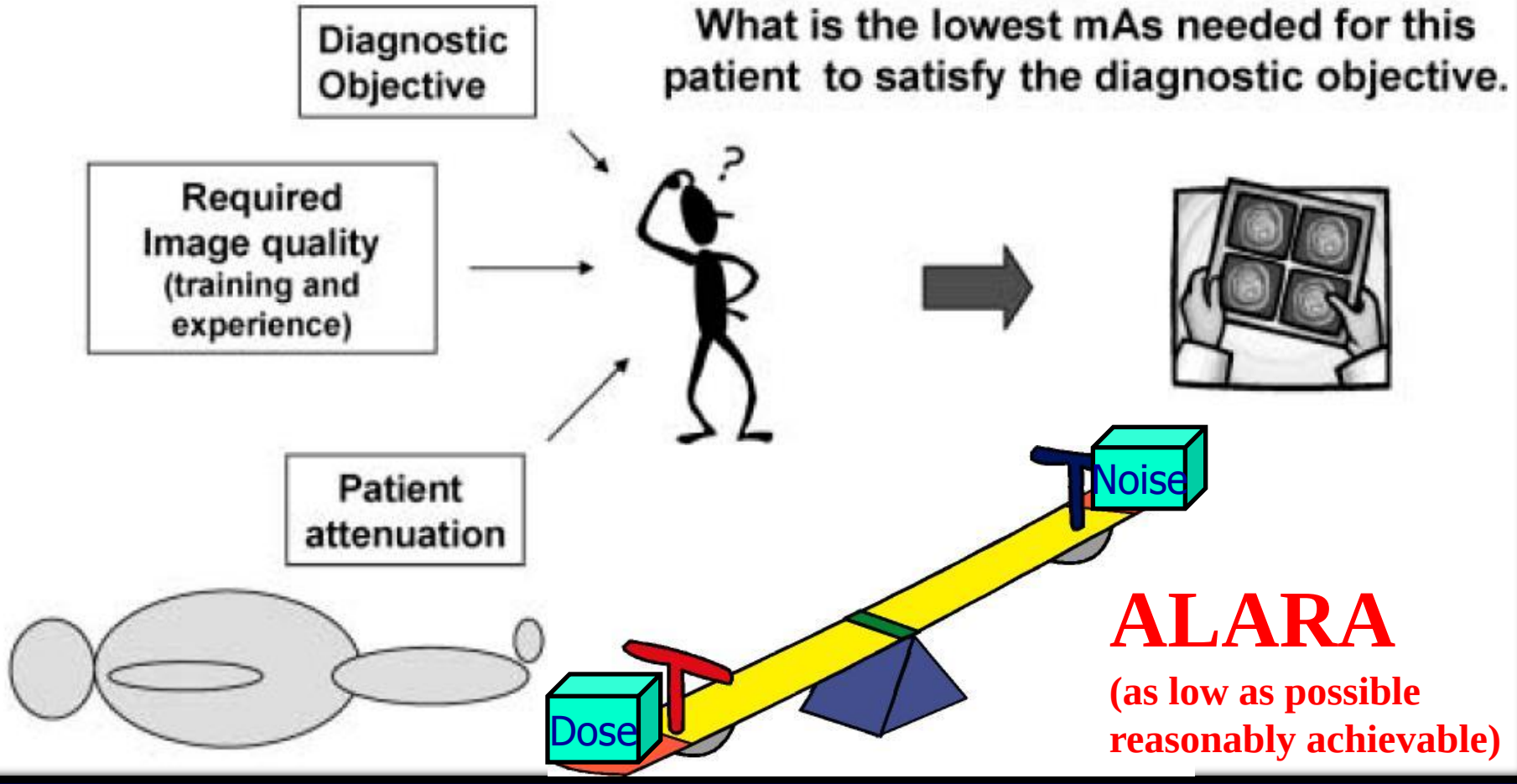


Factors That Determine Radiation Dose to Patient

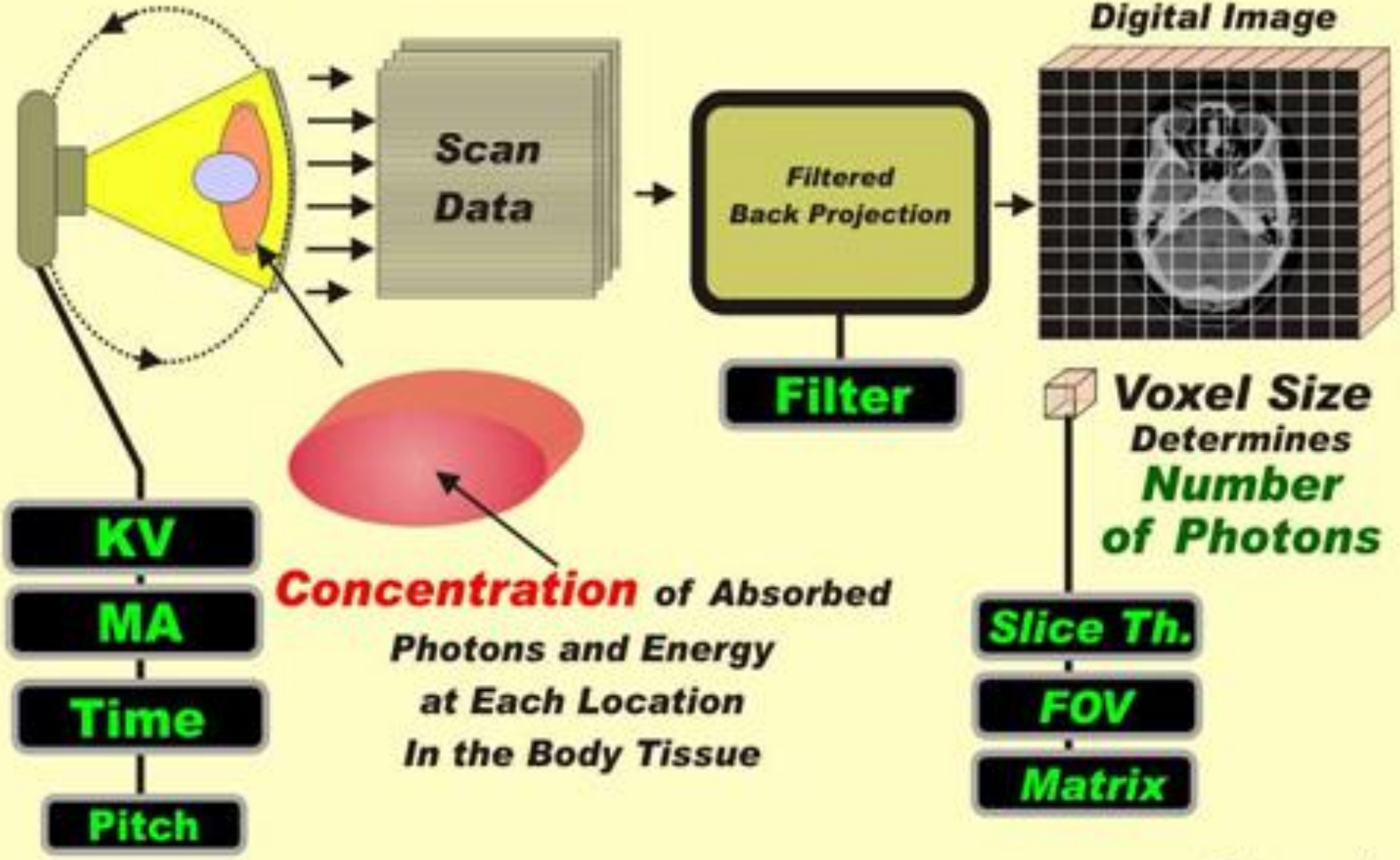


Concentration of Absorbed Photons and Energy at Each Location In the Body Tissue

ALARA (as low as possible reasonably achievable)

