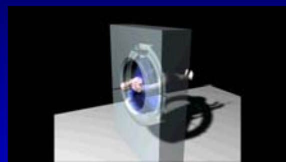
# CT Protocol Optimization over the Range of Patient Age & Size and for Different CT Scanner Types:
## Recommendations & Misconceptions



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## TOPICS:

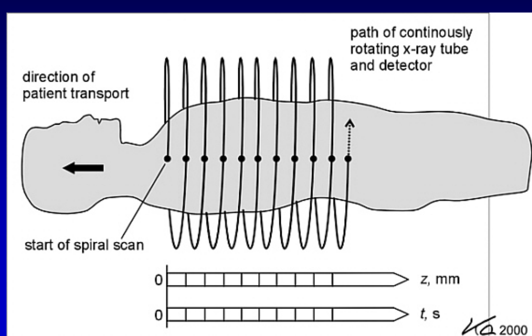
- Computed Tomography Quick Overview
- CT Dosimetry
- Effects of CT Protocols on Image quality and Dose
  - Importance of Understanding AEC in different CT scanners
- Optimization of CT Scan Techniques for Dose & Image Quality Tailored to the Patient Size, Anatomy, and Clinical Task





## Evolution to Helical/ Spiral CT Scanners

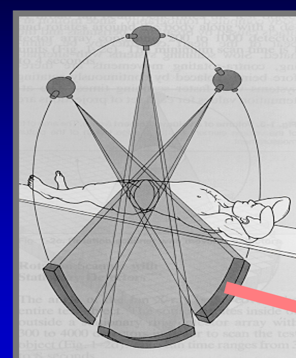
Single Slice Helical/ Spiral CT



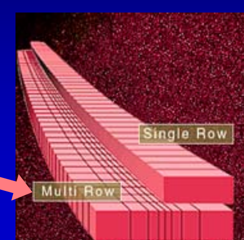





## Evolution to Multislice Scanners
## 2, 4, 8, 16, 64, … ?



Data Acquisition



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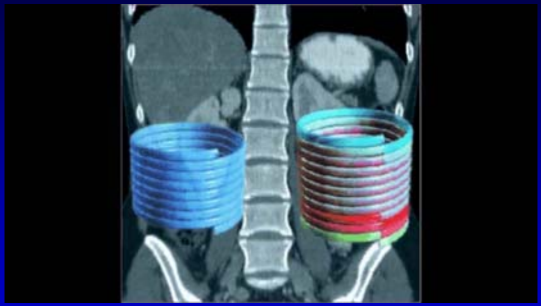



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## Evolution to Multislice Scanners
## 2, 4, 8, 16, 64, … ?

**Definition of Pitch for Single-slice Helical / Spiral Scanning**

$$\text{Pitch} = \frac{\text{Table travel per 360° tube rotation}}{\text{Nominal Slice Thickness}}$$

**Definition of Pitch for Multi-slice Helical / Spiral Scanning**

$$\text{Pitch} = \frac{\text{Table travel per 360° tube rotation}}{\text{Total collimation width of all simultaneously collected slices}}$$



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## CT Protocols

**Scan & Reconstruction Parameters:**

**Pediatric Routine Abdomen/ Pelvis**

From Recon 2: Sa & Co Reformat: Ave., 4.0 mm thick & 2.0 mm interval

| Patient Size: AP + Lateral | 0 - 26 cm | 27 – 31 cm | 32 – 37 cm | 38 – 43 cm | 44 – 55 cm |
|---|---|---|---|---|---|
| *Approximate* Age | Newborn | 6 mo – 2.5 yrs | 3 – 7 yrs | 8 – 12 yrs | 13 - 18 yrs |
| **Protocol Color** | **Pink** | **Red/Purple** | **Yellow/White** | **Blue/Orange** | **Green/Black** |
| **Series 1 - Scout** | | | | | |
| Scout 1: kV / mA | 80 / 10 | 80 / 10 | 80 / 10 | 80 / 10 | 100 / 10 |
| Scout Plane | 180° | 180° | 180° | 180° | 180° |
| Scout 2: kV / mA | 80 / 40 | 80 / 40 | 80 / 40 | 80 / 40 | 100 / 40 |
| Scout Plane | 90° | 90° | 90° | 90° | 90° |
| WW/WL for Scout | 600/50 | 600/50 | 600/50 | 600/50 | 600/50 |
| **Series 2 - Smart Prep – Monitor Phase** | | | | | |
| mA | 20 | 40 | 40 | 40 | 40 |
| Monitoring Delay (sec) | 20.0 | 20.0 | 25.0 | 25.0 | 30.0 |
| Monitoring ISD (sec) | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| Enhancement Threshold | 50 | 50 | 50 | 50 | 50 |
| Diagnostic Delay (sec) | Min. Delay | Min. Delay | Min. Delay | Min. Delay | Min. Delay |



