Scanner Components and Operation – 3



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Major Component -- Gantry

- Ring-shaped part of the CT scanner
 - 70-90 cm
 - 15 30 degree forward or backward tilt
- Houses:
 - Slip rings
 - Generator
 - Cooling system
 - X-ray Tube
 - Filters
 - Collimators
 - Detectors



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X-Ray Tubes

- First and second generation scanners used
 - fixed anode
 - oil-cooled x-ray tubes
- Modern CT uses
 - rotating anode tubes for better tube cooling
 - Focal spot of .5 and 1 mm
 - Small focal spot better detail

- Helical scanner tubes rotate for a longer period, thus the tube must be able to sustain high power levels
- Many technical and design advances have been made.







Straton X-ray Tube

- For Multi slice (MSCT)
- Differences from Traditional
 - Entire tube rotates
 - Entire tube immersed in oil
 - Oil is circulated for cooling
 - Deflected Electron
 beam to 2 focal spots



Due to fastest anode cooling, STRATON never accumulates heat during exposure.



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Protective Housing

- X-rays are emitted isotropically, with equal intensity in all directions
- The tube window is the section of tube designed to let x-rays pass through
- These x-rays are called the useful beam
- All others are termed Leakage Radiation



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Glass Envelope

- Tube is evacuated and contains two electrodes: cathode and anode
- Most tubes are made of pyrex, some newer tubes have metal construction
- As tungsten filament vaporizes in glass tube arcing can be a problem

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Cathode

- Cathode is the negative side of tube
 - Contains: Filament & Focusing Cup.
 - Filament: coil of thoriated tungsten wire and is a source of electrons
 - Tungsten has high melting point 3410°c
 - Focusing cup: filament is embedded in metal focusing cup.
 - Negatively charged focusing cup directs electrons to specific area of anode

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Filament

- Dual Filamnets: most x-ray tubes have a small and large filament
- Filament provides resistance to flow of electrons and the heat produced causes thermonic emissions to occur.
- These are the electrons that strike the target of the Anode







Anode

Anode is the positive side of x-ray tube

- Two types of anode:
 - stationary (no longer used)
 - Rotating
- Functions of anode
 - Anode target surface is where the high-speed electrons from the filament are suddenly stopped, resulting in the production of X-rays

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Focal Spot of Anode

- Small focal spot is associated with small filament.
- Large focal spot is associated with a large filament



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Anode Construction

- Anode construction:
 - copper for shaft
 - graphite and molybdenum light weight and dissipate heat.
- Target:
 - area of anode struck by electrons
 - usually constructed of tungsten/rhenium alloy.
- Tungsten's high atomic # (74) results in high efficiency x-ray production.





Target of Anode

- Rotating anode provides approximately 1000 times more area for electron beam to interact than a stationary anode
- Rotating Anode is driven by an electromagnetic induction motor



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Rotating Disk/Anode

- Made of an RTM alloy:
 - Rhenium
 - Tungsten
 - Molybdenum
- Small target angle (usually 12 degrees)
- Rotation speed of 10,000 rpm





Line Focus Principle

- Line-focus principle: by angling the target an effective focal spot can be created that is smaller than the actual focal spot.
- When target angle is made smaller, effective focal spot will be smaller.
- X-ray tube target angles vary from between 5^o 15^o

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X-RAY TUBE

- Line-focus principle simultaneously:
- Improves spatial resolution of the x-ray beam
- As well as the heat capacity of the anode



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X-Ray Tube Failure

- Tube failure: tube life is extended by using appropriate radiographic factors of mA, kVp and time.
- Almost all tube failure is related to thermal characteristics of x-ray tube.
- Tube heat must be dissipated through radiation, conduction and convection.
- Tube warm-up procedures must be followed per manufacturers instructions

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Gantry Components



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Slip-Ring Technology

- Allows for continuous gantry rotation-faster scan times/no interscan delay
- Referred to as continuous rotation, Volumetric or Helical scanning
- Fast data collection- required for angiography and continuous acquisition protocols
- No high tension cables of the start/stop scanners

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Generator

- Produce high voltage for the creation of x-ray photons
 - Increasing the voltage (i.e., kV) will increase the intensity of the x-ray beam. (quality or Hardness of beam)