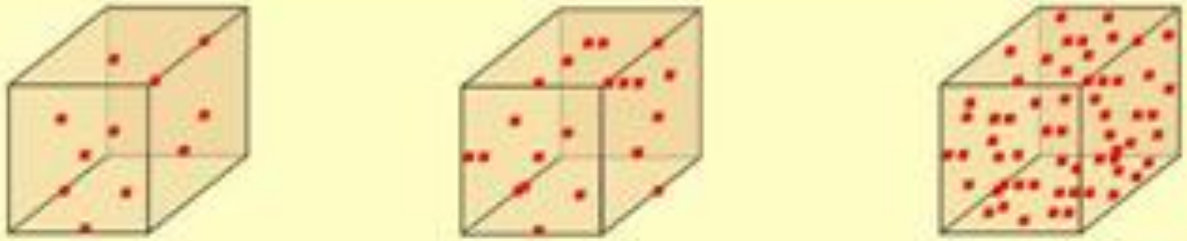


Factors That Determine Image Noise



Decreasing Noise

Requires Increased Photons Absorbed Per Voxel



Produces Increasing Dose

X-ray Photons Interact With Tissue in A Voxel

Radiation Dose

determined by

Concentration

of

Absorbed Energy

per voxel

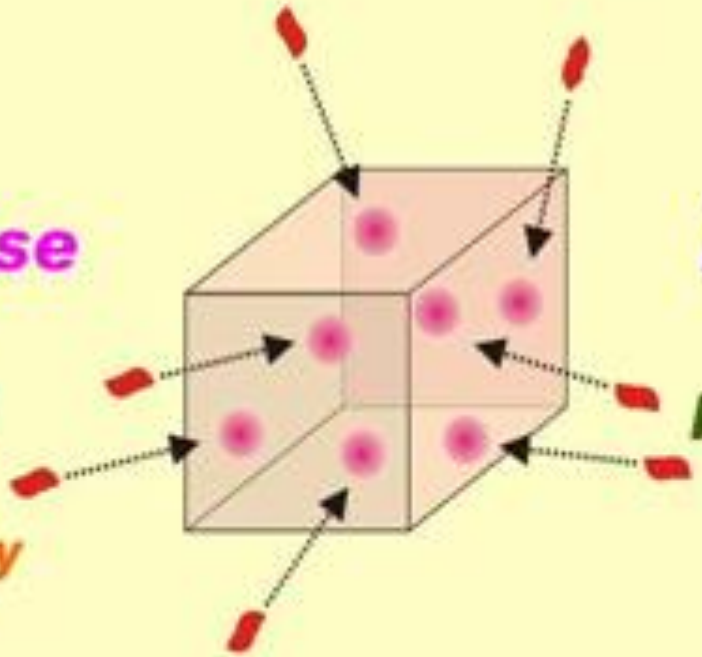


Image Noise

determined by

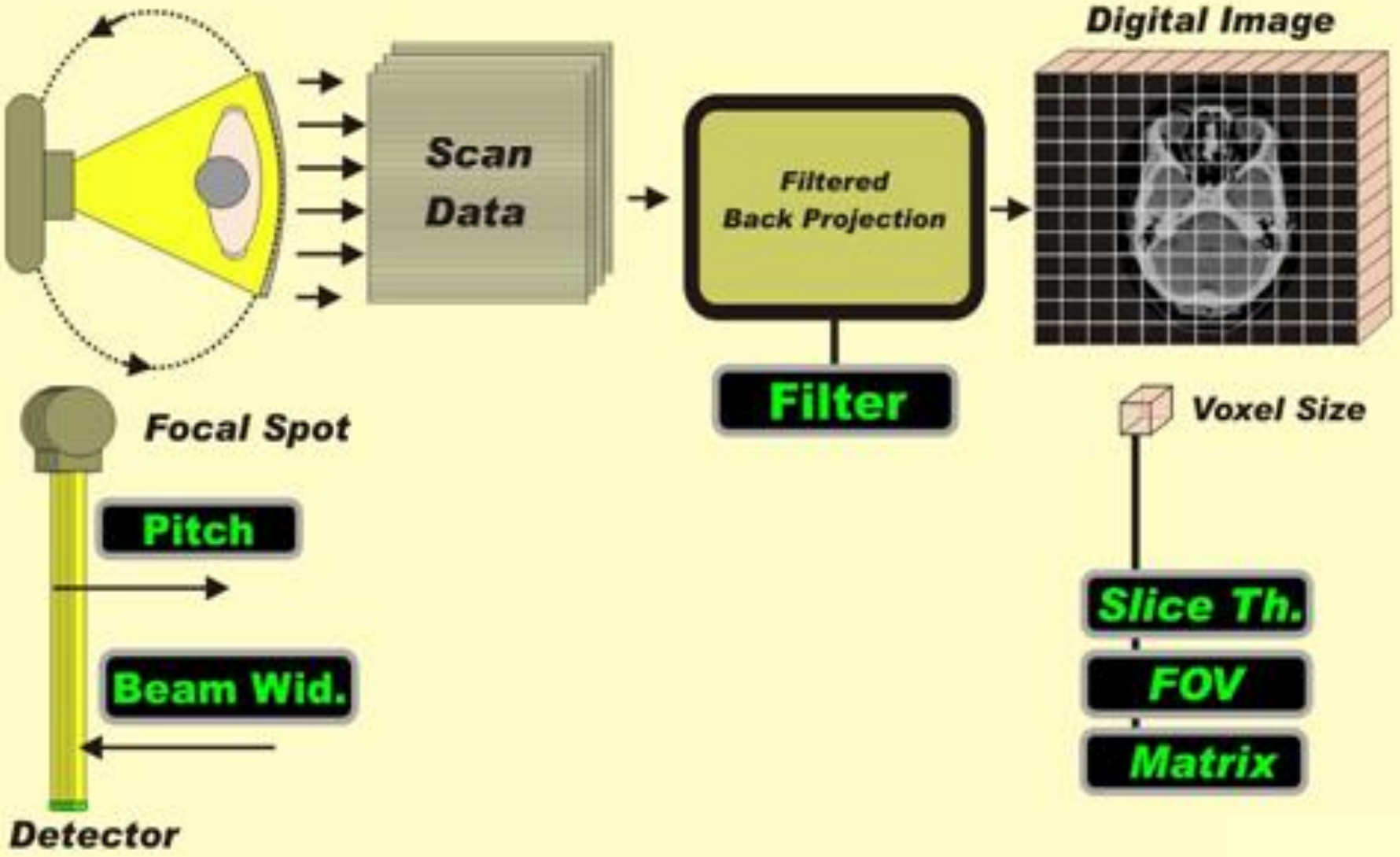
Number of Photons

per voxel

Dose is increased
by
increasing number
of photons.

Noise is reduced
by
increasing number
of photons.

Factors That Determine Image Detail
(Sources of Blurring)



Relationship of Radiation Dose to Image Detail

Lower Dose

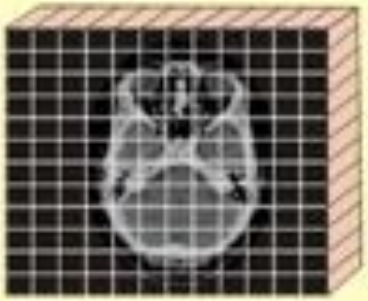
Higher Dose

When detail is increased by

- Decreasing **Slice Th.**
- Increasing **Matrix**
- Decreasing **FOV**

Noise Increases

Because of decreased voxel size



Dose must be **increased** to **reduce noise.**

Radiation dose:

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Medical and Research Center

- A useful mnemonic for achieving low doses in CCTA scans is the 'LOW DOSE' acronym

- Limit scan volume
- Optimize mA
- Work out correct kV to use
- Dose modulate aggressively
- Obsessive heart rate control
- Select prospective triggering
- Evaluate your doses

Scan volume:

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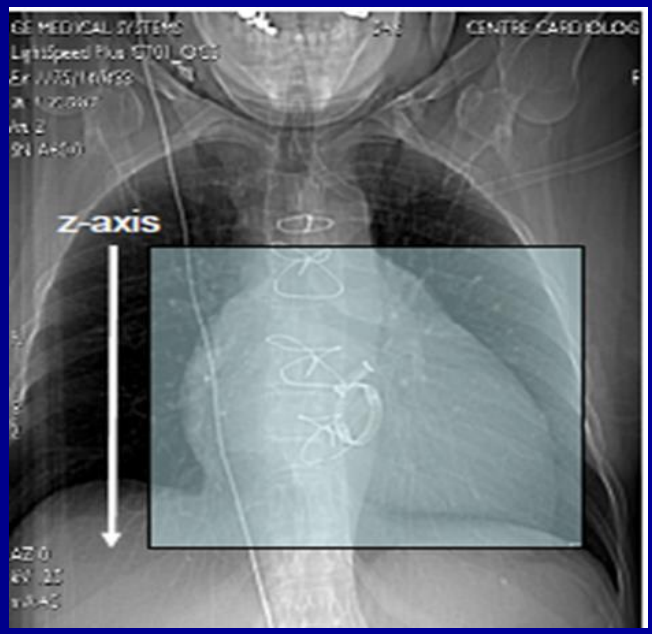
- The scan length should be kept to the z-axis extent that is required
- For a given patient, the dose length product (DLP) is directly proportional to scan length



Tube current (mA):

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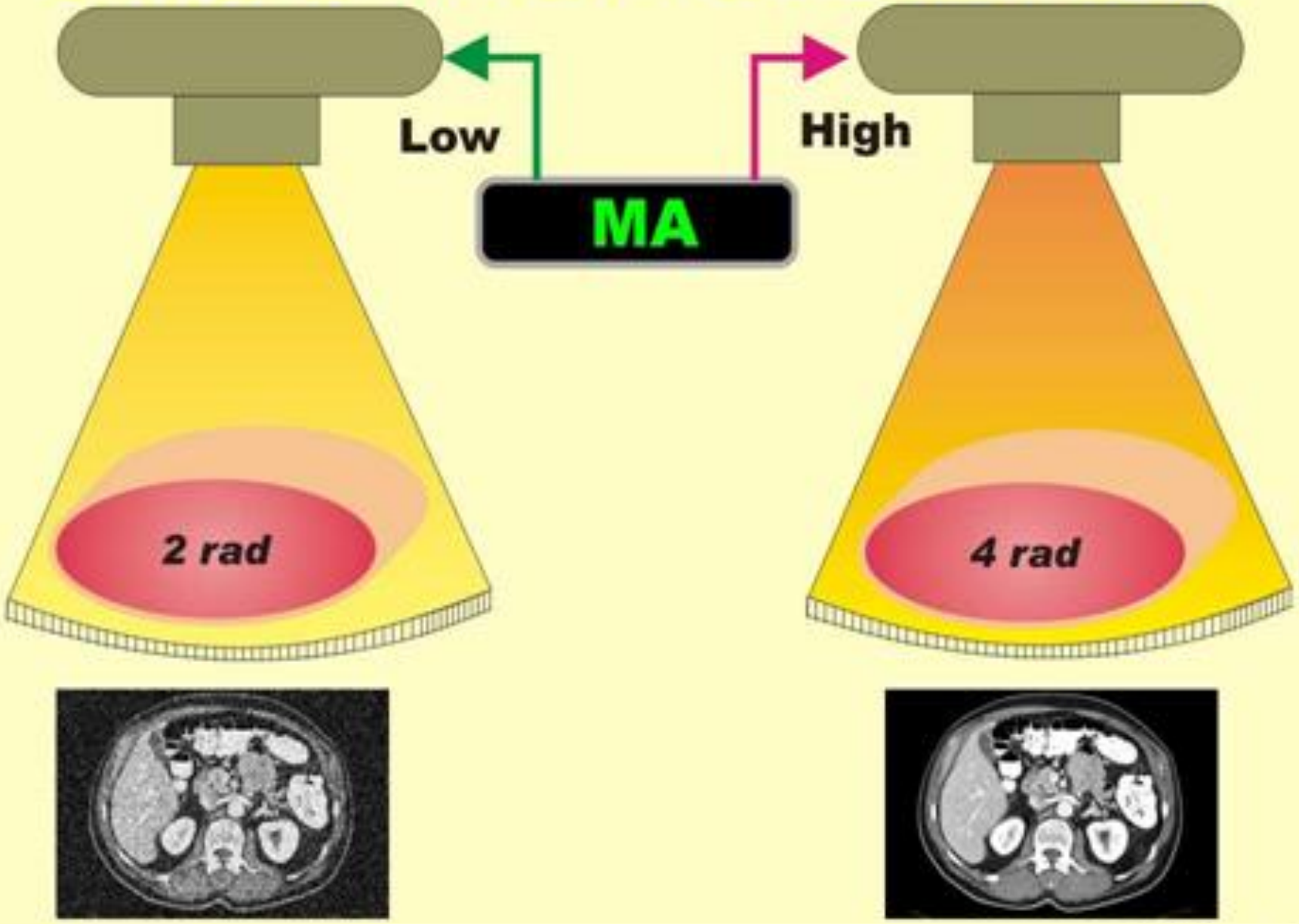
- The tube current (mA) should be carefully selected to give the correct balance between image noise and dose
- Effective dose is directly proportional to the tube current
- Some scanners will automatically adapt the mA to patient size,