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## CT Protocols

| Patient Size: AP + Lateral | 0 - 26 cm | 27 – 31 cm | 32 – 37 cm | 38 – 43 cm | 44 – 55 cm |
|---|---|---|---|---|---|
| *Approximate* Age | Newborn | 6 mo – 2.5 yrs | 3 – 7 yrs | 8 – 12 yrs | 13 - 18 yrs |
| **Protocol Color** | **Pink** | **Red/Purple** | **Yellow/White** | **Blue/Orange** | **Green/Black** |
| **Series 2 - Helical Scan** | | | | | |
| Scan Type | Helical | Helical | Helical | Helical | Helical |
| Beam Collimation (mm) | 20 | 20 | 20 | 40 | 40 |
| Detector Rows | 32 | 32 | 32 | 64 | 64 |
| Detector Configuration | 32 x 0.625 | 32 x 0.625 | 32 x 0.625 | 64 x 0.625 | 64 x 0.625 |
| Scan FOV | Small Body | Small Body | Small Body | Small Body | Medium Body |
| Pitch | 1.375 | 1.375 | 1.375 | 1.375 | 1.375 |
| Speed (mm/rot) | 27.5 | 27.5 | 27.5 | 55 | 55 |
| Rotation Time (sec) | 0.4 | 0.4 | 0.4 | 0.6 | 0.7 |
| kV | 80 | 80 | 80 | 80 | 100 |
| Smart mA or Manual mA | Smart mA | Smart mA | Smart mA | Smart mA | Smart mA |
| Smart mA min/max mA Range | 15-200 | 25-300 | 40-540 | 40-610 | 60-760 |
| **Noise Index** | **12** | **14** | **15.5** | **17.5** | **17** |
| (Manual mA –[**Ref** w/ ASiR]) | (140) | (210) | (380) | (430) | (530) |
| **Dose Reduction Guidance (%)** | **0** | **0** | **0** | **0** | **0** |
| Slice Thickness (mm) | 3.75 | 3.75 | 3.75 | 3.75 | 5.0 |
| Interval (mm) | 2.00 | 2.00 | 2.00 | 2.00 | 3.0 |

# CT Protocols

| Patient Size: AP + Lateral | 0 - 26 cm | 27 – 31 cm | 32 – 37 cm | 38 – 43 cm | 44 – 55 cm |
|---|---|---|---|---|---|
| *Approximate Age* | Newborn | 6 mo – 2.5 yrs | 3 – 7 yrs | 8 – 12 yrs | 13 - 18 yrs |
| **Protocol Color** | **Pink** | **Red/Purple** | **Yellow/White** | **Blue/Orange** | **Green/Black** |
| *Recon 1:* | | | | | |
| DFOV | 20 | 20 | 20 | 25 | 25 |
| Recon Type | Detail | Detail | Detail | Detail | Standard |
| WW/ WL | 550/100 | 550/100 | 550/100 | 550/100 | 400/60 |
| Recon Option | Plus | Plus | Plus | Plus | Plus |
| **ASiR Setup** | **Slice 40%** | **Slice 40%** | **Slice 40%** | **Slice 40%** | **Slice 40%** |
| Recon 2: | | | | | |
| DFOV | 20 | 20 | 20 | 25 | 25 |
| Recon Type | Detail | Detail | Detail | Detail | Detail |
| WW/ WL | 500/80 | 500/80 | 500/80 | 500/80 | 400/60 |
| Recon Option | Plus | Plus | Plus | Plus | Plus |
| Recon Option | IQ Enhance | IQ Enhance | IQ Enhance | IQ Enhance | IQ Enhance |
| **ASiR Setup** | **Slice 40%** | **Slice 40%** | **Slice 40%** | **Slice 40%** | **Slice 40%** |
| Slice Thickness (mm) | 1.25 | 1.25 | 1.25 | 1.25 | 1.25 |
| Interval (mm) | 0.625 | 0.625 | 0.625 | 0.625 | 0.625 |



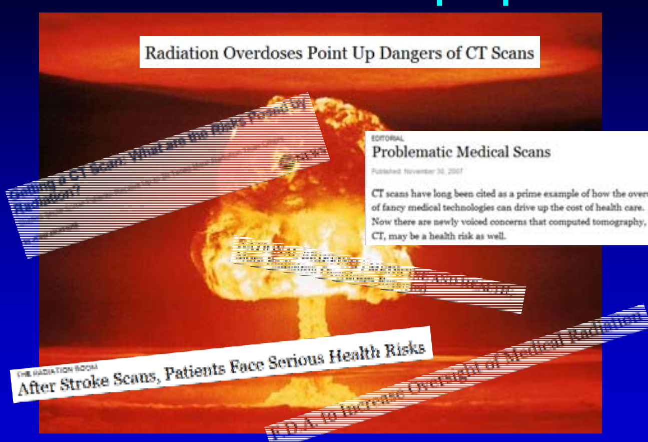


# Dose in Computed Tomography





# Radiation scares people








# Skin Damage from CT

**All these skin burns/ hair loss were due to perfusion CT scans for stroke diagnosis – these scans were performed incorrectly at about 8 or more times the proper dose.**

