THE READING HOSPITAL SCHOOL OF HEALTH SCIENCES
MEDICAL IMAGING PROGRAM
BASICS OF CT--2022

PLEASE STARE INTO MY EYES FOR ONE MINUTE. THEN SCROLL DOWN.

THANK YOU, YOUR CAT SCAN IS NOW COMPLETED.

DATA ACQUISITION /
IMAGE RECONSTRUCTION
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Data Acquisition

Method by which a patient is scanned to obtain enough data for image reconstruction

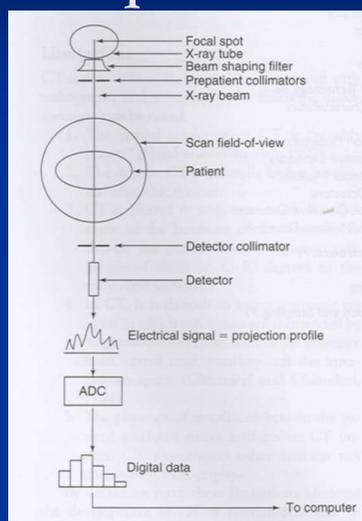*how the image is taken

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Data Acquisition

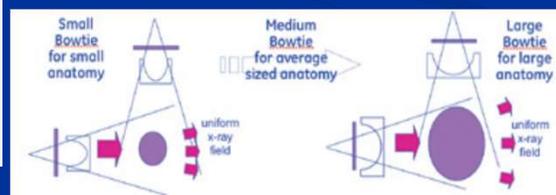**Two Basic Elements for Data Acquisition:**

- **Beam Geometry**
  - **Size, shape (SFOV) and motion of beam and its path**
- **Components--Physical devices**
  - **Some examples:**
    - ***Pre-patient collimators*: Shape the beam**
    - ***Detectors*: Measure beam transmission through patient**
    - ***ADC:* Convert information into digital data for input in computer**

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Basic Steps of Data Acquisition System

Focal spot
X-ray tube
Beam shaping filter
Prepatient collimators
X-ray beam

Scan field-of-view

Patient

Detector collimator

Detector

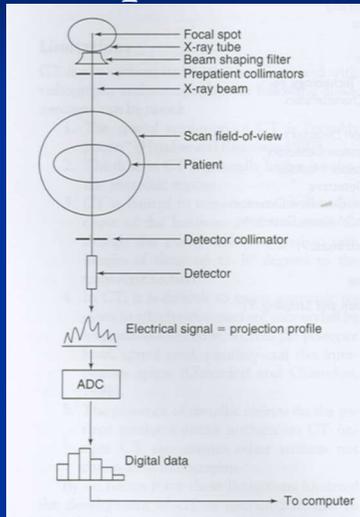Electrical signal = projection profile

ADC

Digital data

To computer

- **1. The tube and detector are always in alignment**
- **2. The tube and detector scan the patient to collect a large # of transmission measurements**
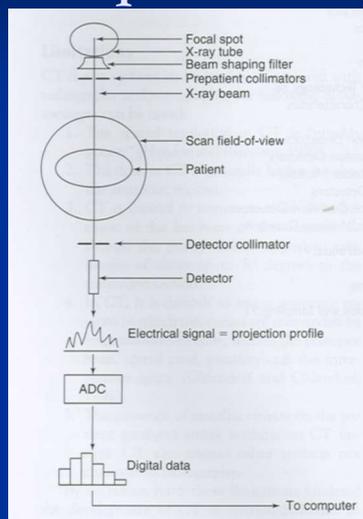- **3. The beam is shaped by a special filter (bowtie filter)**

Small Bowtie for small anatomy

Medium Bowtie for average sized anatomy

Large Bowtie for large anatomy

uniform x-ray field

uniform x-ray field

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Basic Steps of Data Acquisition System

Focal spot
X-ray tube
Beam shaping filter
Prepatient collimators
X-ray beam

Scan field-of-view
Patient

Detector collimator

Detector

Electrical signal = projection profile

ADC

Digital data

To computer

- 4. The beam is collimated to pass through only the slice of interest (pre-patient collimator)
- 5. The beam is attenuated by the patient, passes through the post patient collimator, and the detector measures the transmitted photons

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Basic Steps of Data Acquisition System