Tube current (mA)

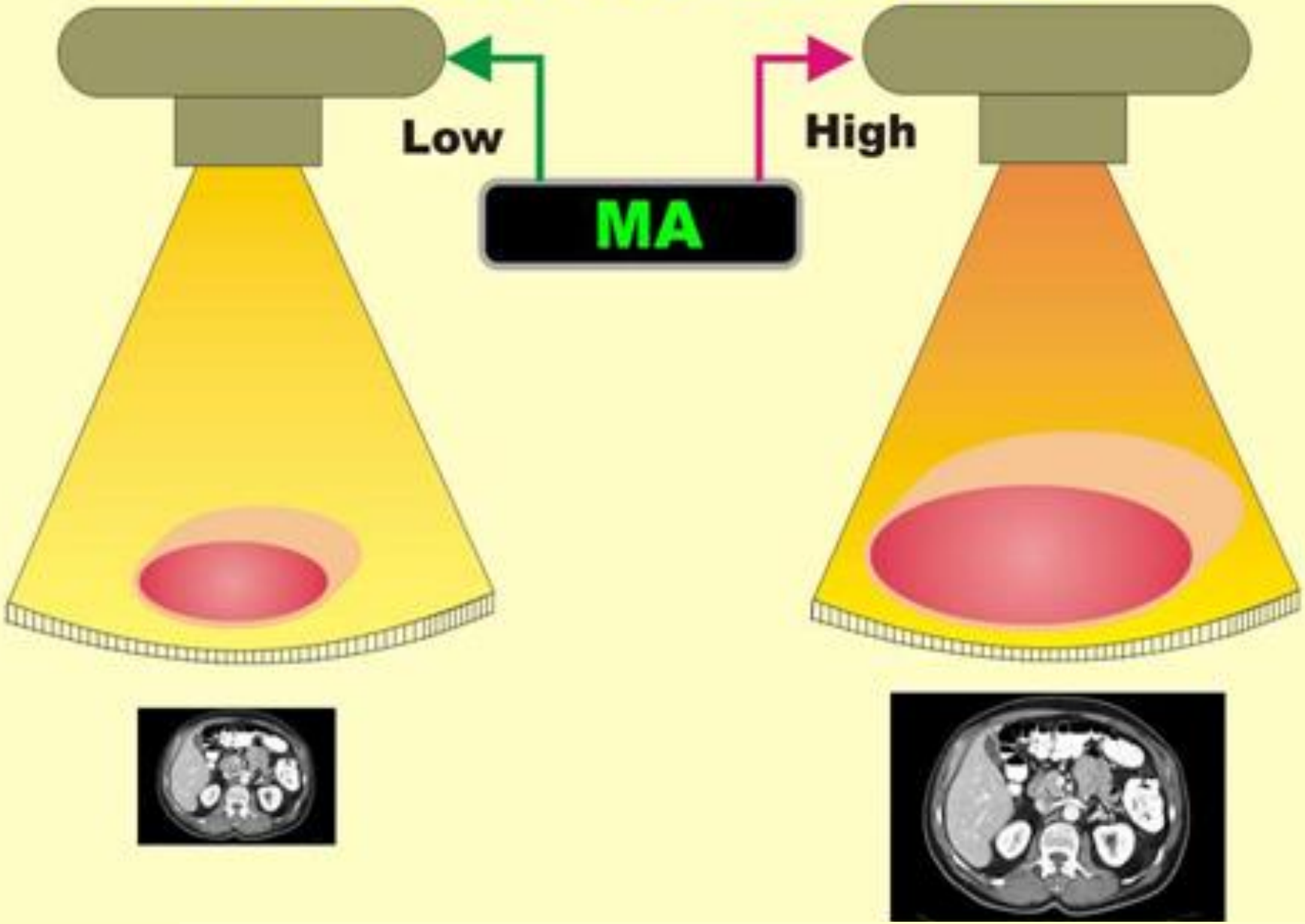
Lower tube current (mA):

- Lower tube current (mA) should be used for scanning kids.
  - *High tube current is required only when there is a need for high image detail (in low contrast settings)*
- Decrease of mA according to body diameter and use of exposure charts if AEC is not available (dose reduction 70-80%),
- Use of tube current modulation technology results in dose reduction by 60% for paediatric scanning,

