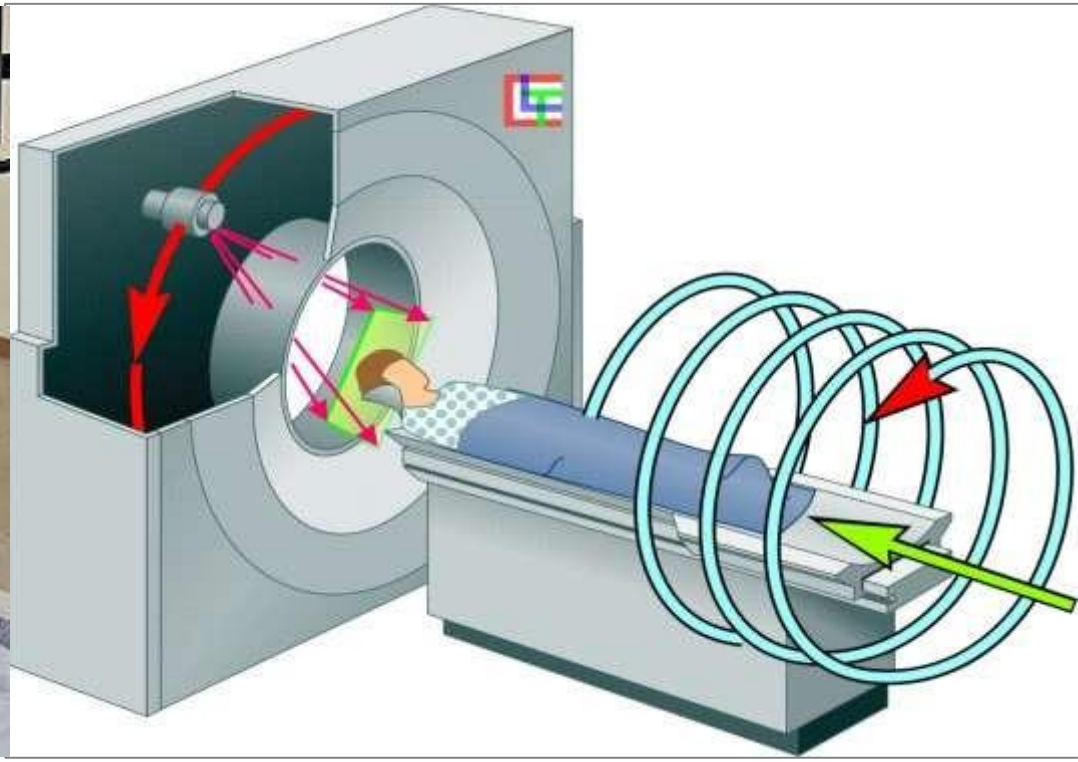
Computed Tomography Scan



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Objectives

On completion of this lecture, the participants will be able to:

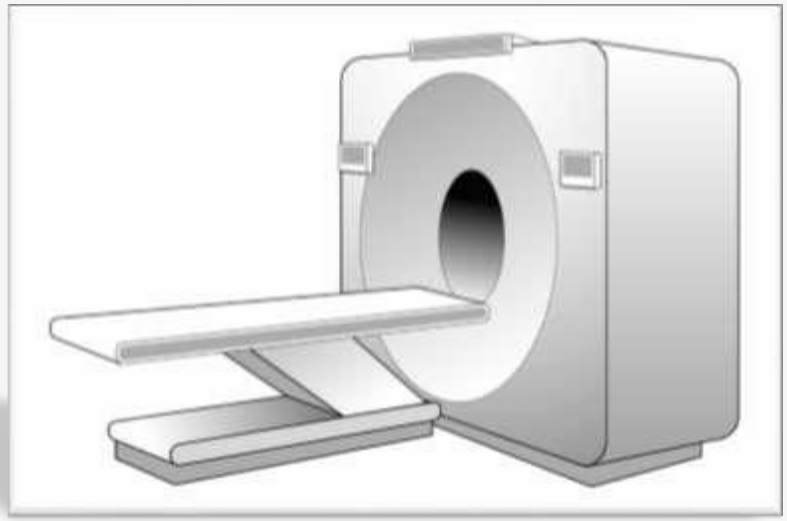
- Understand the working principle of CT scan machine.
- Discuss the various components and their functions.
- Perform operation of CT.
- Understand usage of different contrast medias.