Focal spot
X-ray tube
Beam shaping filter
Prepatient collimators
X-ray beam

Scan field-of-view
Patient

Detector collimator

Detector

Electrical signal = projection profile

ADC

Digital data

To computer

- 6. The detector converts the photons into an electrical signal
- 7. The signals are converted by the ADC
- 8. The digital data is sent to the computer for image reconstruction where mathematical equations occur (algorithms)

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Methods of Data Acquisition

Three Methods:
- **Localizer**
- **Conventional/ Serial CT Scan**
- **Helical, Spiral, or Volumetric CT**
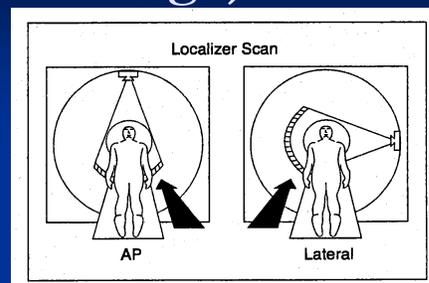
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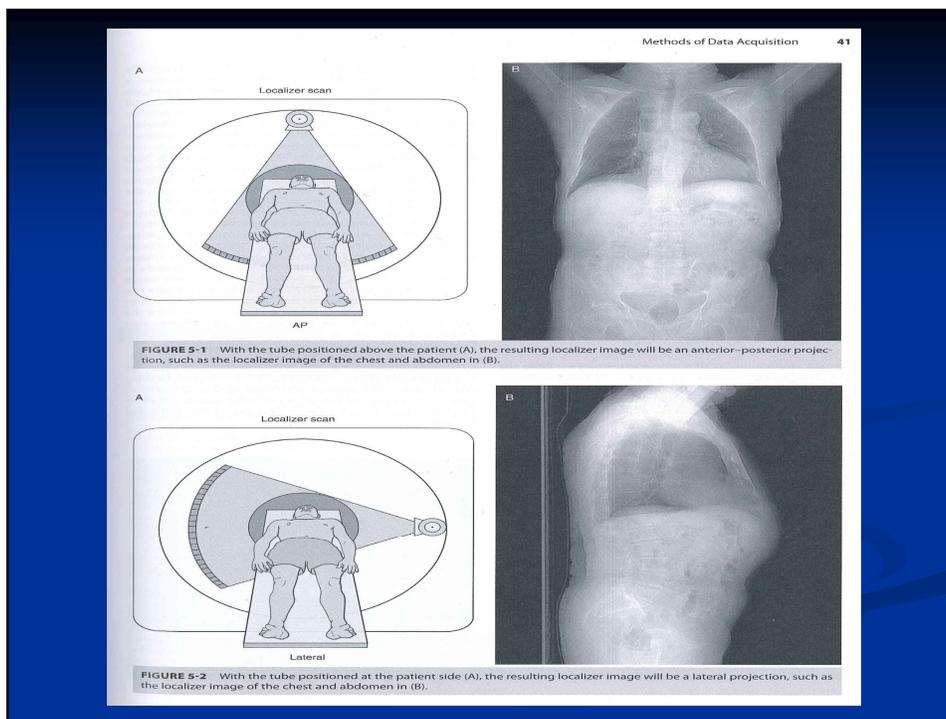# Localizer Scan (scout image)

Stationary tube/Patient table
   motion

- *Function:*
    - Provides an image of superimposed tissues (like x-ray)
    - Large field of view
    - Allows alignment of cross sectional slices with specific structures
        - Select the DFOV
        - Save the scout image with lines on to use as a reference to the cross sectional images

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FIGURE 5-1 With the tube positioned above the patient (A), the resulting localizer image will be an anterior–posterior projection, such as the localizer image of the chest and abdomen in (B).

FIGURE 5-2 With the tube positioned at the patient side (A), the resulting localizer image will be a lateral projection, such as the localizer image of the chest and abdomen in (B).