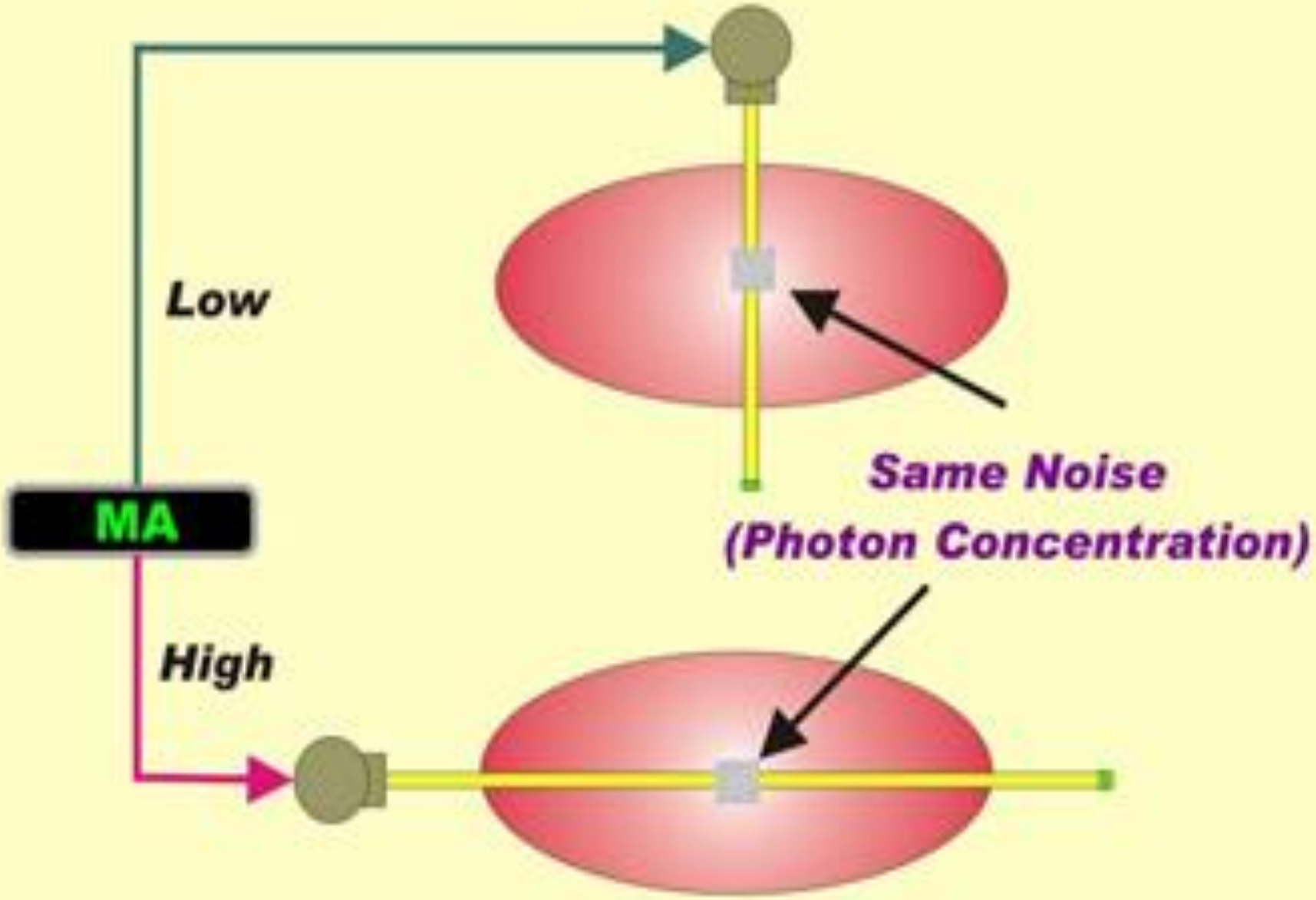
Effect of MA on Dose and Noise



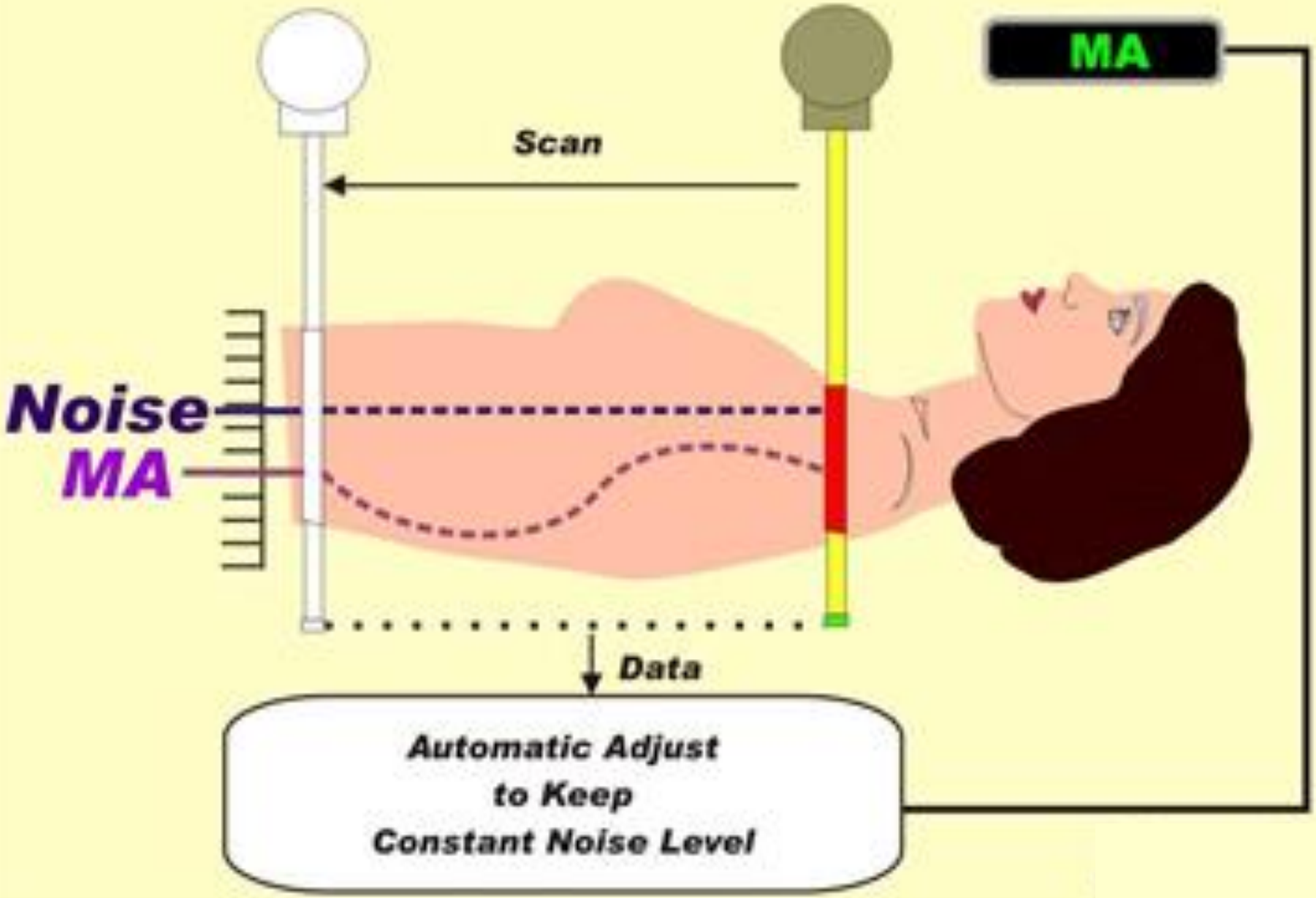
Select MA for Body Size



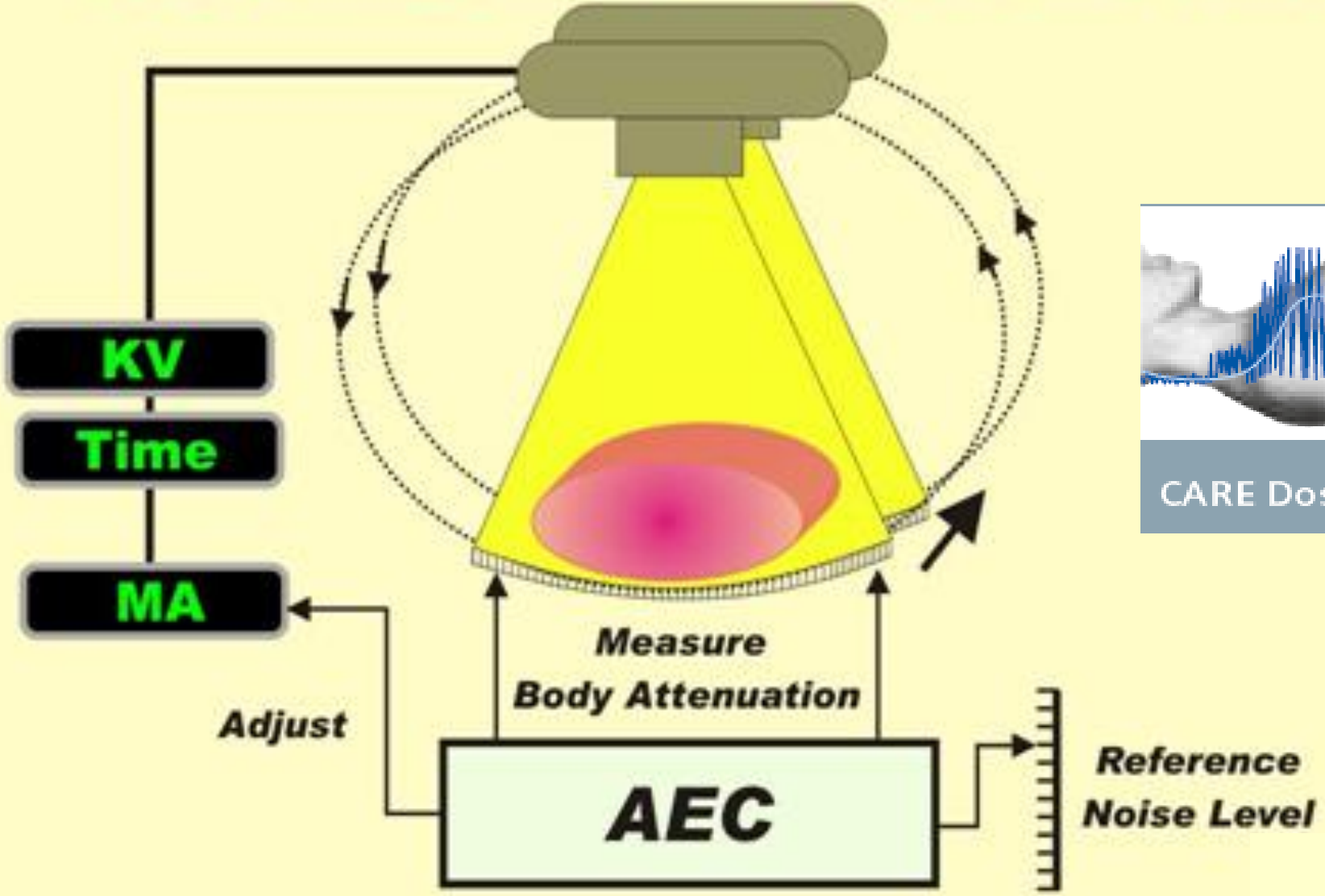
Fit MA to Body Attenuation

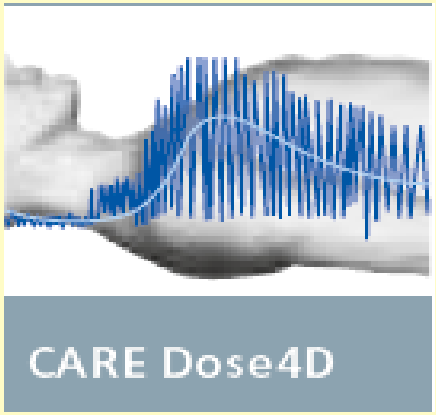


Automatic MA Control



Automatic Exposure Control to Optimize Radiation Dose and Noise





Tube voltage (kV)