What Is CT Scan?

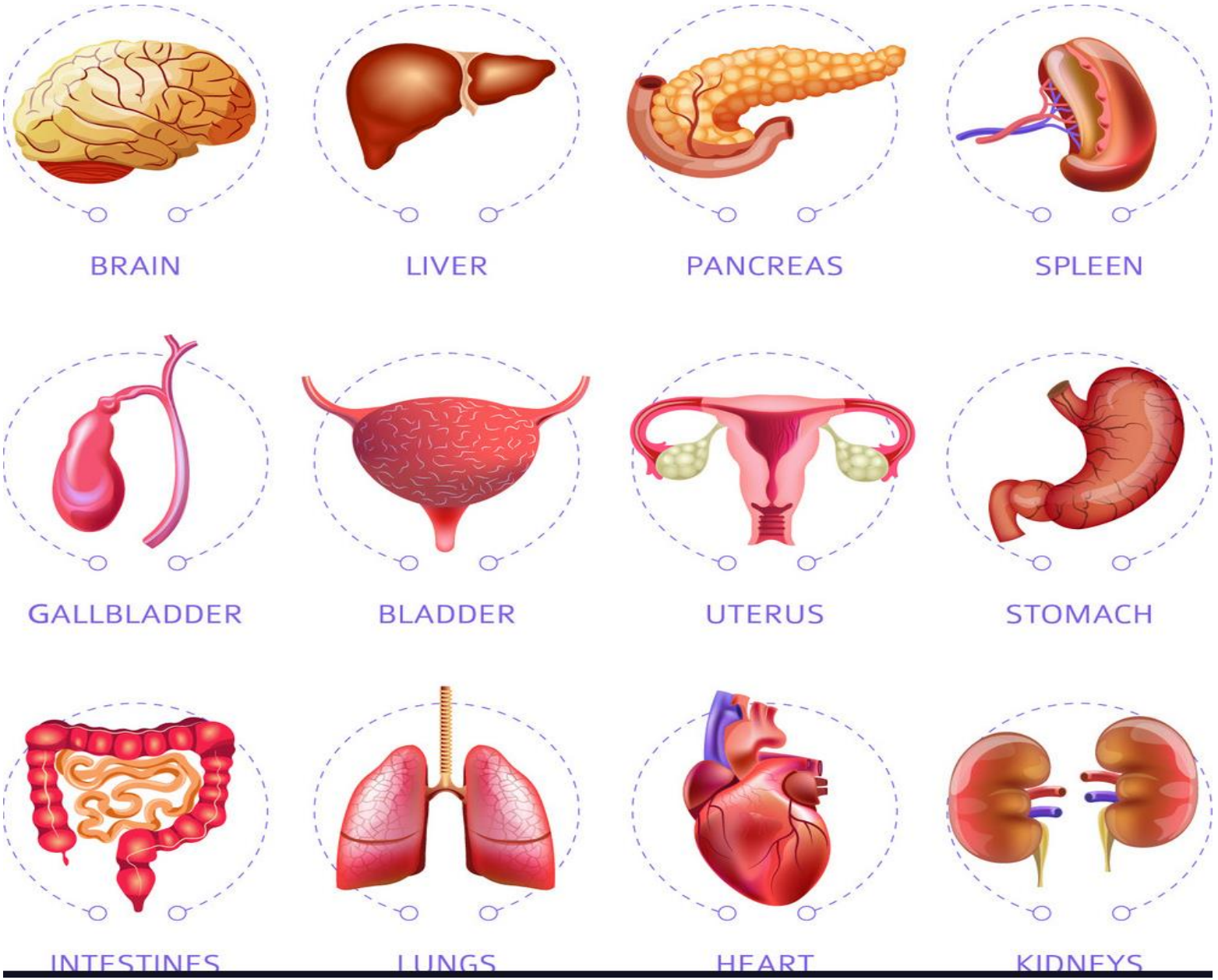
CT stands for

Computed Tomography

It is a procedure, in which we study internal organs of the body to see any disease in it without cutting.