# RADIATION UNITS

| | | New SI Units | | Old Conventional Units |
|---|---|---|---|---|
| **Absorbed Dose** | *Units:* | gray (Gy) | or | rad (r) |
| **Equivalent Dose** | *Units:* | sievert (Sv) | or | rem |
| **Effective Dose** | *Units:* | sievert (Sv) | or | rem |



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# RADIATION UNITS

## Absorbed Dose

gray (Gy) or rad [1 Gy = 100 rad]

Energy absorbed per unit mass of tissue

Important for skin effects/ effects on specific organs

## Equivalent Dose

sievert (Sv) or rem [1 Sv = 100 rem]

Equivalent dose = absorbed dose x radiation weighting factor ($w_R$)



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# RADIATION UNITS

## Effective Dose

*The concept of effective dose takes into account the risk to the person exposed to radiation that is **not uniform** over the entire body.*

*Different organs have different sensitivities to radiation*

*This is expressed by the **tissue weighting factor: $w_T$***



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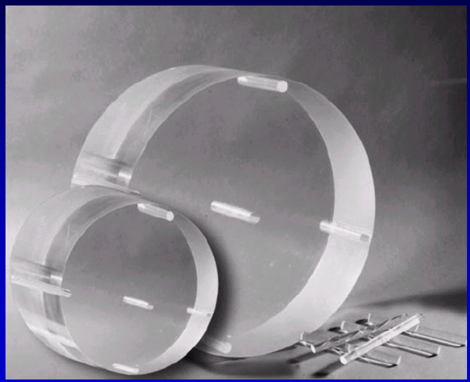
# CT Dose

- CTDI Phantoms



## CT Dose

- CTDI
  - $CTDI_{100}$ measured at the center of the phantom is called $CTDI_{100}$ (center)
  - $CTDI_{100}$ measured near the surface of the phantom is called $CTDI_{100}$ (surface) or $CTDI_{100}$ (peripheral)





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## CT Dose

- CTDI
  - $CTDI_w$ is a weighted value of $CTDI_{100}$ that attempts to give the average volume dose in the central slices of an extended scan length and phantom (again, for contiguous axial slices or for helical scanning at a pitch of 1). It is defined as:

$$CTDI_w = 1/3\ CTDI_{100}\ (center) + 2/3\ CTDI_{100}\ (surface)$$





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## CT Dose

- CTDI
  - If you then take into account the effect of pitch on dose for a helical/ spiral scan then you have another version of CTDI:

$$CTDI_{vol} = CTDI_w / Pitch$$

  - This is an approximation that attempts to give the average volume dose in the central slices of an extended scan length and phantom.





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## CT Dose

- DLP
  - A final dosimetry measure is the Dose Length Product (DLP) which is defined as:

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

and has units of mGy • cm

- $CTDI_{vol}$ and DLP are the radiation units provided by the CT Scanner.

## CT Dose

- DLP
  - **Estimates** of a patient's effective dose (E) can be derived from the values of DLP for an examination. Use the following equation containing a coefficient k appropriate to the examination:

$$E = k \times DLP$$



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## CT Dose

- Effective Dose from DLP
  - Values of k for Adult scans:

| Region of Body | k (mSv / mGy•cm) | | Phantom |
|---|---|---|---|
| Head | 0.0023 | 0.0021 | 16 cm |
| Head & Neck | | 0.0031 | 16 cm |
| Neck | 0.0054 | 0.0059 | 32 cm |
| Chest | 0.017 | 0.014 | 32 cm |
| Abdomen | 0.015 | 0.015 | 32 cm |
| Pelvis | 0.019 | 0.015 | 32 cm |

⇑ From 2 different sources ⇑



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## CT Dose

- Effective Dose from DLP
  - Values of k for Pediatric scans:

| Region of Body | 0 Year | 1 Year | 5 Year | 10 Year | Phantom |
|---|---|---|---|---|---|
| | k (mSv / mGy•cm) | | | | |
| Head | 0.0087 | 0.0054 | 0.0035 | 0.0027 | 16 cm |
| Head & Neck | 0.0100 | 0.0068 | 0.0048 | 0.0040 | 16 cm |
| Neck | 0.0210 | 0.0168 | 0.0121 | 0.0094 | 16 cm |
| Chest | 0.0739 | 0.0482 | 0.0739 | 0.0237 | 32 cm |
| Abdomen | 0.0841 | 0.0530 | 0.0357 | 0.0249 | 32 cm |
| Pelvis | 0.0701 | 0.0446 | 0.0300 | 0.0219 | 32 cm |



