1

CT Registry Review

May 19, 2018 and May 20, 2018

CT Physics

May 20, 2018

Content Specs:

- Patient Care
  - 22
- Safety
  - 20
- Image Production
  - 55
- Procedures
  - 68

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Content Specs:

- Patient Care
  - 22
- Safety
  - 20
- Image Production
  - 55
- Procedures
  - 68

Image Formation – 30

Image Evaluation and Archiving - 25

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Objectives

- Identify the basic components, as well as their functions, of a CT scanner.
- Define CT Scanner geometry as it relates to detector configuration.
- Explain the CT imaging parameters and their relationship to the physical principles of radiation interaction.
- Discuss the different methods of image acquisition and reconstruction.
- Explain the principles of image quality and how image display effects these principles.
- Discuss artifacts; their causes and how to resolve them.
- Define and explain the post-processing techniques used in CT.
- Discuss the archiving, networking and security of CT images.

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Image Formation

- CT System Principles, Operation, and Components
- Imaging Parameters and Data Acquisition
- Imaging Processing

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Image Formation

- CT System Principles, Operation, and Components
  - 1. Tube
    - X-ray production
    - Warm-up procedures
  - 2. Collimation/beam width
  - 3. Generator
  - 4. Detectors
    - Detector configuration
    - Detector collimation
  - 5. Data Acquisition
  - 6. Computer and Array Processor
- Imaging Parameters and Data Acquisition
- Imaging Processing

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Image Formation:
CT System Principles, Operation, and Components

- The CT Scanner System
  - The CT x-ray tube generator
  - The CT x-ray tube
  - The CT beam filter
  - The CT collimators
  - The CT detectors and the DAS
  - The computer

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Image Formation:
CT System Principles, Operation, and Components

- Generator
  - CT scanners use three-phase power
  - High frequency generators
    - Located within the CT gantry
    - Low-voltage, low frequency AC current is changed to high-frequency DC current for use by the CT x-ray tube
    - Power ratings range from 20 to 100kW

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Image Formation:
CT System Principles, Operation, and Components

- Tube
  - Rotating anode CT x-ray tubes made of rhenium, tungsten, and molybdenum (RTM) alloy
    - CT x-ray tubes for spiral imaging may include a graphite base body for high thermal capacity
    - Small target angle (12 degrees)
    - Rotation speed of 3600 to 10,000 revolutions per minute
  - Straton CT X-ray tube
    - Useful for MSCT scanners
    - Anode is immersed in oil, resulting in high cooling rates
      - Allows for high mA and long exposure times for increasing anatomical coverage
  - Cathode consists of an electron beam that is deflected to strike the anode at two focal spots.

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Image Formation:
CT System Principles, Operation, and Components

- Tube
  - X-ray production
    - Bremsstrahlung – "brems" - breaking or slowing (German origin)
      - Incident electron and the nucleus
    - Characteristic
      - Incident electron and inner shell electron
  - Reactions
    - 1. Photoelectric Absorption
    - 2. Coherent Scatter
    - 3. Compton Scatter
    - 4. Pair Production
    - 5. Photodisintegration

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Image Formation:
CT System Principles, Operation, and Components

- Tube
  - Warm-up procedures
  - Diagnostic imaging systems need a warm-up period before the system performs optimally. This may include the boot-up of the system and operating system, warm-up of the x-ray tube, calibration of detectors, and stabilization of displays.
- In CT, an air calibration is usually carried out at least on a daily basis. Certain manufacturers also build an x-ray tube warm-up procedure into the boot-up of the system, which has to be completed before the system will function.