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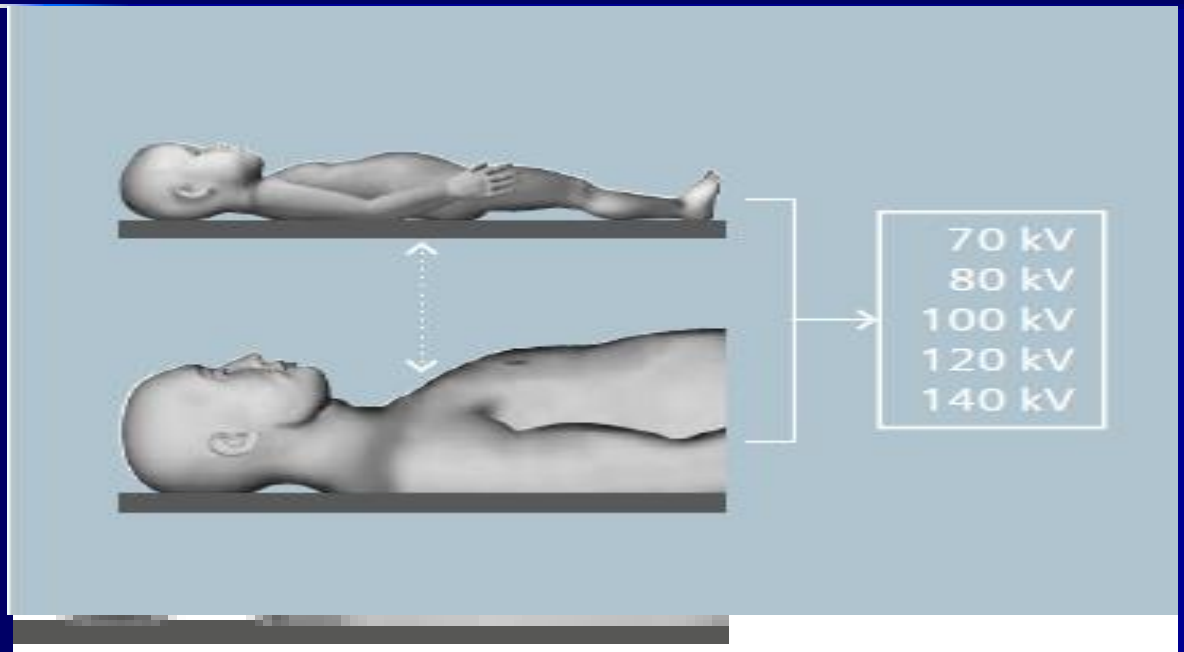
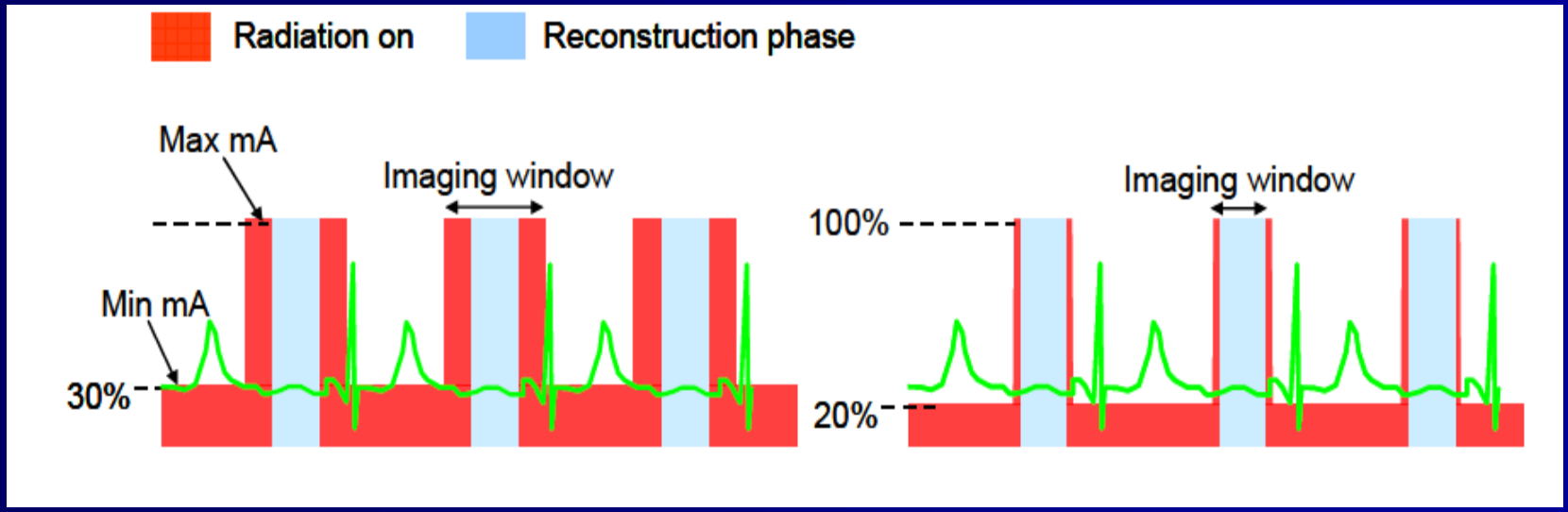
- Dose is approximately proportional to the square of tube voltage (kV)
- Larger patients will require higher kV's to obtain sufficiently low noise levels, since the maximum mA available may be limited
- in smaller patients the kV should be reduced to 100 or even 80, as this results in dose reduction of 30 - 50% whilst maintaining adequate contrast-to-noise ratio
- Reduction from 120 to 100 kV should be considered at a BMI of below 30 kg/m2
- Lowering of kVp enhances contrast



CARE kV

ECG-controlled tube current (dose) modulation:

- The user can also select the width of the maximum mA window
- Narrower imaging windows will result in lower doses, but provide less flexibility in the reconstruction phase
- A low, stable heart rate and a high temporal resolution allow narrower imaging windows



Min dose:

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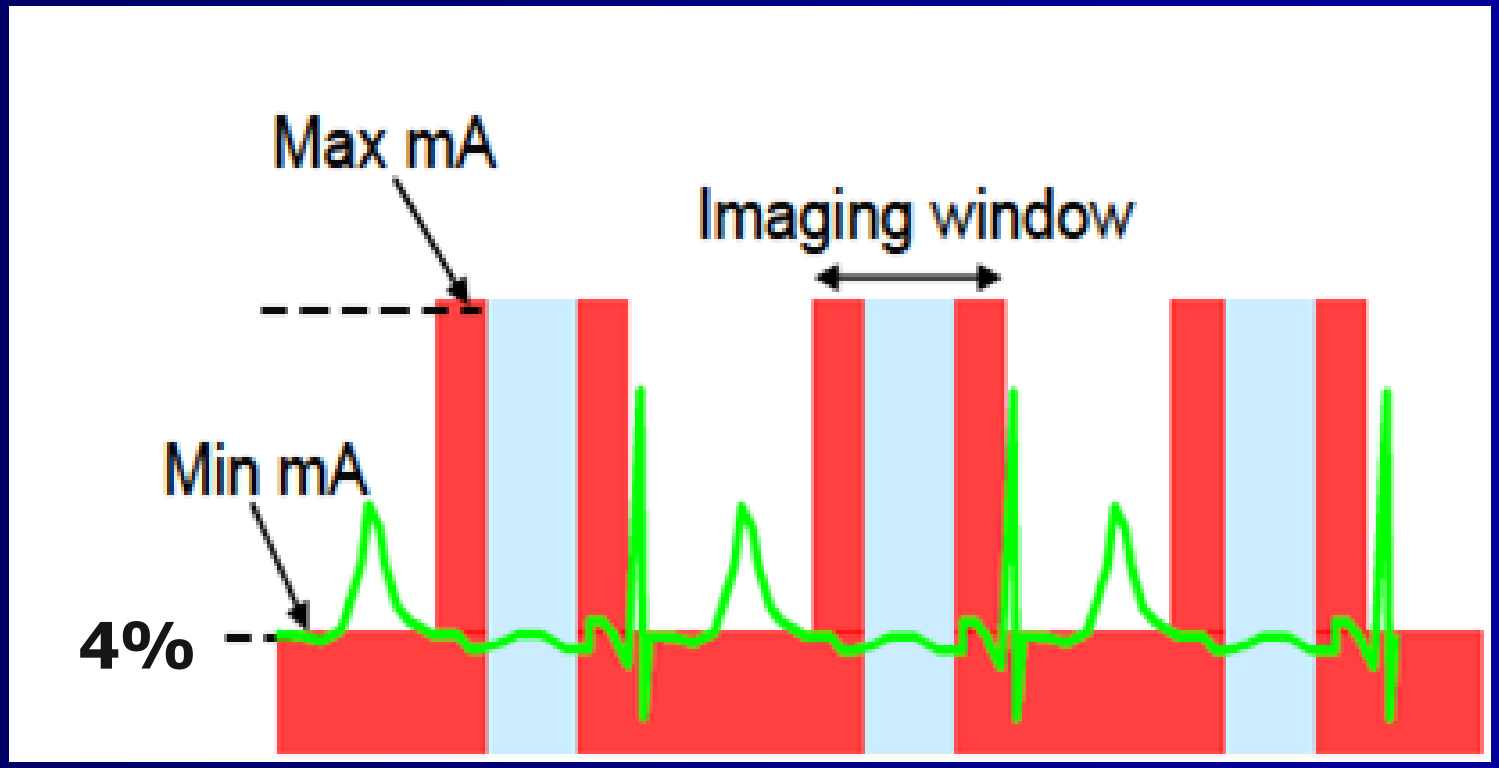
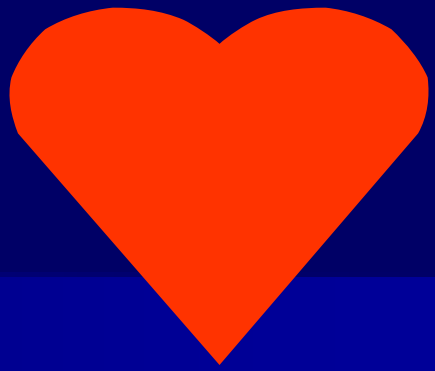
Medical and Research Center



Heart rate control:



- The use of beta blockers to regulate and control heart rate will generally lead to dose reduction
- The main reason for this is that at low, regular heart rates prospective ECG-triggering can be used (axial or helical)
- Low, steady heart rates also result in reduced doses in retrospective scanning modes
- the use of aggressive ECG-controlled tube current modulation, with a narrow imaging window is possible, also lowering dose

Scan mode:

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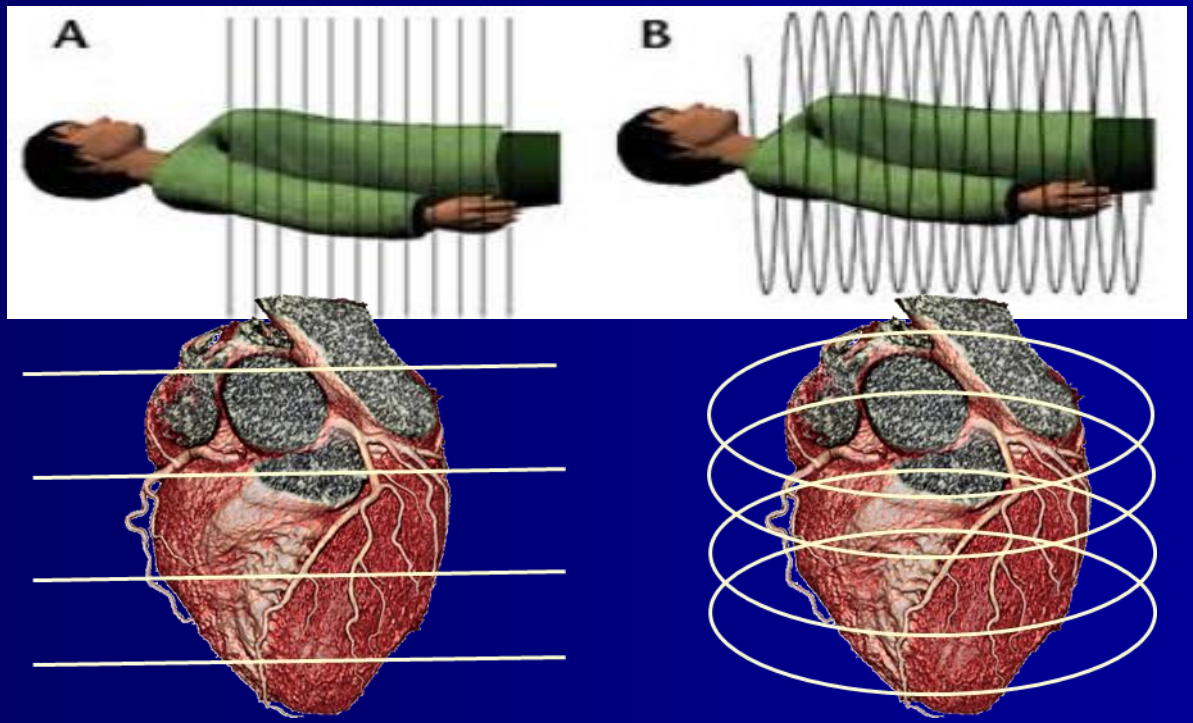
The method selected will depend on equipment capabilities, the aims of the examination and on patient heart rate and stability

Scan mode:

Shaheed Rajaei's Cardiovascular
Medical and Research Center

- Axial (Sequential)
- Helical



Scan mode:

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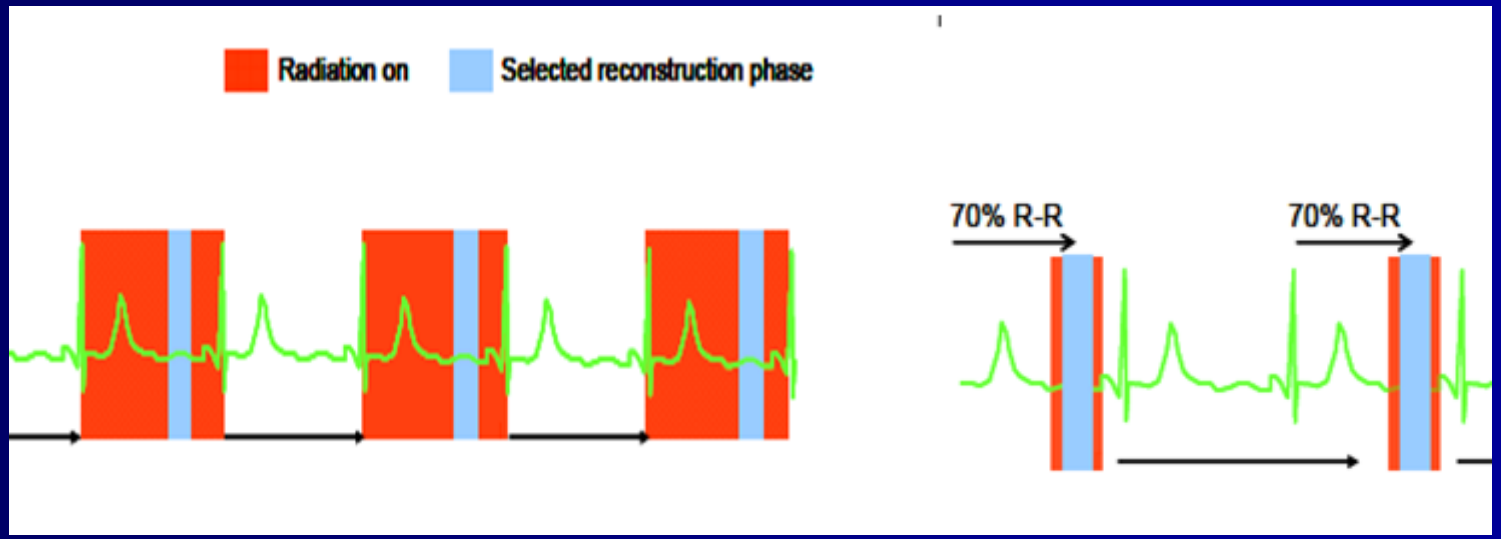
Medical and Research Center