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Conventional/ Serial CT Scan

X-ray Tube vs. Patient

- **X-ray tube rotates around the patient**
  - **3rd vs. 4th Generation Scanners**
- **Patient table remains stationary**
  - **Acquiring Adjacent slices**

- ***Raw Data* – data measured in each projection**
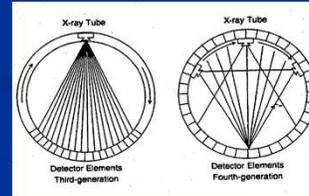
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Helical/ Spiral/ Volumetric CT Scan

- Continuous data collection (volume) through multiple projections during continuous patient translation through the gantry

  *needed for 3D image reconstruction

- **Requirements to perform Helical scans:**
  - Scanner must be of continuous rotation (1989- slip ring)
  - Contain high heat capacity x-ray tube
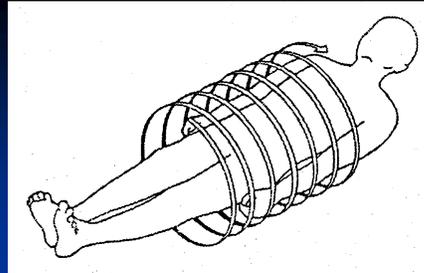 - Rapid cooling capacity
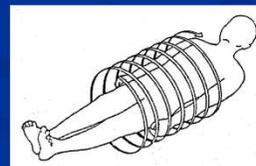
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Helical CT Scan

Raw Data – data measured in each projection
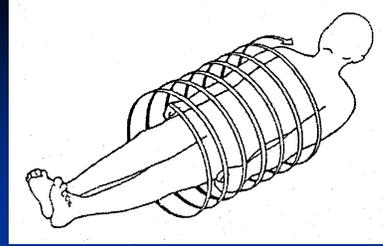
- **Information must be divided into individual cross-sectional slices**
- **Mathematical interpolation must be run to divide the different samples from the different planes and raw data from different slices**
  - **Reconstruction to form final images**

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Helical CT Scan

- *Advantages:*
  - Complete organs may be scanned in one breath hold
  - Many slices acquired at a time
  - Less chance of mis-registration with inconsistent breath holding
 - Smaller amount of contrast needed
  - 3-D reconstruction

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FIGURE 5-6   Slice misregistration caused by patient breathing. These two slices are taken at contiguous table positions; slice (A) is the last slice in the first group of axial slices. The patient was allowed to breathe and then once again asked to hold his breath. Slice (B) was the first slice in the second group of scans. Slice (B) is just 5 mm more inferior, yet it appears dramatically more inferior. It is possible to miss lesions as large as 1 cm as a result of slice misregistration.

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Data Acquisition

Multislice Detector Array (7th generation)

- Requires several parallel detector arrays that contain thousands of individual detectors
- Requires a fast large-capacity computer
  - Quickly energizing a large detector array results in larger volume imaging
  - Increased coverage with decreased amount of time
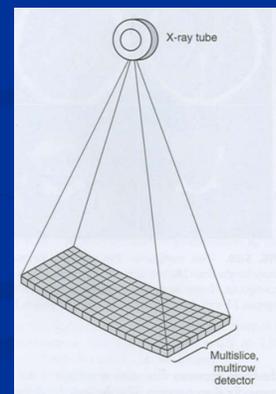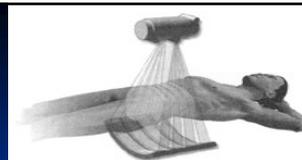
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Image Reconstruction

*Algorithm- s*et of rules or directions for getting specific output (reconstruction) from specific input (raw data)

- **In CT, computers use these algorithms to process raw data into reconstruction images**

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Fourier Transform/ Transformation

- Primary mathematical method used in CT for image reconstruction
- Takes complex data and arranges it into more useful forms

- For example: in music Fourier transform can separate music into functions which makes it easier to be recorded onto CD
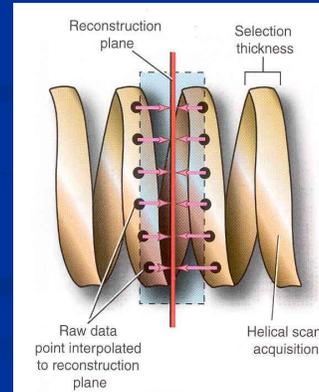
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Image Reconstruction

Interpolation

The projecting of raw data between two known values

- **Used to create a wide variety of sections that are reconstructions of data**
  - **No additional radiation exposure**