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Image Formation:
CT System Principles, Operation, and Components

- CT x-ray tube filtration
  - Removes long wavelength x-rays(low and slow) that do not play a role in CT image formation.
    - Produces a "harder" beam
    - Reduces patient dose
  - Shapes the energy distribution across the radiation beam to produce uniform beam hardening

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Image Formation:
CT System Principles, Operation, and Components

- Collimation/beam width
  - Prepatient
  - Postpatient
  - Predetector

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Image Formation:
CT System Principles, Operation, and Components

- Formation of CT Images
  - The formation of CT images by a CT scanner involves 3 steps
    - Data acquisition
    - Image reconstruction
    - Image display
      - Manipulation
      - Storage
      - Networking

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Image Formation:
CT System Principles, Operation, and Components

- Data Acquisition System – DAS
  - Refers to the collection of x-ray transmission measurements from the patient
    - Special electronic detectors measure the attenuation of the x-ray beam as it passes through the patient.
  - Geometry
    - The construction arrangement of the CT x-ray tube and the detectors used in the collection of transmission measurements.
    - Historically:
      - 1st generation – Pencil beam
      - 2nd generation – Fan beam
      - 3rd generation – Spiral – Fan beam
      - 4th generation – Fixed detector – Spiral – Fan beam
      - 5th generation – EBCT
      - 6th generation – Dual source - Spiral – Fan beam
      - 7th generation – Flat panel DR or detector bank – Cone beam

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Image Formation:
CT System Principles, Operation, and Components

- Detectors
  - Types of detectors
    - Energy Integration detector (EI)
    - Dual Layer detector
    - Direct Conversion detector

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Image Formation:
CT System Principles, Operation, and Components

- Detectors
  - Convert x-ray photons to electrical energy.
  - Electrical energy then becomes digital data.
  - Detector materials:
    - Scintillation Detector
      - Solid state detectors that consist of a scintillation crystal coupled to a photodiode.
      - Used to improve the performance efficiency of the detector to improve image quality and reduce artifacts.
      - Scintillation crystal converts the x-ray photons into light photons.
      - The photodiode converts the light photons into electrical sig[illegible]

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Image Formation:
CT System Principles, Operation, and Components

- Detectors
  - Scintillation Crystals used in CT
    - Cadmium tungstate and a ceramic material
    - Rare Earth Oxides
      - Yttria
      - Gadolinium Oxysulfide (UFC)
        - Ultrafast ceramic (UFC)
      - Most recently Lutetium (Lu) based garnet has been introduced for use in CT.

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Image Formation:
CT System Principles, Operation, and Components

- Detectors – Dual layer
  - Scintillation Crystal
    - Top layer – low density scintillator – Zinc Selenide (ZnSe)
      - Absorbs low energy x-ray photons
    - Bottom layer - high density scintillator (gadolinium oxysulfide)
      - Absorbs high energy x-ray photons
    - Both are a scintillation crystal coupled to a photodiode.
    - Both layers are integrated to ensure optimum performance.

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Image Formation:
CT System Principles, Operation, and Components

- Detectors
  - Proprieties of detectors
    - Capture efficiency
    - Absorption efficiency
    - Stability
    - Response time
    - Afterglow
    - Dynamic range

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Image Formation:
CT System Principles, Operation, and Components

- Detectors
  - Detector configuration
    - Describes the number of data collection channels and the effective section thickness determined by the data acquisition system settings.

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Image Formation:
CT System Principles, Operation, and Components

- Detectors
  - 1. measures the transmitted radiation beam
    - Based on attenuation properties
  - 2. Encodes these measurements into binary data
  - 3. Transmits binary data to the computer
    - Where they will be assigned CT numbers

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Image Formation:
CT System Principles, Operation, and Components

- Attenuation – CT Numbers – aka Hounsfield numbers
- Window Width – Image Contrast
- Window Level – Image Brightness

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Image Formation:
CT System Principles, Operation, and Components

- Computer and Array Processor
  - High speed
  - Large amount of storage
  - Fast

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Image Formation:
CT System Principles, Operation, and Components

- Patient table
- Operators Console

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Image Formation

- CT System Principles, Operation, and Components
- Imaging Parameters and Data Acquisition
  - 1. Parameters
    - kVp
    - mAs
    - Pitch
    - Acquisition thickness
    - x,y,z planes
    - Scan field of view
  - 2. Acquisition
    - Axial/sequential
    - Helical/spiral
    - Volumetric
- Imaging Processing

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Image Formation:
Imaging Parameters and Data Acquisition