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## CT Dose

- Effective Dose from DLP
  - There's an app for that:
  - CT Dose Free:

## CT Dose

- Possibility of a large mistake (factor of 2 or more) in calculating pediatric effective doses:
  - With some scanners the pediatric body doses were based on the DLP from a **16 cm phantom**: this was the ACR recommended phantom.
  - However with other scanners the pediatric body doses were based on the DLP from a 32 cm phantom





## CT Dose

- Thus you must pay attention to the phantom size used for the $CTDI_{vol}$ and the DLP value given on the scanner for the values to be meaningful.
  - Most manufactures that did use the 16 cm phantom for the pediatric body are now switching to the use of the 32 cm phantom instead. So beware.





## CT Dose

- You have to be careful even when using these tables:
  - The dose is calculated for a “standard size patient” and many (or most) patients are larger.
  - This changes the dose estimate.
  - This effect on the $CTDI_{vol}$ has been investigated by two AAPM task groups.





## CT Dose

- They used a method called “Size-Specific Dose Estimates” (SSDE) to provide dose corrections for the $CTDI_{vol}$. See the following AAPM Reports:
  - AAPM Report No. 204 & No 220.
- However these reports warn you against using these corrections to correct the DLP or the estimated dose for patient size
  - The patient model for calculating the $E_{DLP}$ still uses a standard patient size.

# Effect of CT Protocols on Image Quality and Dose



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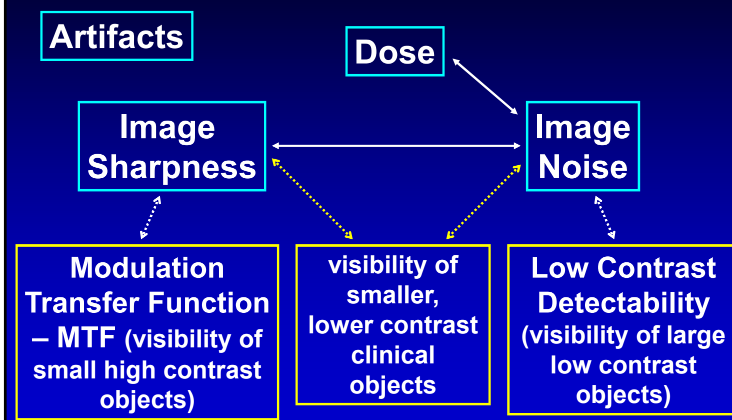
## Image Quality and Dose:



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## Axial Basic Scan & Reconstruction Techniques Affecting Image Quality & Dose

- kV
- mAs – mA & rotation time
- Slice thickness



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## Helical Basic Scan & Reconstruction Techniques Affecting Image Quality & Dose

- kV
- mAs – mA & rotation time
- Slice thickness
- Pitch

## Helical Scan Techniques Affecting Image Quality & Dose

### Definition of Pitch for Multislice Helical / Spiral Scanning:

$$\text{Pitch}_{coll} = \frac{\text{Table travel per 360° tube rotation}}{\text{Total collimation width of all simultaneously collected slices}}$$







## Helical Scan Techniques Affecting Image Quality & Dose

- The image noise and patient dose for helical scanning is generally a function of **mA x rotation time / pitch** which is often referred to as "**Effective mAs**":

**Effective mAs = mAs / pitch**







## Helical Scan Techniques Affecting Image Quality & Dose

Effective mAs = mAs / pitch

- Siemens and Toshiba scanners use the term "Effective mAs" in their scan techniques.
- Phillips uses the term "mAs / slice", which means the same as effective mAs.







## Helical Scan Techniques Affecting Image Quality & Dose

Effective mAs = mAs / pitch

- You may change the mA, rotation time, or pitch values, but if the effective mAs remains constant, so does the $CTDI_{vol}$ and the patient dose.
- If the effective mAs remains constant the image noise will also remain constant or nearly so.

# Manual vs. Automatic Exposure

## One deficiency of CT Scanners before 2001

- They did not contain any type of “phototimer” or automatic exposure control (AEC) to assure a proper patient dose.
- Therefore, manual technique charts were needed for different patient sizes.
- Usually this was not done ➡ so that techniques more suited for larger patients were used on all patients resulting in unneeded radiation exposure.



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# Automatic Exposure Control in CT Scanners

- Modern CT scanners have some type of automatic exposure control (AEC) that changes the mA during the scan.
- There are two basic types of AEC that can be used separately or together:
  - The scanner varies the mA at different axial positions of the patient.
  - The scanner varies the mA as the tube rotates around the patient.
- It is optimal to use both types together if the scanner allows it (Most do allow it).