Extrapolation

The projecting of raw data beyond the range of known values
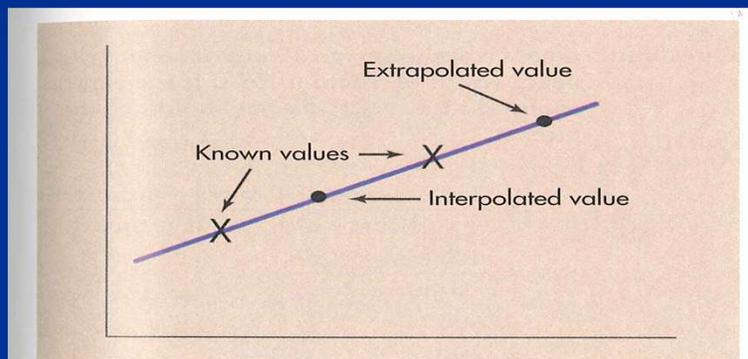
Reconstruction plane

Selection thickness

Raw data point interpolated to reconstruction plane

Helical scan acquisition

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Image Reconstruction

Interpolation / Extrapolation

Extrapolated value

Known values →

Interpolated value

FIGURE 23-33 Interpolation estimates a value between two known values. Extrapolation estimates a value beyond known values.

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Image Reconstruction

Retrospective Reconstruction

The saving of the patient's "raw" data from a scan

- Allows post-scanning manipulation
- Allows re-manipulation of images from the raw data that is saved
  - *Example*: Lumbar spine- once original images are displayed it is determined that a different algorithm would be better

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Image Reconstruction - Algorithm
Filter Back Projection

- Filter refers to mathematical function
- Images from all projections (angles) placed together to form one image
  - Raw data from each projection added and averaged from attenuation
  - Image produced is not very sharp (rough edges- not accurately represented)
  *uses Fourier transform to reduce noise

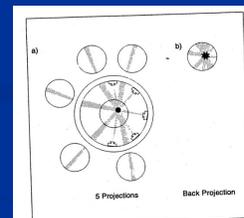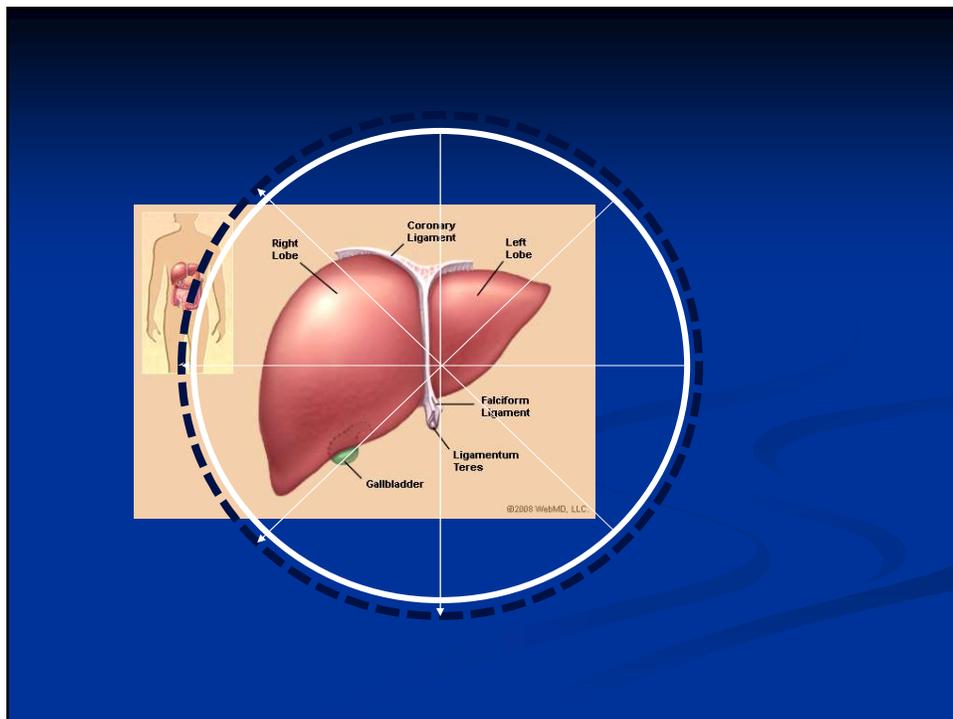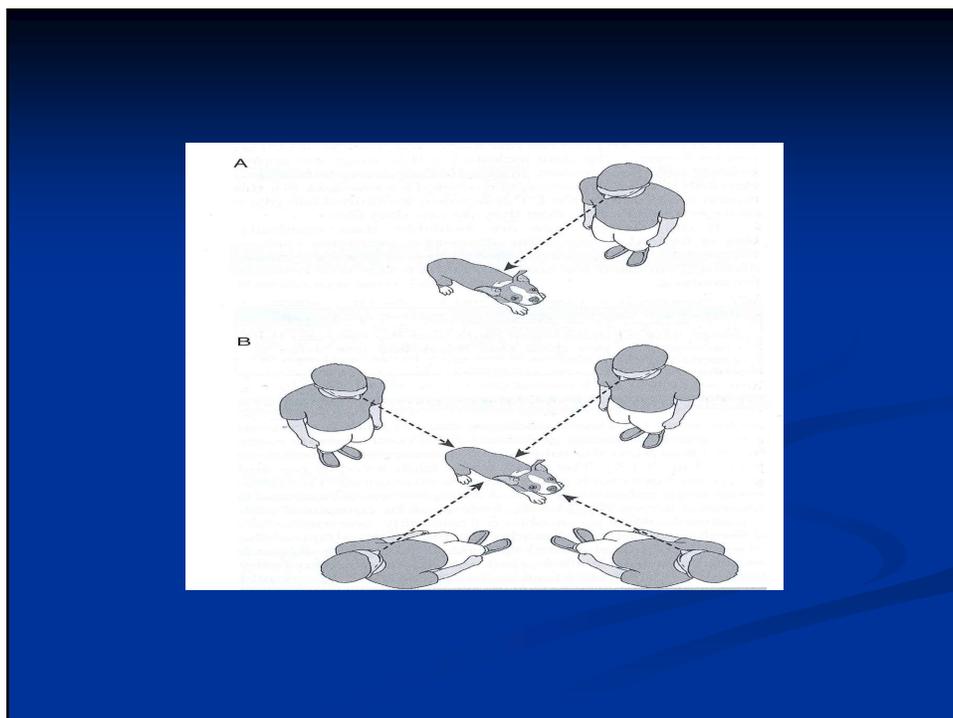5 Projections   Back Projection