- 1. Parameters
  - kVp
  - mAs
  - Pitch
  - Acquisition thickness
  - x,y,z planes
  - Scan field of view

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Image Formation:
Imaging Parameters and Data Acquisition

- kVp
  - Typical kVp settings : 100, 120, 140
  - Used to adjust the energy level of the x-ray beam
  - Controls the contrast of the image

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Image Formation: Imaging Parameters and Data Acquisition

- mAs
  - mA and Scan Time
  - mA controls the quantity of x-rays
  - CT mAs settings are relatively high (200 mAs)
  - Increased scan time increases the x-ray photons

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Image Formation: Imaging Parameters and Data Acquisition

- Pitch
  - The ratio of the distance the table travels per revolution (in millimeters) to the total nominal beam collimation (in millimeters).

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Image Formation: Imaging Parameters and Data Acquisition

- Acquisition thickness
  - How much of the anatomy will be covered or acquired.

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Image Formation:
Imaging Parameters and Data Acquisition

- x,y,z planes
  - Z plane = axial plane – The CT main plane
  - X plane is a Sagittal plane (a reconstruction plane)
  - Y plane is a Coronal plane (a reconstruction plane)

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Image Formation:
Imaging Parameters and Data Acquisition

- Scan field of view
  - Area of anatomy to scan in centimeters (cm)
- Display field of view
  - Area of scanned anatomy to be displayed on the monitor. Further discussed in the next section!

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Image Formation:
Imaging Parameters and Data Acquisition

- 2. Acquisition
  - Axial/sequential
  - Helical/spiral
  - Volumetric

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Image Formation:
Imaging Parameters and Data Acquisition

- Axial/sequential (Slice by Slice)
  - The CT x-ray tube rotates around the patient.
  - The CT x-ray tube stops and the patient is moved, via the CT table, into the next defined scan position.
  - Process continues until the entire region of interest is scanned.

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Image Formation:
Imaging Parameters and Data Acquisition

- Helical/spiral
  - Continuous rotation of the CT x-ray tube around the patient.
    - Made possible by the slip ring.
  - Patient is moved through the gantry aperture as the CT x-ray tube rotates around the patient's body.
  - Process continues until the entire region of interest is scanned.

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Image Formation:
Imaging Parameters and Data Acquisition

- Volumetric
  - AKA - MSCT or Multislice CT
  - Uses Helical/Spiral or Cone beam technology.
  - Single breath hold capabilities.

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Image Formation

- CT System Principles, Operation, and Components
- Imaging Parameters and Data Acquisition

- Imaging Processing
  - 1. Reconstruction
    - Filtered back projection
    - Iterative reconstruction
    - Interpolation
    - Reconstruction algorithm
    - Raw data versus image data
    - Prospective/retrospective reconstructive
    - Reconstruction
    - Reconstruction thickness
    - Reconstruction interval
  - 2. Post-Processing

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Image Formation:
Imaging Processing - Reconstruction

- An advancement of the Back-Projection method
  - Summary of multiple projections to produce an image
  - Does not produce a sharp image of the object and therefore is not used in the clinical CT
- Filtered back projection
  - Also known as the convoluted method
  - The projection profile is filtered or convoluted to remove the blurring found in simple back projection techniques
  - Commonly used in CT systems today

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Image Formation:
Imaging Processing - Reconstruction

- Iterative reconstruction
  - Starts with an assumption and compares this assumption with measured values, makes corrections to bring the two into agreement, and then repeats this process over and over until the assumed and measured values are the same or within acceptable limits".
  - Iterative algorithms consist of three steps
    - Input
    - IR Loop
    - Output

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Image Formation: Imaging Processing - Reconstruction

- Examples of Iterative Reconstruction Algorithms
  - GE Healthcare:
    - Adaptive Statistical Iterative Reconstruction (ASIR)
    - Veo Model-based Iterative Reconstruction Veo (MBIR)
  - Siemens:
    - Image Reconstruction in Image Space (IRIS)
    - Sinogram-Affirmed Image Reconstruction (SAFIRE)
  - Philips:
    - iDose (iterative processing in projection and image domains (iDOSE)
  - Toshiba:
    - Adaptive Iterative Dose Reduction (AIDR)

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Image Formation: Imaging Processing - Reconstruction

- Interpolation
  - Reconstructs the spirally acquired images into what looks like individual slices
- Two types
  - 1. 360-degree linear interpolation
  - 2. 180-degree linear interpolation –The most common type.