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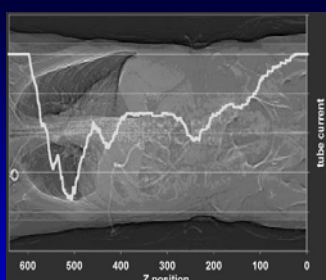
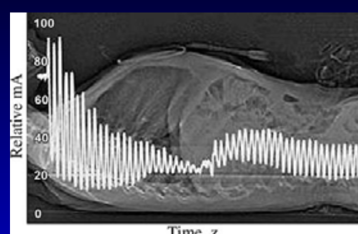
# Automatic Exposure Control in CT Scanners




The scanner varies the mA at different axial positions of the patient.




The scanner varies the mA at different axial positions of the patient and also varies the mA as the tube rotates around the patient.



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# Automatic Exposure Control in CT Scanners

- Caution: The methods used by different manufacturers to perform AEC in CT are very different and may achieve very different clinical results.

## Automatic Exposure Control in CT Scanners

- Some scanners (GE, Toshiba) try to keep the image noise constant as patient size increases: the automatic exposure control is adjusted by selecting the amount of noise that you wish in the image. This is done by selecting a **"Noise Index"** or **"SD"** (standard deviation).
  - Typical values of Noise Index are **2.5 to 3.5** for a standard adult head scan and **12 to 20** for the body (for a 5 mm slice thickness).
  - The scanner attempts to keep the image noise constant by adjusting the mA within set limits.





## Automatic Exposure Control in CT Scanners

- For scanners that use a "Noise Index" or "SD" for AEC:
  - The dose for a scan depends both on the "Noise Index" or "SD" **AND** the **slice thickness** selected for the **first** image reconstruction.
  - Let's say you want to view reconstructed slice thicknesses of both 5 mm and 1.25 mm:

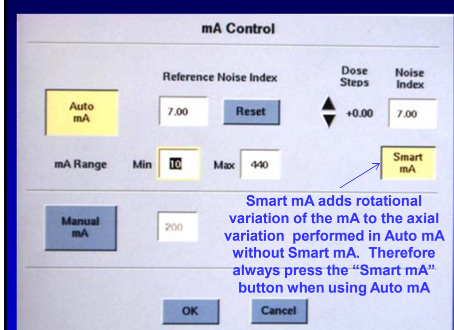
    Suppose the first image reconstruction has a slice thickness of 5 mm with a Noise Index of 12. If the first image reconstruction is switched to a slice thickness of 1.25 mm, the Noise Index needs to be changed to 24 to keep the dose constant.





## Automatic Exposure Control in CT Scanners

### GE Example:




With GE scanners you must select whether you will be using manual techniques "Manual mA" or AEC techniques "Auto mA".

"Manual mA" uses an actual mA setting, "Auto mA" uses a Noise Index setting.

Having one set correctly in a protocol does nothing to insure the other is properly set.





## Automatic Exposure Control in CT Scanners

- Other scanners (Siemens, Philips) allow you to select the **"Effective mAs"**, or the **"mAs/ slice"** that you would use for an "reference" size patient. For Siemens scanners this selection is called the **"Quality reference mAs".**
- In AEC mode the scanner then automatically increases or decreases the effective mAs for larger or smaller patients. This is done by varying the mA.

**Effective mAs**
**mAs/ slice** = (mA x rotation time) / pitch

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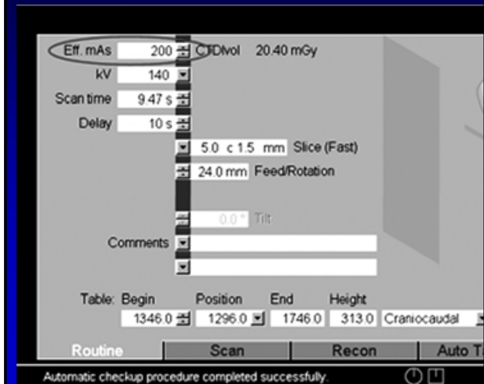
## Automatic Exposure Control in CT Scanners

### Siemens:




With Siemens scanners you select the "Eff. mAs" whether you will be using manual techniques **OR** AEC techniques.

In manual mode this is the actual eff. mAs used and in AEC mode it is the eff. mAs that you would desire for an "reference" size patient.

There is not the use of 2 different parameters for manual & AEC mode.



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## Automatic Exposure Control in CT Scanners

- Scanners that try to keep the image noise constant have the problem that they can quickly reach the maximum mA "ceiling" before getting to very large patients.
- Scanners that use a reference mAs setting will generally allow the mA to increase only modestly with increased patient size, allowing the image noise to increase substantially for large patients.
- What is needed is a new AEC approach and the use of higher kV for larger patients.