- Retrospective
- Prospective

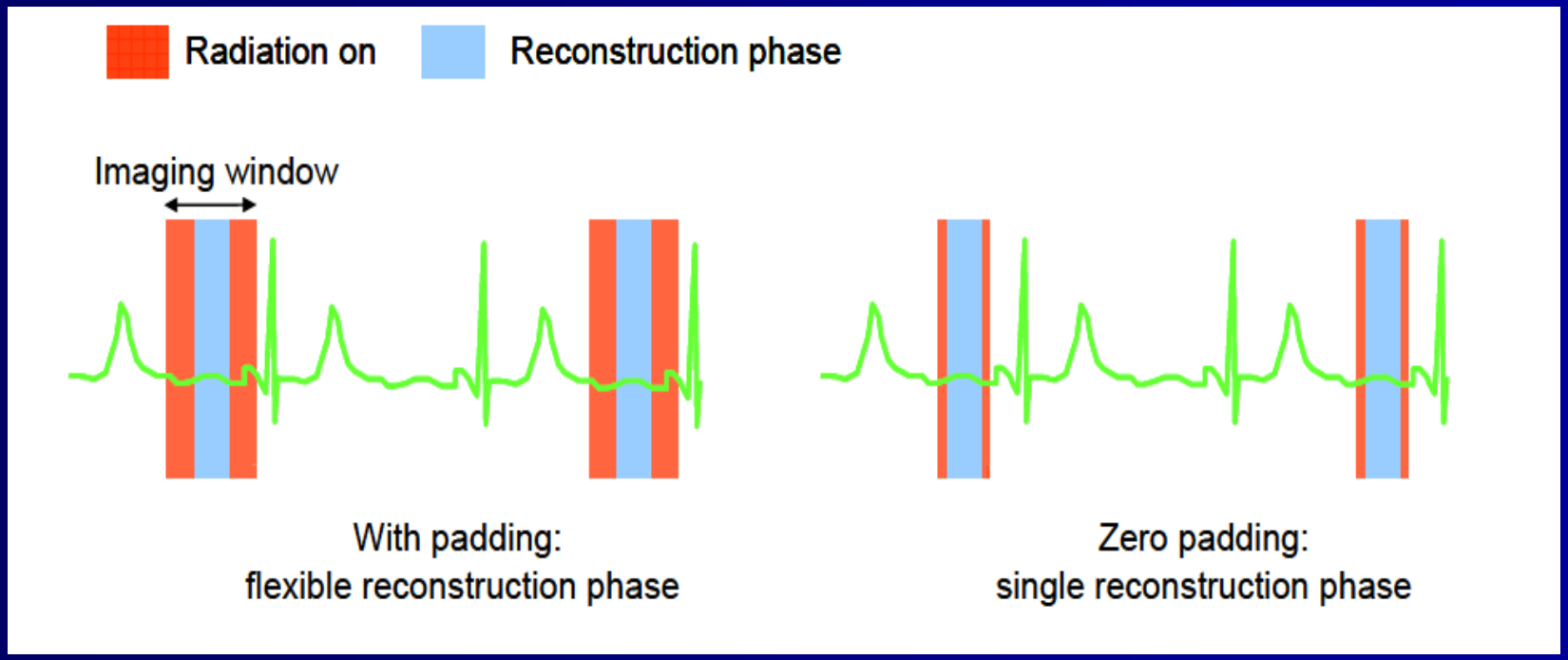


Retrospective

Prospective

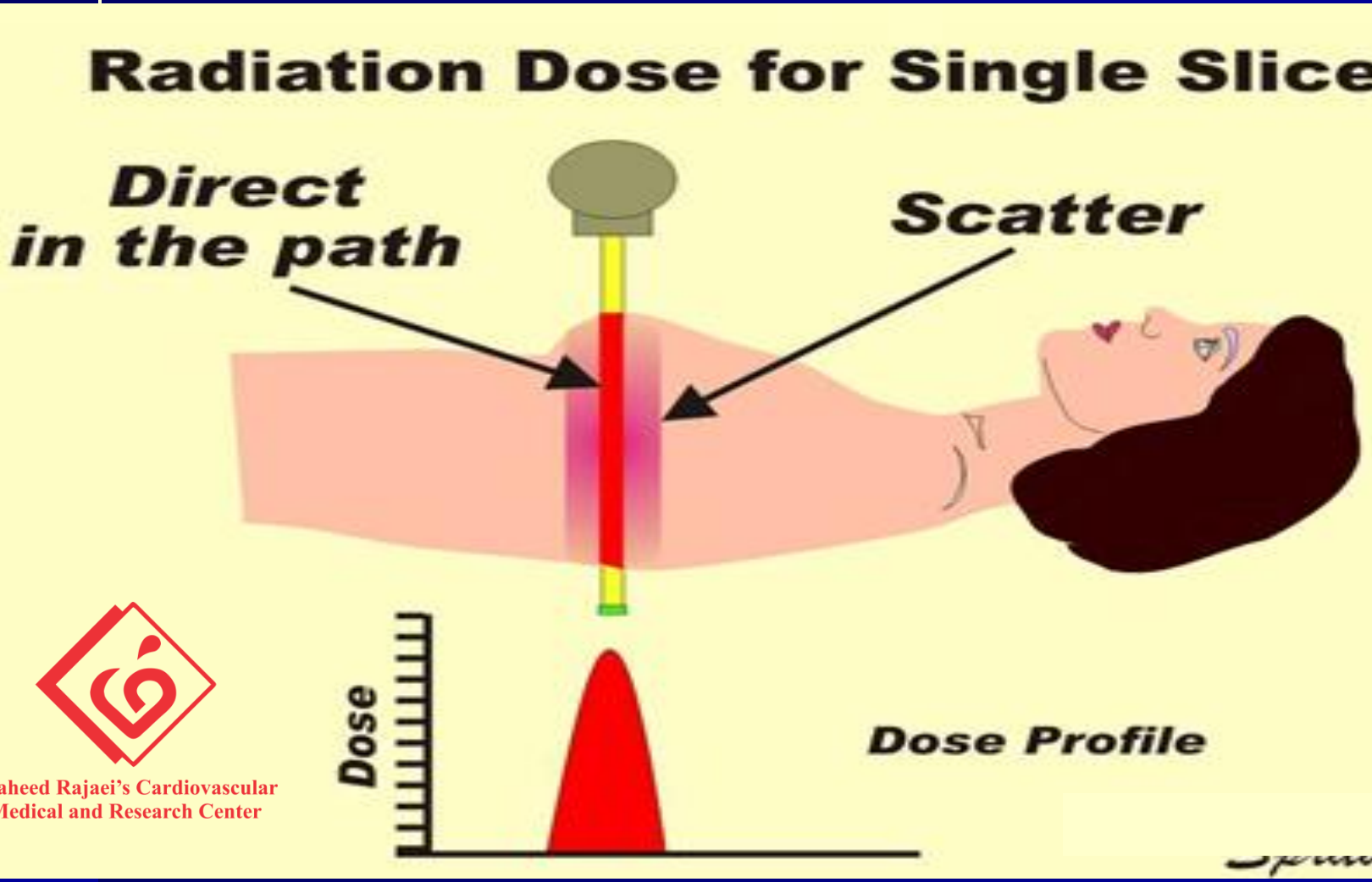
Prospectively ECG-triggered scan modes :

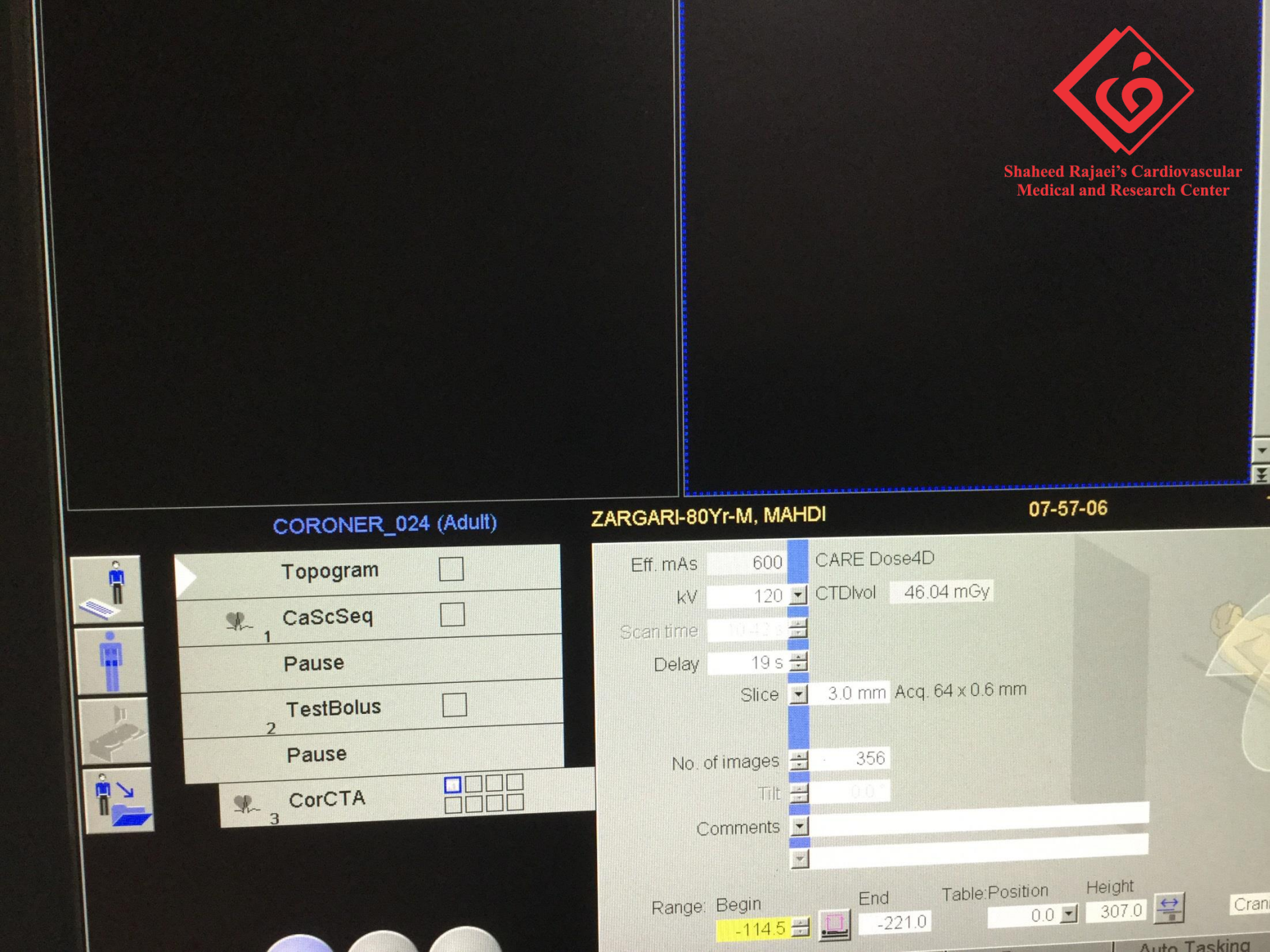
- Prospectively ECG-triggered axial scans with and without ‘padding



- The drawback of prospectively ECG-triggered modes is that it does not allow for functional