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Image Formation: Imaging Processing - Reconstruction

- Reconstruction algorithm – Filters!
  - Bone
  - Standard
  - Sharp
  - Smooth
  - Edge
  - Lung

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Image Formation:
Imaging Processing - Reconstruction

- Raw data versus image data
  - Raw data is the result of preprocessed scan data that are subjected to the image reconstruction algorithm used by the scanner!

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Image Formation:
Imaging Processing - Reconstruction

- Prospective/retrospective reconstruction
  - Prospective Reconstruction is done as the scan is acquired.
  - Retrospective Construction is done after the scan has been acquired.

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Image Formation:
Imaging Processing - Reconstruction

- Reconstruction thickness
  - Slice thickness
    - Slice thickness is an imaging parameter selected by the operator used in CT to define a dimension of depth adapted to the area of interest.

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Image Formation:
Imaging Processing - Reconstruction

- Reconstruction interval
  Slice spacing or interval is determined by collimator spacing in a single array of detectors, further determined by the number and size of the detector elements grouped into each data channel.

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Image Formation:
Imaging Processing – Post Processing

- 2. Post-Processing
  - Multi-planar reformation (MPR)
  - 3D rendering 9MIP, SSD, VR)
  - Quantitative analysis (e.g., distance, diameter, calcium scoring, ejection fraction)

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Image Formation:
Imaging Processing – Post Processing

- Multi-planar reformation (MPR)
  - A method of altering the data that places the data in an different plane. CT is scanned in the axial plane; with only a few exceptions. But there may be a need to visualize the anatomy in another plane.

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Image Formation:
Imaging Processing – Post Processing

- 3D rendering (MIP, SSD, VR)
  - Methods of altering the data collected by the CT scanner in an different representation. CT has the capability of collecting massive amounts of data. These software adaptations allow for better visualization of the anatomy or pathology in question.

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Image Formation:
Imaging Processing – Post Processing

- Quantitative analysis (e.g., distance, diameter, calcium scoring, ejection fraction)
  - QCT is a type of Computed Tomography that calculates and displays bone density in three dimensions.

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Image Evaluation and Archiving

- Image Display
  - 1. pixel, voxel
  - 2. matrix
  - 3. image magnification
  - 4. display field of view
  - 5. window level, window width
  - 6. cine
  - 7. geometric distance or region of interest (ROI) (e.g., mean, standard deviation [SD])
- Image Quality
- Artifact Reconstruction and Reduction
- Informatics

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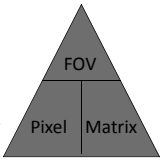
Image Evaluation and Archiving: Image Display

- Pixel
  - Pixel = Picture element
    - The formula used to discover pixel size is:
      - FOV/Matrix x FOV/Matrix = pixel size mm^2
    - The larger the matrix, the smaller the pixel size
      - e.g. 512 x 512 has a pixel size that is →
      - and 256 x 256 has a pixel size that is →



*Smaller pixels will give you better spatial resolution!

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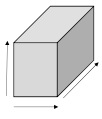
Image Evaluation and Archiving: Image Display

- Voxel
  - Voxel = Volume element
    - The formulas used to discover voxel size are:
      - FOV/Matrix x FOV/Matrix x slice thickness = voxel size mm^3
      - Pixel x Pixel x Slice thickness = voxel size mm^3



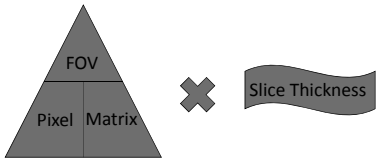


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Image Evaluation and Archiving:
Image Display

- Matrix
  - A series of columns and rows made up of pixels.