Internal Organs of The Body



CT SCAN: Introduction

- Computed tomography is also known as "CAT scanning" (Computed Axial Tomography).
- Tomography is from the Greek word *"tomos"* meaning "slice" or "section" and *"graphia"* meaning "describing".
- Computed tomography is an examination that uses X-ray and computer to obtain a cross-sectional image of the human body.

History

- Invented in 1972 by British engineer Godfrey Hounsfield of EMI Laboratories, England and by South Africa-born physicist Allan Cormack of Tufts University, assachusetts.
- Hounsfield and Cormack were later awarded the Nobel Peace Prize for their contributions to medicine and science.
- The first clinical CT scanners were installed between 1974 and 1976. The original systems were dedicated to head imaging only, but "whole body" systems with larger patient openings became available in 1976.
- CT became widely available by about 1980.

Equipment

- The CT scanner is typically a large, box-like machine with a hole, or short tunnel in the center.
- The Patient will lie on a narrow examination table that slides into and out of this tunnel.
- Rotating around patient, the x-ray tube and electronic x-ray detectors are located opposite to each other in a ring, called a gantry.
- The computer workstation that processes the imaging information is located in a separate control room, where the technologist operates the scanner and monitors examination.

System Components

All computed tomography systems consist of the following four major sub-systems:

i. **Scanning system**—This takes suitable readings for a picture to be reconstructed, and includes X-ray source and detectors.

ii. **Processing unit**—This converts these readings into intelligible picture information.

iii. **Viewing part**—It presents this information in visual form and includes other manipulative aids to assist diagnosis.

iv. **Storage unit**—This enables the information to be stored for subsequent analysis.

How a CT system works?

- A motorized table moves the patient through a circular opening in the CT imaging system.
- While the patient is inside the opening, an X-ray source and a detector assembly within the system rotate around the patient. A single rotation typically takes a second or less. During rotation the X-ray source produces a narrow, fan-shaped beam of X-rays that passes through a section of the patient's body.
- Detectors in rows opposite the X-ray source register the X-rays that pass through the patient's body as a snapshot in the process of creating an image. Many different "snapshots" (at many angles through the patient) are collected during one complete rotation.
- For each rotation of the X-ray source and detector assembly, the image data are sent to a computer to reconstruct all of the individual "snapshots" into one or multiple cross-sectional images (slices) of the internal organs and tissues.

Working Principle

Beams from one or several small X-ray sources are passed through the body and intercepted by one or more radiation detectors. These radiation detectors produce electrical impulses that are proportional to the intensity of the X-ray beam emerging from the body.

The intensity of the X.ray beam exiting the body is determined by:

a. The energy of the X-ray source
b. The distance between the source of X-rays and the detector
c. The attenuation of the beam by materials in the object being scanned.

Working Principle

The efficiency of the scanning system can be increased multiple folds by using multiple X-ray beams and equivalent number of detectors.

Each scan produces a penetration or absorption profile.

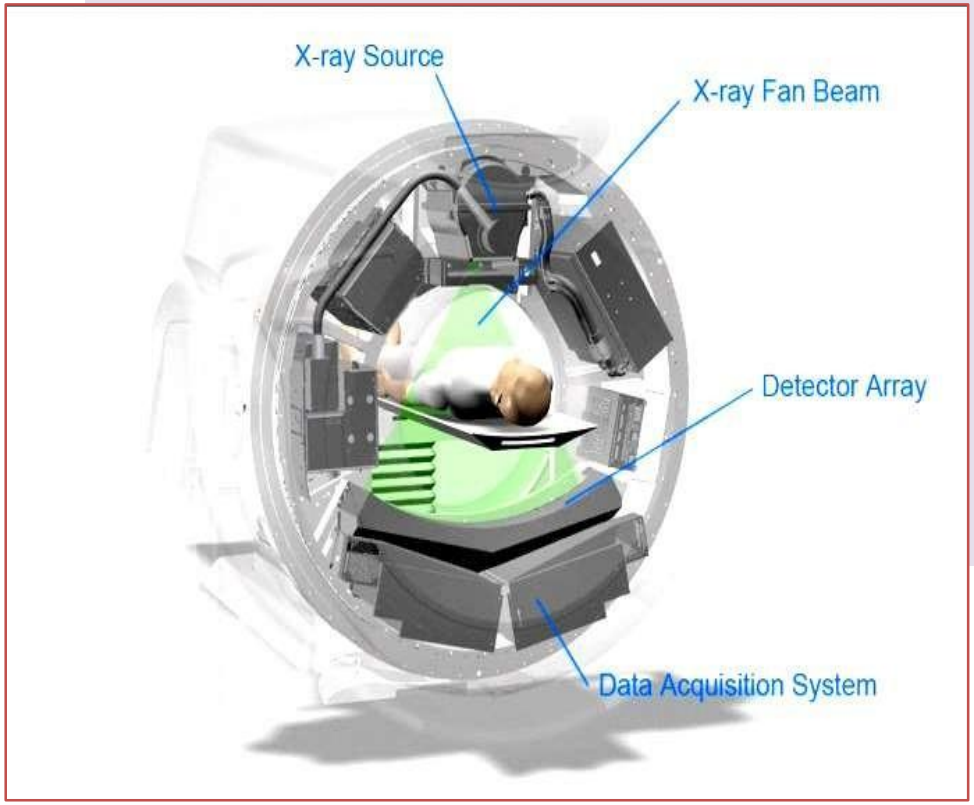
However, construction of the requires image profiles obtained at different angles through the patient under study. The X-ray source and detector assembly are rotated around the patient (360^{o}) to produce multiple profiles of the particular site of interest.