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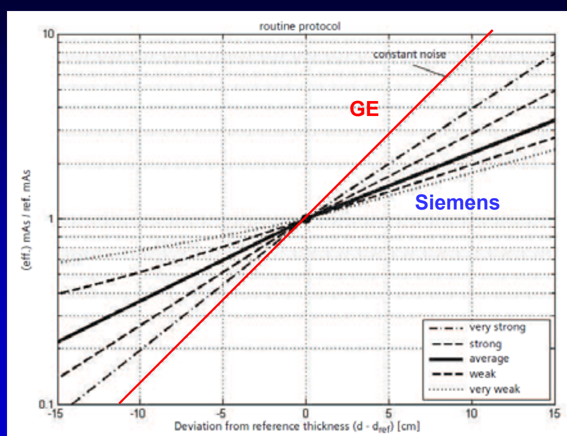
## Automatic Exposure Control in CT Scanners



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## Automatic Exposure Control in CT Scanners

### A Concern with All CT Scanner:

- Proper centering of the patient is very important for the proper operation of the AEC system.
- A common problem is mis-centering the patient too low in the scan field.
- This can "fool" the AEC and also produce variable image quality over the patient.

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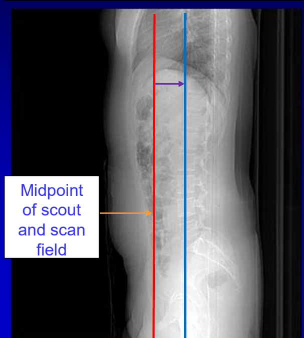
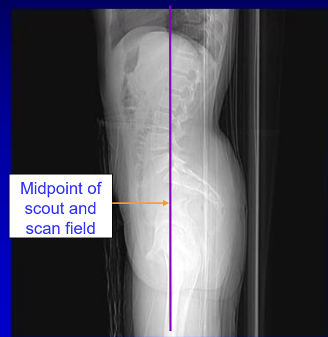
## Automatic Exposure Control in CT Scanners

### A Concern with All CT Scanners:

Patient positioned 6 cm too low




Patient positioned properly



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## Automatic Exposure Control in CT Scanners

### A Concern with All CT Scanner:

- Most scanners use the last scout / topogram to adjust the mA modulation (though fine tuning can be done real time with some scanners.)
- Thus if the last scout/ topogram performed is a AP or PA a patient positioned too high or too low will fool the scanner into thinking that the lateral dimension is larger or small than reality.
- Thus a lateral scout / topogram should be the last performed

  

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## Image De-noising with Iterative Reconstruction

- Iterative Reconstruction (IR) is an additional step after performing Filtered Back Projection (FBP) which can reduce image noise
- Scanner manufacturers often make unrealistic claims on possible dose reductions based on the amount of noise reduction obtained with full strength IR
- However - Image noise reduction DOES NOT correlate well with actual improvements in Low Contrast Detectability (LCD) when using IR

  

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## Image De-noising with Iterative Reconstruction

- One manufacturer claims a 40% dose reduction compared to FBP with the use of a moderate IR strength
- You will get the same image noise with this 40% dose reduction with this use of IR
- However the LCD will be substantially degraded
- Our tests indicate that you can only reduce the dose by 10% if you want the same LCD or the same diagnostic quality using this IR

## Image De-noising with Iterative Reconstruction

- Other problems with IR:
- You will get a substantially modified image noise, texture which can interfere with your ability to "read through the noise"
- Image blurring can occur, particularly with sharp algorithms.
- Real image textures give difficulties to the IR reconstruction, adversely affecting the image:
  - The image noise may not be reduced as much
  - Some of the image texture may be erased





## Other newer innovations in CT scanners to improve image quality and/or dose

- The introduction of 70 kV for smaller pediatric patients: head or body scans.
- Auto kV selection that uses patient attenuation and clinical task to select optimal scan kV.
  - Patient size affects the kV selection.
  - The importance of iodine or bone in the imaging will also affect the kV selection, since this would lower the optimal kV.

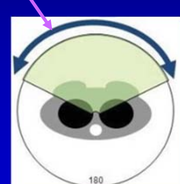




## Other newer innovations in CT scanners to improve image quality and/or dose

- mA modulation that decreases the mA over the anterior part of the patient to reduce dose to the anteriorly positioned organs (organ dose modulation)
  - Attempts to reduce dose to the breast, lens of the eye.
  - Limitations: Degree of mA reduction; effectiveness compared to simply reducing the effective mAs by a small amount.

Reduced mA








# Optimizing CT Protocols:

# Misconceptions

# and

# Recommendations

## for Scan and Imaging Parameters

## kV

### Misconceptions:

- Scanning at 140 kV will reduce patient dose for any type of CT scan: head, body, adult or pediatric.
- For head scans, 140 kV should be used through the posterior fossa region to reduce image artifacts from bone.





## kV

### Recommendations:

- If we ignore beam hardening artifact limitations and CT scanner power limitations:
  - The theoretical optimal kV, for any CT imaging, is the kV that will give the highest ratio of contrast to noise at a given patient dose.