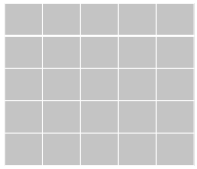

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Image Evaluation and Archiving:
Image Display

- Image magnification
  - The enlargement of an image or a region of an image where the pixel size does not change.
  - Disadvantage – image blur, distortion

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Image Evaluation and Archiving:
Image Display

- Display Field Of View (DFOV)
  - 30 cm
- Scan Field Of View (SFOV)
  - 48 cm

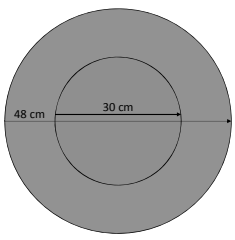

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Image Evaluation and Archiving:
Image Display

- Attenuation – CT Numbers
  - Tissue controls the rate of attenuation

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Image Evaluation and Archiving:
Image Display

- Attenuation – CT Numbers – aka Hounsfield numbers
- Window Width – Image Contrast
- Window Level – Image Brightness

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Image Evaluation and Archiving:
Image Display

- Window Level and Window Width
- Window Width
  - WW on Image Contrast
    - As the WW increases, the contrast decreases
    - As the WW decreases, the contrast increases
    - Contrast is optimized with medium WW settings
- Window Level
  - WL on Image Brightness

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Image Evaluation and Archiving: Image Display

- Cine
  - Viewing images in a movie-like fashion.
    - Overlapping thin image sets are used
    - Pro - Increased spatial resolution
    - Con – Increased dose to the patient

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Image Evaluation and Archiving: Image Display

- Geometric distance or region of interest (ROI) (e.g., mean, standard deviation [SD])
  - Measurement tools to evaluate size or content of an anatomical structure or pathology.

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Image Evaluation and Archiving

- Image Display
- Image Quality
  - 1. Spatial Resolution
  - 2. Contrast Resolution
  - 3. Temporal Resolution
  - 4. noise and Uniformity
  - 5. Quality Assurance and Accreditation
  - 6. CT Number (Hounsfield Units)
  - 7. Linearity
- Artifact Reconstruction and Reduction
- Informatics

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Image Evaluation and Archiving:
Image Quality

- Spatial Resolution
  - The ability to resolve closely placed objects that are significantly different from their background.

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Image Evaluation and Archiving:
Image Quality

- Contrast Resolution
  - Is the ability to differentiate a structure that varies only slightly in density from its surroundings.
  - System sensitivity
    - Low-contrast sensitivity

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Image Evaluation and Archiving:
Image Quality

- Temporal Resolution
  - An indication of a CT system's ability to freeze motions of a scanned object; performance parameter that deals in time or speed of data acquisition.
    - Important parameter when you want to minimize motion.

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Image Evaluation and Archiving:
Image Quality

- Noise and Uniformity
  - Noise – a random variation in CT numbers caused by attenuation of the x-ray beam as it passes through the anatomy of interest. Noise may also be caused by disturbances that interfere with the normal flow of data through pathways of computers and other electrical devices.
  - Uniformity – the condition of being equal across all areas of a same tissue sample. For example, when you are doing a water phantom for QC and you take sample measurements at the center and along the periphery of the phantom all measurements will be within a set variance to be considered normal.

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Image Evaluation and Archiving:
Image Quality

- Quality Assurance and CT Accreditation (ACR)
  - QA is a program of Quality Control tests that periodically evaluate the performance of specific equipment. In this case CT equipment.
    - There is a specific list of tests for CT equipment. This list displays the frequency of each test and the normal variance permitted.
    - The 3 principles of a good QA program are;
      - Regular performance of QC tests to insure accurate results
      - Prompt interpretation of results
      - Documented results with documentation of correction – if needed.
  - Accreditation is a voluntary program that demonstrates to patients and personnel of the CT facility the safety and effectiveness of their CT imaging services.