• Early scanners used high-voltage stand alone transformer that were bulky with high tension cable from

the generator to the x-ray tube

- Now high frequency generator are used
 - Smaller and more efficient at x-ray production
 - Located inside the gantry
- kVp range settings 80, 120 & 140
 - High kVp reduces patient dose by allowing a lower mAs
 - Reduces heat load by using lower mA setting
- mA range settings 20-500 Advanced Health Education Center[®]



Cooling Systems

- The production of x-ray energy results in a large amount of by-product heat
- Blowers, filters, or other devices help to dissipate the excess heat







Filters

- CT X-ray beams have long and short wavelengths polychromatic.
 - Original scanner had monochromatic beam that satisfied the Lambert-Beer exponential attention law
 - Beam needs to be monochromatic on nearly monochromatic for reconstruction purposes. (Lambert-Beer exponential attenuation law)
- CT Filter has dual Purpose
 - Removes long wavelengths (low energy) x-rays that contribute to patient dose but DO NOT help form the image
 - This is called beam hardening
 - Filtration shapes the energy distribution across the radiation beam to produce uniform beam hardening . This reduces beam hardening artifacts

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Bowtie Filters and Beam Hardening





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Collimation

- Restricts the x-ray beam to a specific area
- Reduces scatter radiation
- Improves contrast resolution
- Decreases patient dose



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Collimation

- Two collimators in CT:
 - Pre-patient
 - Post patient or Pre-detector
- Pre-patient collimator
 - positioned near the x-ray source
 - Controls the patient dose
- Post Patient Collimator
 - Removes scatter and improves image quality





Collimators

- Both sets of collimators insure a constant beam width
- Improves Contrast Resolution
 - Contrast Resolution is the ability to differentiate small density
 - differences on the image
 - Reducing scatter always improves contrast resolution
- Post patient collimators control the slice thickness by widening or narrowing the x-ray beam.

• As the slice thickness changes so does voxel size. Advanced Health Education Center

Detector - Scintillation (solid state)

- Converts x-ray energy into light, and then the light is converted into electrical energy
- Consist of scintillation crystals coupled to a photomultiplier (PM) tube
- Early scanners used sodium iodide crystals couple to PM tubes
- Today most scintillators are cadmium tungstate or high-purity rare earth oxides
- The detector efficiency rate of solid state detectors is 99%.
- Automatically recalibrated between scans.





Detector Gas - Ionization Detectors

- Based on the principle of ionization
- Gas-filled detector array uses small ion chambers filled with high-pressure xenon or other gas
- Each ion chamber is about 1mm wide with essentially no inter-space
- Has excellent stability and fast response times but detector efficiency is only 50%.





Detector Characteristics

- Efficiency :
 - The ability to capture, absorb, and convert x-ray photons to electrical signals.
 - Capture efficiency:
 - The efficiency with which the detectors can obtain photons transmitted thru the patient
 - Size of detector face
 - Spacing of detectors
 - Absorption efficiency:
 - the number of photons absorbed by the detector
- Stability
 - Steadiness or ability to stay in calibration
- Response Time
 - Speed of detecting and recovering to capture a new photon

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Data Acquisition System (DAS)

- Positioned Between
 - Detector array and Computer
- 3 functions:
 - Measures the photons that pass through the patient and strike the detectors
 - Converts data from analog to digital
 - Transmits binary data to computer

Data Acquisition System

The DAS consists of the following parts



- X-ray photons come on the detector.
- The detector detects the intensity in form of current.
- The current is converted into voltage.
- The analog integrator removes spikes.
- The analog signal is converted into digital form.
- This signal can now be processed and reconstructed in the computer.

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Summary of Process

- Tube
- Filter
- Collimators
- Patient
- Post patient collimators (not shown)
- Detector
- DAS
- Computer to make image

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Patient Table

- The process of moving the table within the gantry by a specified measure is called incrementation, feed, step, or index
- The degree to which a table can move horizontally is called the scannable range
 - This determines the extent a patient can be scanned without repositioning

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Consoles

CT Consoles - 2 types

- Operating
 - Key Boards
 - Mouse
 - Flats Screens for viewing and programing
- Viewing







Archival Devices

- Old Systems
 - Magnetic Tapes
 - Magnetic
 - Floppy and Hard
 - Film
- New Stystems
 - CDs
 - PACS (Picture Archiving and Communicating System)

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PACS



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