## kV

### Recommendations:

- For all Head CT scans and all Head or Body Pediatric scans this “theoretical optimal” would be close to 80 kV.
- For Adult Body CT scans this “theoretical optimal” will range from 80 kV up to 140 kV.





## kV

### Recommendations:

- Modern CT scanners now have higher x-ray power & much more efficient use of this power through multi-slice design.

  They also have improved beam hardening/ bone correction algorithms.

  These improvements allow you to use lower kV settings – closer to the theoretical optimal.

# Optimal kV Technique Setting for Axial or Helical Scanning

## kV - Head CT – Peds and Adult

- Use 70 - 80 kV for Peds Head 0 - 2y w/wo IV contrast.
- Use 80 kV for Peds Head 2 - 6y w IV contrast.
- Use 100 kV for Peds Head 2 - 6y wo IV contrast.
- Use 100 kV for Adult Head w IV contrast.
- Use 120 kV for Adult Head wo IV contrast.





# Optimal kV Technique Setting for Axial or Helical Scanning

## kV – Body CT - Peds

- Use 80 kV for all Peds Body for whom the sum of lateral and AP dimensions is less than 44 cm w/wo IV contrast. If available, 70 kV can be used.
- Use 100 kV for Peds Body for whom the sum of lateral and AP dimensions is between 44 - 55 cm wo IV contrast.
- Use Adult protocols for larger patients.





# Optimal Technique Setting for Axial or Helical Scanning

## kV – Body CT – Adults – wo IV contrast

- Use 100 kV for Small Adults for whom the sum of lateral and AP dimensions is less than 60 cm.
- Use 120 kV for Medium Size Adults.
- Use 140 kV for Large Adults for whom the sum of lateral and AP dimensions is greater than 80 cm.
  - 140 kV for Large Adults reduces image noise and provides better image quality without large exposure increases.





# Optimal Technique Setting for Axial or Helical Scanning

## kV – Body CT – Adults – w IV contrast

- Use 80 kV for Small Adults for whom the sum of lateral and AP dimensions is less than 60 cm.
- Use 100 kV for Medium Size Adults.
- Use 120 kV for Large Adults for whom the sum of lateral and AP dimensions is greater than 80 cm.
  - Note: the use of lower kV produces a significant increase in the contrast of iodine, with better optimization of contrast to noise.

# kV

## Recommendations:

- For scanning the neck or upper thorax, the amount of lateral attenuation through the shoulders is a serious problem for average to large size patients.
- It will cause some degree of horizontal streaking artifact through the shoulder, which is actually a noise effect.



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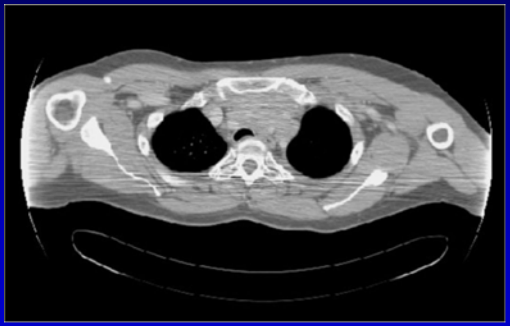
## Artifact due to the patient extending outside the Scan Field of View; ALSO “Stringy” noise artifact





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# kV

## Recommendations:

- Here the solution is to *increase* the kV from 120 kV to 140 kV in adults for shoulder imaging to reduce the amount of lateral attenuation through the shoulders as much as possible and thus reduce this “noise” streaking artifact.



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# kV and Pitch - Pediatric

## Misconceptions:

- Using 140 kV for children to reduce dose.

  On the contrary this will generally raise the dose for equal image quality and is not recommended.

- Using a pitch greater than 1.0 for children is often strongly recommended to reduce radiation dose.

  This is totally misguided, as we will see shortly.

# Pitch

## Misconceptions

- Scanning at higher pitch should be used as a strategy to reduce adult or pediatric patient dose and is always the best way to reduce scan time and motion artifact and blur.

WRONG!!!





# Pitch

## Misconceptions:

- A pitch of less than one over-irradiates the patient due to scanning overlap, and thus wastes radiation dose.
- Thus one should avoid using a pitch less than one, particularly in pediatric scans.

WRONG!!!





# Pitch

THE MEDICAL PHYSICS CONSULT

MAHADEVAPPA MAHESH, MS, PhD, RICHARD L. MORIN, PhD

The Correct Selection of Pitch for Optimal CT Scanning: Avoiding Common Misconceptions

*Frank N. Ranallo, PhD, Timothy Szczykutowicz, PhD*

Today's state-of-the-art CT scanners include many features that aid in the selection of optimal technique parameters. Vendors offer solutions for choosing the optimal beam energy (tube voltage), automatic exposure control (AEC) via tube current modulation, control, patient positioning within the gantry, and patient-specific contrast injection protocols. The trend seems to be leading to a "push button" CT scanner in which only the dose, noise level, and image sharpness, determined by the clinical indication,

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# Pitch

## Recommendations:

- Changing the pitch from 1.0 to 0.5 increases the patient dose by a factor of 2 but also decreases image noise.
- These effects on dose and noise are the same as increasing the mA or the rotation time by a factor of 2.
  - But decreasing the pitch has the added advantage of decreasing helical artifacts.