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Image Evaluation and Archiving:
Image Quality

- CT Number (Hounsfield Units)
  - CT numbers are based on the attenuation of x-rays through a particular type of tissue.
  - Hounsfield units are CT numbers!
    - Godfrey Hounsfield created the numbered system to represent the attenuation energy received by the IR as x-ray passed through a particular tissue.
    - The first range was -500 for air, 0 for water, and +500 for bone.
    - This was later changed to -1000 for air, 0 for water, and +1000 for bone – this is what we use today!

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Image Evaluation and Archiving: Image Quality

- Linearity refers to the linear relationship of CT numbers to the linear attenuation coefficients of the object to be imaged.

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Image Evaluation and Archiving

- Image Display
- Image Quality
- Artifact Recognition and Reduction
  - 1. Beam hardening or cupping
  - 2. Partial volume averaging
  - 3. Motion
  - 4. Metallic
  - 5. Edge gradient
  - 6. Patient positioning (out-of-field)
  - 7. Equipment induced
    - Rings
    - Streaks
    - Tube arc
    - Cone beam
    - Capping
- Informatics

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Sources of Image Artifact

- The patient
- The imaging process
- Equipment problems
  - Malfunctions
  - Imperfections
- Technologist error

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Beam-Hardening Artifact

- Appearance
  - Dark bands or streaks
  - Cupping at the center of the image
- Cause
  - Object size increases, low energy photons attenuated
  - Radiation beams have different path lengths
- Correction
  - Filter
  - Software

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Image Evaluation and Archiving: Artifact Recognition and Reduction

- Beam hardening or cupping

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Partial Volume Artifact

- Appearance
  - CT number representing an object is false
- Cause
  - Object is not fully within a slice thickness
  - Multiple objects in a slice
    - CT number is an average of all tissue types within the slice
- Correction
  - Thinner slices
  - Computer algorithms

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Image Evaluation and Archiving:
Artifact Recognition and Reduction

- Partial volume averaging

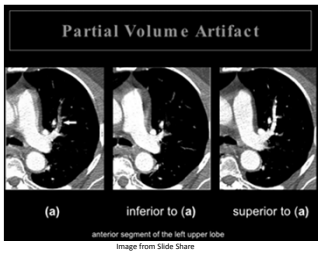

Image from Slide Share

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Motion Artifact

- Appearance
  - Streaks
- Cause
  - Inability of reconstruction algorithm to account for inconsistencies
- Correction
  - Immobilize patient
  - Short scan times
  - Software

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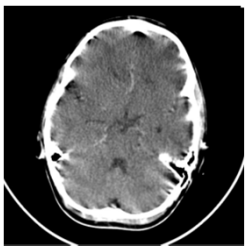
Image Evaluation and Archiving:
Artifact Recognition and Reduction

- Motion



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Metallic Artifact

- Appearance
  - Streak and star-shaped artifact
- Cause
  - Metallic object absorbs radiation, resulting in an incomplete projection profile
- Correction
  - Remove all metallic objects
  - Software

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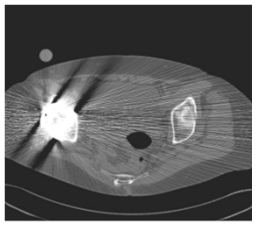
Image Evaluation and Archiving: Artifact Recognition and Reduction

- Metallic



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Edge Gradient Effect

- Appearance
  - Streaks
- Cause
  - Imaging an object that with an irregular shape or with a great difference in density
    - Inconsistent attenuation information
- Correction
  - When applicable, over sample data beyond 360°
  - Thinner slices

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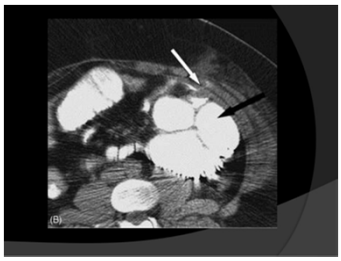
Image Evaluation and Archiving:
Artifact Recognition and Reduction

- Edge gradient



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Out-of-field Artifact

- Appearance
  - Shading or streaking
- Cause
  - Anatomy out of the scan field of view contributes toward the attenuation and hardening of the x-ray beam
- Correction
  - Ensure all anatomy is contained within SFOV
  - Increase SFOV if possible