Fig. 2-9

a.) Projections are collected from many different points of view during the scan.

b.) These projections are combined in the back projection technique to form an image. In the unfiltered back projection, a typical star artifact is seen.
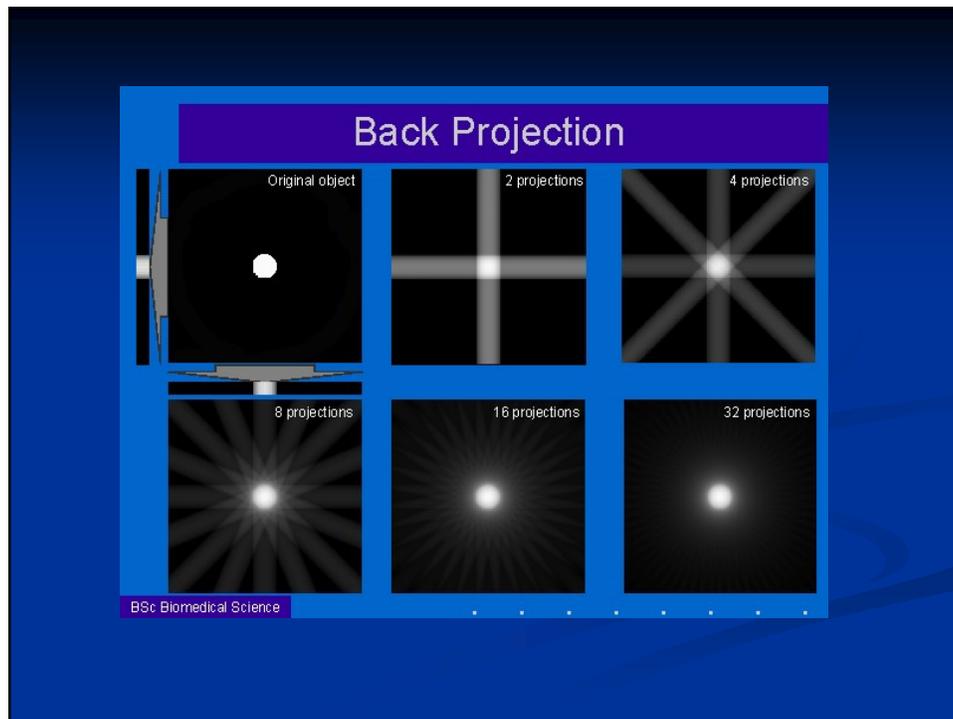
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Image Reconstruction - Algorithm