Dose monitoring and dose definitions



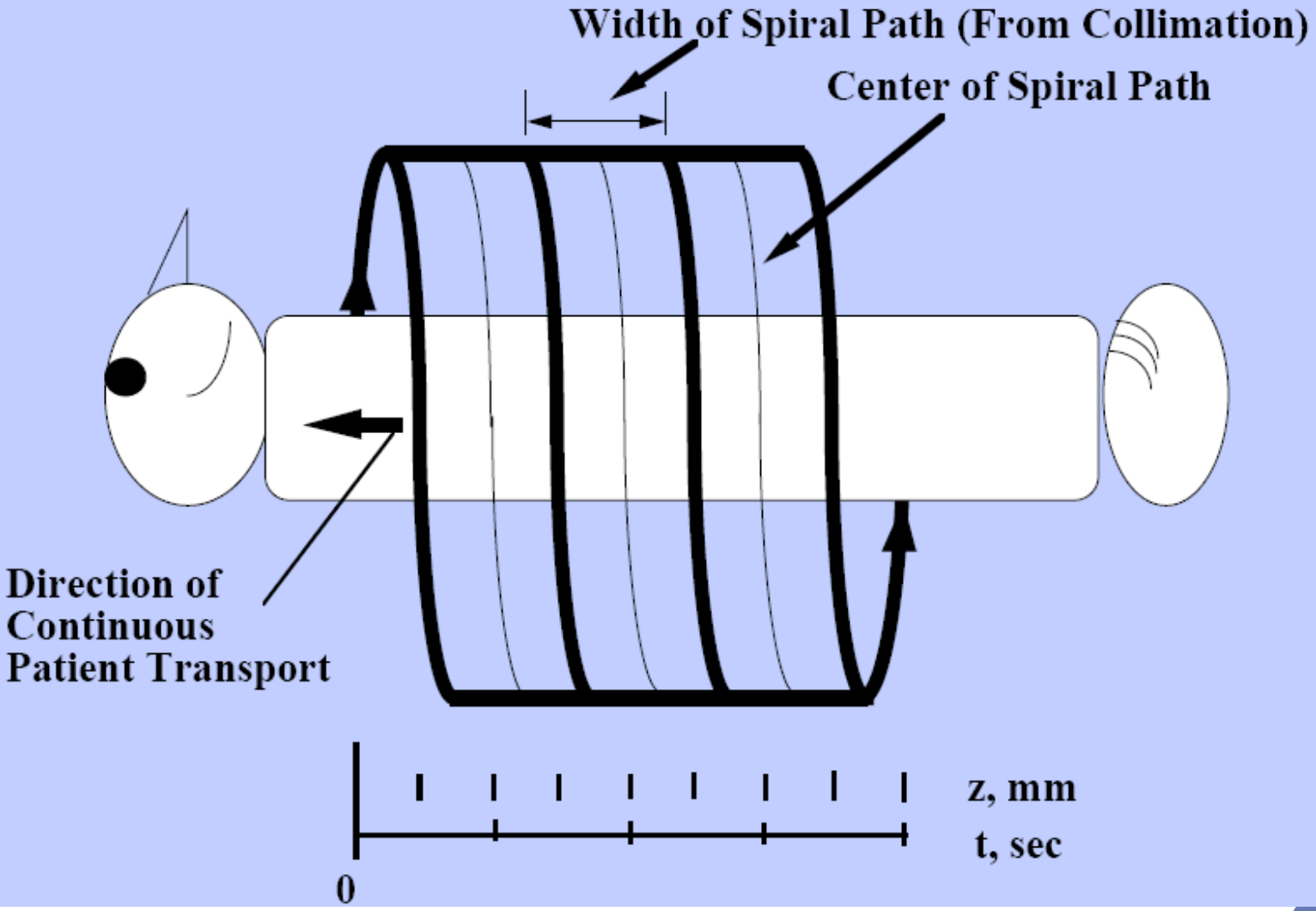

Shaheed Rajaei's Cardiovascular
Medical and Research Center
CORONER_024 (Adult)
ZARGARI-80Yr-M, MAHDI
07-57-06
Topogram
CaScSeq
1
Pause
TestBolus
2
Pause
CorCTA
3
Eff. mAs
600
CARE Dose4D
kV
120
CTDIvol
46.04 mGy
Scan time
Delay
19 s
Slice
3.0 mm
Acq. 64 x 0.6 mm
No. of images
356
Tilt
Comments
Range: Begin
-114.5
End
-221.0
Table:Position
0.0
Height
307.0
Auto Tasking

Equipment, Protocol, Dose and Image Quality

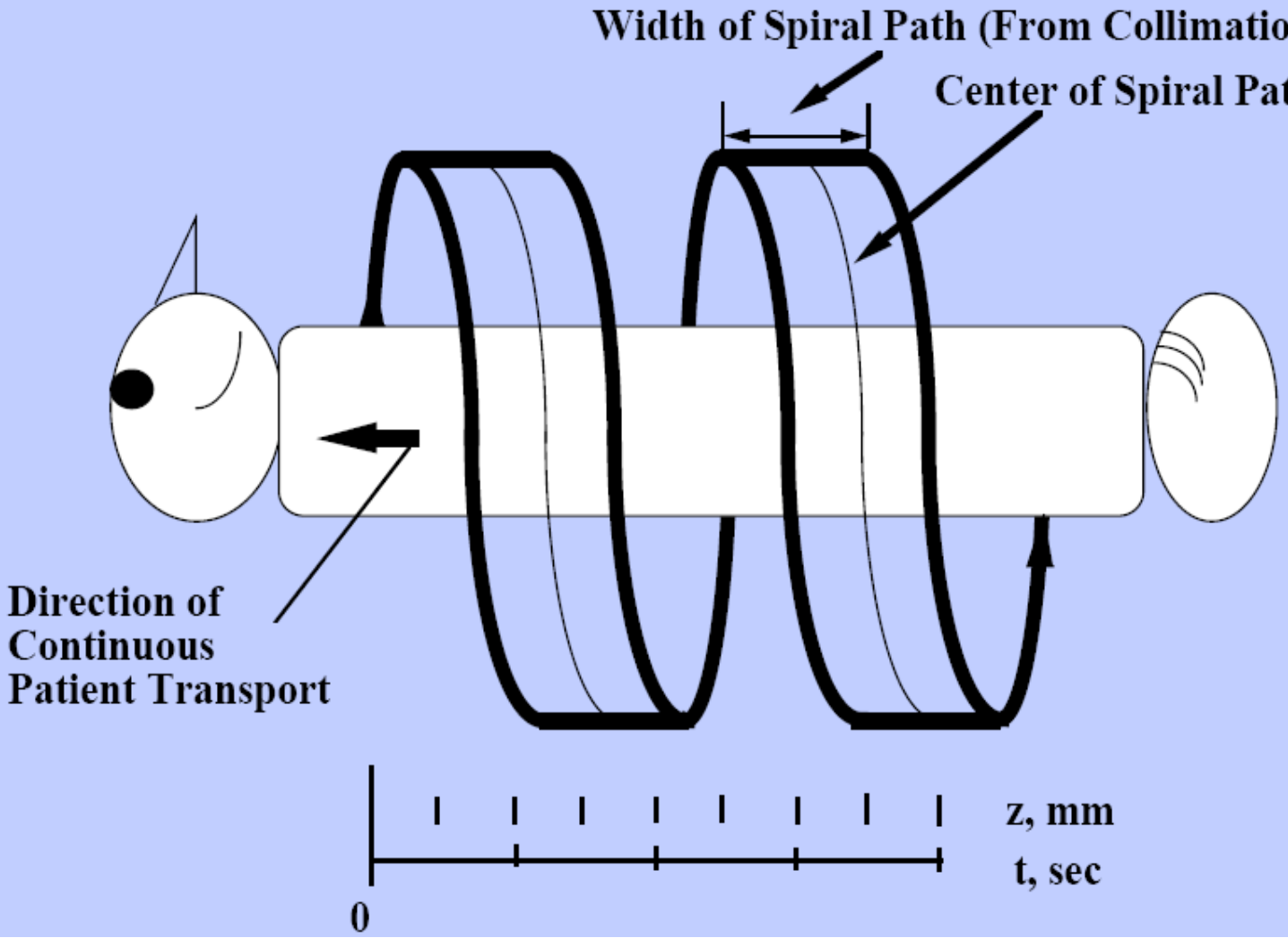
1. Image thickness:

- Should be chosen depending on the size of the child and the application
- Use maximal acquisition collimation (assuming this would result in scanning at lower mA) appropriate for specific diagnosis
- Narrow collimation in MSCT and 1 mm slices on some SDCT result in a higher dose (increase in mAs to maintain image quality)

Pitch=1; Contiguous Spiral



Pitch=2; Extended Spiral



Equipment, Protocol, Dose and Image Quality

2. Pitch:

- SDCT: a pitch factor 1.5 is recommended for most examinations
  - *25% reduction in dose compared with using a pitch of 1*
- MDCT: reduction in dose due to greater pitch may not be achieved
  - *tube current (mA) can be automatically adjusted to keep the dose and noise the same*

Equipment, Protocol, Dose and Image Quality

5. Gantry Tilt

- A straight gantry results in irradiation of a smaller volume of tissue compared with a tilted gantry and is recommended.
- Exception: tilt is used to avoid unnecessary exposure of sensitive tissues, e.g. in brain CT for avoiding the orbits.

Equipment, Protocol, Dose and Image Quality

7. Reconstruction Algorithm

- Appropriate reconstruction algorithms, window levels and window settings should be used

Equipment, Protocol, Dose and Image Quality

9. Viewing Conditions:

- Make sure windows levels and settings are adequate and that the monitors are calibrated.

Equipment, Protocol, Dose and Image Quality

10. Shielding:

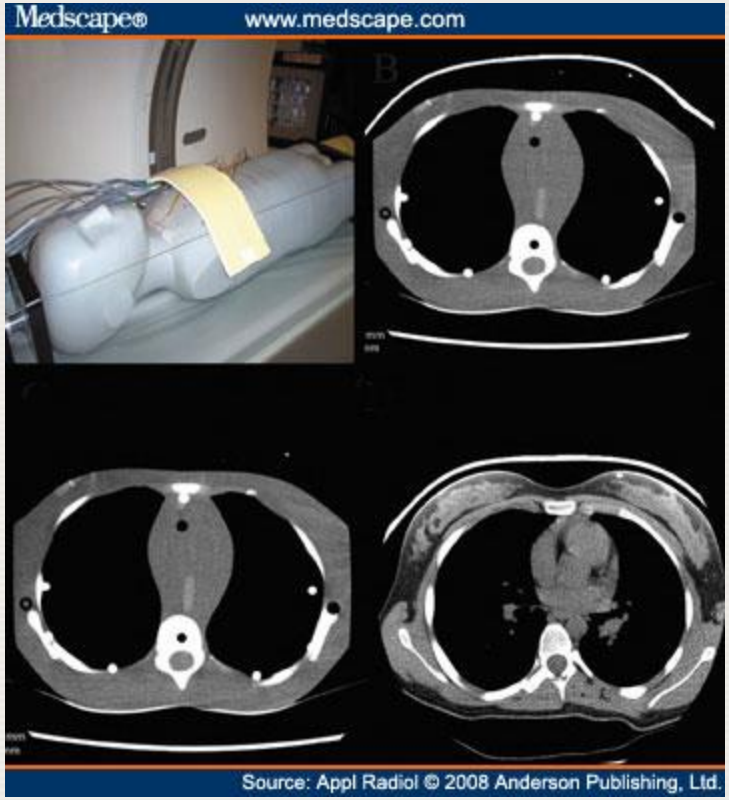
- Lead shielding can be place over the male gonads if:
  - *the edge of the volume of investigation is less than 10-15cm away*
  - *it does not interfere with the image*

Dauer, et al, BMC Medical Imaging 2007, 7:5 doi:10.1186/1471-2342-7-5

Equipment, Protocol, Dose and Image Quality

10. Shielding:

- The use of reusable bismuth attenuation shields is possible for sensitive organs such as the eyes, gonads, breasts and thyroid.



Equipment, Protocol, Dose and Image Quality

11. Training

- The examination should always be supervised by a radiologist experienced in paediatric imaging

If all listed factors are taken into consideration, significant dose reduction can be achieved

Radiologists, Physicists and Technologists' Responsibilities

- Improve awareness of need to decrease CT radiation dose to children.
- Be committed to make a change in daily practice by team work between radiologists, technologists, referring healthcare providers and parents.
- Medical physicists, radiologists, technologists and department managers should review vendor or other CT protocols and "down-size" them for children.