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Image Evaluation and Archiving:
Artifact Recognition and Reduction

- Patient positioning (out-of-field)

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Image Evaluation and Archiving:
Artifact Recognition and Reduction

- Equipment induced
  - Rings
  - Streaks
  - Tube arc
  - Cone beam
  - Capping

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Image Evaluation and Archiving:
Artifact Recognition and Reduction

- Rings

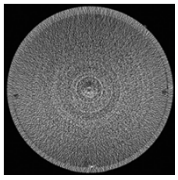
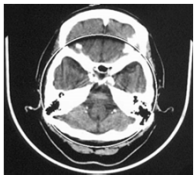

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Image Evaluation and Archiving:
Artifact Recognition and Reduction

- Streaks

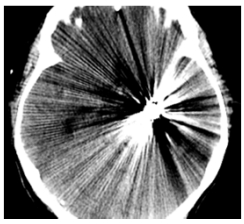

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Image Evaluation and Archiving:
Artifact Recognition and Reduction

- Tube arc

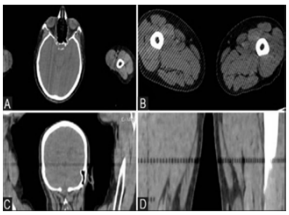

Image is from the *Indian Journal of Radiology and Imaging*

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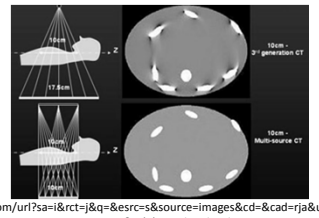
Image Evaluation and Archiving:
Artifact Recognition and Reduction

- Cone beam



Obtained from https://www.google.com/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&cad=rja&uact=8&ved=2ahUKEwjPgrWP6OfaAhVL6YMKHXKFBJsQjB16BAgBEAQ&url=https%3A%2F%2Fwww.auntminnie.com%2Findex.aspx%3Fsec%3Dlog%26itemID%3D76261&psig=AOvVaw3Wv8W0Cnven2REmotFQ3vt&ust=1525377448706539

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Image Evaluation and Archiving:
Artifact Recognition and Reduction

- Capping

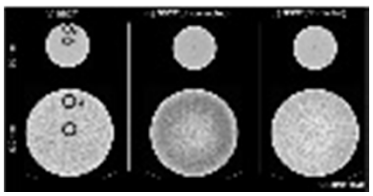

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Image Evaluation and Archiving

- Image Display
- Image Quality
- Artifact Reconstruction and Reduction

- Informatics
  - 1. Hard/Electronic Copy (e.g., DICOM file format)
  - 2. Archive
  - 3. PACS and electronic medical record (EMR)
  - 4. Security and confidentiality
  - 5. Networking

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Image Evaluation and Archiving: Informatics

- Hard/Electronic Copy (e.g., DICOM file format)
  - Imaging facilities have large servers that store an electronic copy of all exams performed at that facility.
  - DICOM is a special storage and sending format.
  - DICOM
    - D – Digital
    - I – Imaging and
    - CO – Communications in
    - M - Medicine

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Image Evaluation and Archiving: Informatics

- Archive
  - Images are stored temporarily on the machine that acquired them.
  - Images are then archived more permanently on CD's, DVD-R's, and in the cloud.

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Image Evaluation and Archiving:
Informatics

- PACS and electronic medical record (EMR)
- PACS
  - P – Picture
  - A – Archiving and
  - C – Communication
  - S – System
- EMR
  - This is a secure medical record stored electronically of the patients health information.

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Image Evaluation and Archiving:
Informatics

- Security and confidentiality
- HIPAA
  - H – Health
  - I – Insurance
  - P – Portability and
  - A – Accountability
  - A – Act
  - **HIPAA** (Health Insurance Portability and Accountability Act of 1996) is United States legislation that provides data privacy and security provisions for safeguarding medical information.

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Image Evaluation and Archiving:
Informatics

- Networking
  - Network topologies
    - Local Area Network – LAN
    - Metropolitan Area Network – MAN
    - Wide Area network - WAN

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