# Pitch

## Recommendations:

- The effect of increased dose at lower pitch is easily countered by reducing the rotation time or mA in manual mode.
- There is NO increase in dose when decreasing pitch in AEC mode since the AEC mode in all scanners will keep the dose constant as the pitch is changed.



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# Pitch

## Recommendations:

- Lowering the pitch and decreasing the exposure time by the same factor will keep the patient dose and exam time constant, but provide better image quality – *you get something for nothing!*



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# Pitch

## Recommendations:

*Example:*

- *Change a 1.0 sec rotation time and a pitch of 1.6 to*

  *a 0.5 sec rotation time and a pitch of 0.8*



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# Pitch

## Recommendations:

- For head scanning ALWAYS use a pitch of less than 1.0 to minimize helical artifact for adult or pediatric scanning.
- Best results are usually obtained with a pitch just above 0.5: 1 .

## Pitch

### Recommendations:

- For body scanning use a pitch of less than 1.0 whenever possible to minimize helical artifacts and allow more radiation for the adequate imaging of larger patients.
- When decreasing pitch in body scans, you need to be aware of breath hold limitations and contrast considerations .





## Proper Use of Higher Pitch

### Recommendations:

- When to increase pitch (greater than 1.0):
  - For pediatric and adult body scanning a shorter total scan time may allow a reduction in contrast volume.
  - You may find that using a pitch greater than 1.0 allows a shorter total scan time with the available scan rotation times. Important in pediatric body scanning.





## Axial vs. Helical Scanning

### Misconceptions:

- Heads should always be scanned using the axial rather than the helical mode or you will get a lower quality image.





## Axial vs. Helical Scanning

### Recommendations:

- Helical scanning will almost always allow an exam with equal or better image quality than an axial scan if you have a CT scanner with 16 or more slices and select proper scan techniques.
- Axial scanning is still useful if required for positioning of the patient to avoid artifacts, since tilting the gantry is not allowed with helical scanning.

## Axial vs. Helical Scanning and slice reconstruction interval

### Recommendations:

Advantages of Helical scanning:

- Shorter total scan time with less chance for patient motion during the scan.
- The ability to reconstruct slices at intervals less than the slice thickness.

VERY IMPORTANT!





## Axial vs. Helical Scanning and slice reconstruction interval

### Recommendations:

- With axial scanning, the slice reconstruction incrementation is normally equal to the slice thickness.





## Axial vs. Helical Scanning and slice reconstruction interval

### Recommendations:

- With helical scanning, the slice reconstruction incrementation can be set at any value. The best z-resolution is obtained by reconstructing at intervals ½ of the actual slice thickness – this particularly helps with multiplanar reformatting.
- This is a significant advantage of helical scanning that is often not utilized.



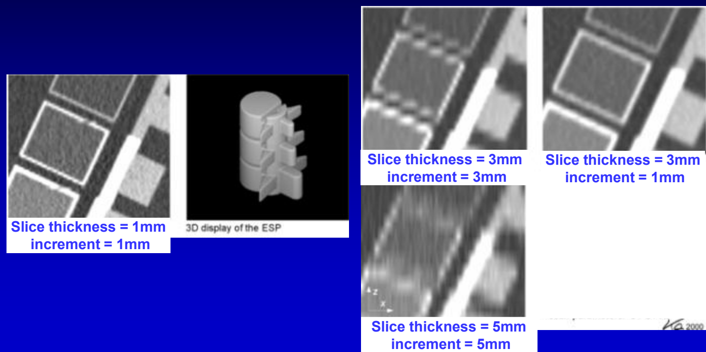


## Axial vs. Helical Scanning and slice reconstruction interval

### Recommendations:

- When creating slices for reformatting of axial images to a modified axial plane, or for sagittal or coronal images, ALWAYS use thin slices as the source images, if this is not done automatically by the scanner. DO NOT USE 5 mm slices!
- For soft tissue recons use 1.0 to 1.5 mm slice thickness.
- For bone or high res recons use 0.5 to 0.75 mm slice thickness.

# Axial vs. Helical Scanning and slice reconstruction interval








# Optimizing CT Protocols

- This talk has discussed some the most important ideas in CT protocol optimization.
- A final thought: After optimizing all other parameters:
  - Reduce the patient dose to a level that produces consistently diagnostic scans – and no lower!