Filter Back Projection

■Correction algorithm is applied to accentuate the edges of the information in the raw data

  ■Performed prior to image reconstruction

  ■ Exact representation of image is achieved

■Process of applying filtration to the data is called ***convolution***.

→ →

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Image Reconstruction - Algorithm

Convolution

Process of modifying pixel values by a mathematical formula through a filter function

- **"Mask" - Overlaps acquired data to reconstruct the image**
 - **Removes star-like blurs from back-projection**

Deconvolution

Process of returning the pixel values to their original level by the reverse process

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Image Reconstruction - Algorithm

Multiplanar Reformation (MPR)

- Post processing technique performed on image data which produces new slice from a set of CT scans
  - Initiated from operator console or workstation
  - Example: creating coronal and sagittal images
- Utilized for images in planes that would otherwise be difficult or impossible to acquire
  - Original slices must be contiguous with no gaps (thin slices)
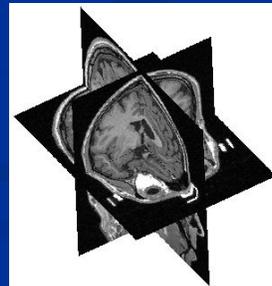
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Image Reconstruction - Algorithm

Multiplanar Reformation

- Software that allows CT to show an entire volume in one image- three dimensional
- Very time consuming
    - Independent workstations
- Examples
    - Maximum Intensity Projection (MIP)
    - Shade Surface Display (SSD)
   - Shade Volume Display (SVD)

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Image Reconstruction - Algorithm

Maximum Intensity Projection (MIP)

- Simplest form of three dimensional imaging
- Reconstruction can be done quickly
- Good for showing vasculature from surrounding tissue
    - CTA (angiography)
- Only uses 10% of the data points to create a three dimensional image
    - Reconstructs using the highest pixel value from the data collected
    - Very high contrast
    - Can be rotated on the workstation

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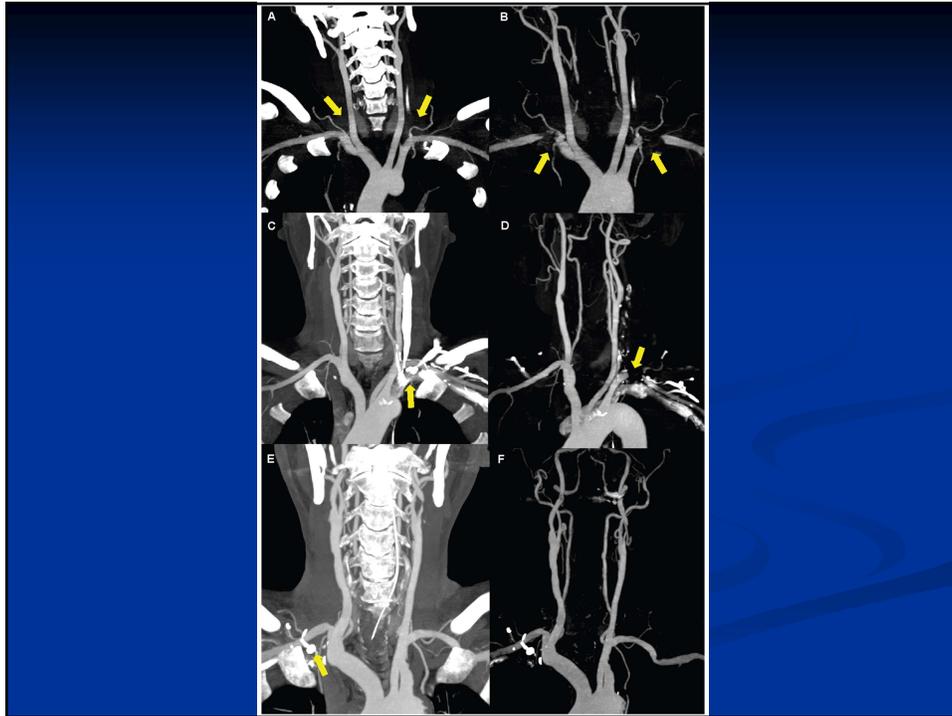
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Image Reconstruction - Algorithm

Shade Surface Display (SSD)

- Does not generate images of cross-sections of anatomy but images the surface of the anatomical structure
  - Initiated from operator console or workstation
- Stack transverse slices to form volume of anatomical data (contiguous slices necessary as to not miss any data)
- Reconstruction process dependent on separating different tissue types in the scanned images
  - *Example*: Technologist selects a tissue surface of skin reconstruction or bone reconstruction

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Image Reconstruction -Algorithm

Shade Surface Display (SSD)

Applications

- **Vessel display, soft tissue, other viscera**
- **Relationships between vasculature and viscera (thrombus or calcifications)**
- **Surface and internal detail of anatomy**
  - **Virtual colonoscopy**
- **Benefits for orthopedic and craniofacial surgery, neurosurgery, and radiation therapy**

https://emex-medical.ru/diagnostika-v-germanii/diagnostika-raka-kishechnika-v-germanii/
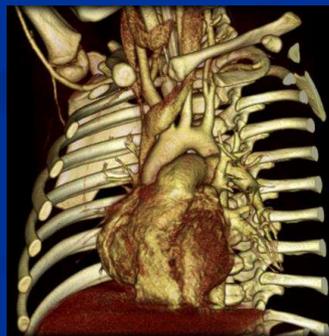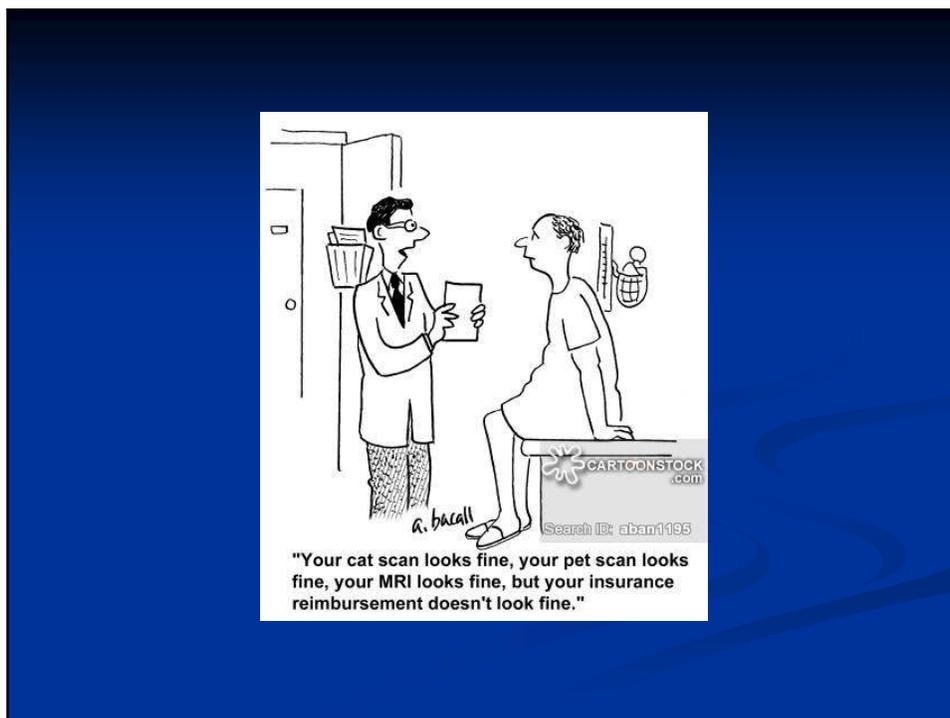
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Image Reconstruction - Algorithm

- Shaded Volume Display (SVD)
  - Utilizes a 3-D semitransparent representation
  - This process utilizes all voxels that contribute to the image
    - Shows multiple tissues and their relationship to one another

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https://www.oatext.com/Cinematic-and-volume-rendering-of-a-scaphoid-fracture.php

http://www.auntminnie.com/index.aspx?sec=rca&sub=rsna_2015&pag=dis&ItemID=112908

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