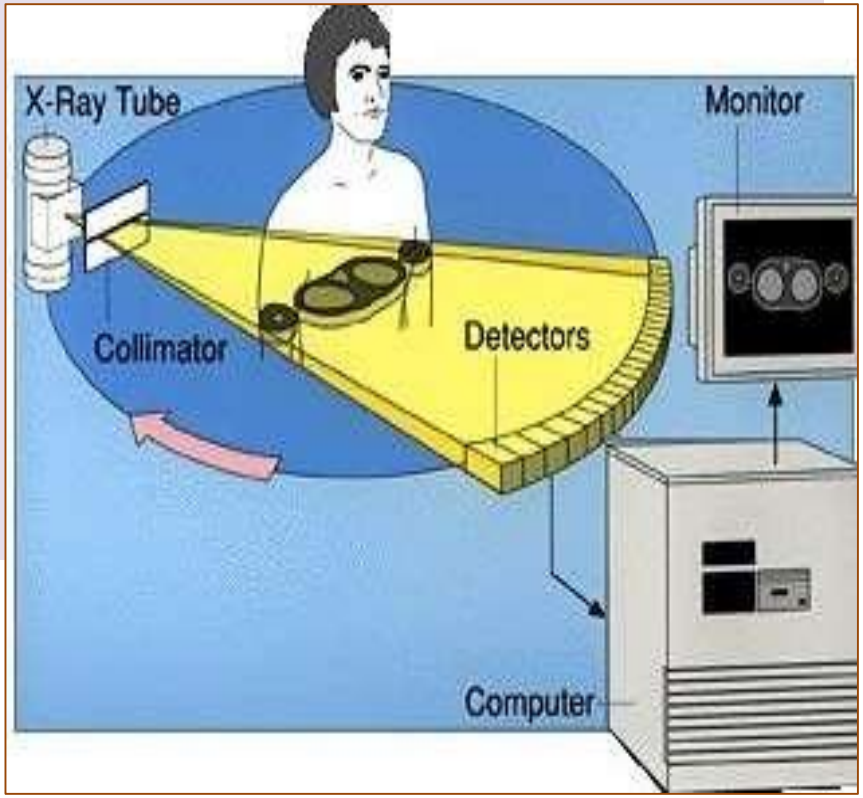
Components of CT Scan

Gantry

Data Acquisition System

Operating Console





Structure of CT Scan Machine

A CT Scanner basically consist of

- Control Panel
- Gantry
- CPU
- Memory
- X.ray tube
- Collimator
- Rotating X-ray Beam
- Rotating X-ray Detector
- Data Acquisition Unit
- Image Reconstruction Unit
- Monitor and Printer

Gantry

- The gantry assembly is the **largest of these systems**.
- Can be tilted upto 360 degree.
- It is made up of all the equipment related to the patient, including

  -the patient **Support,**

  -the **Positioning couch**,

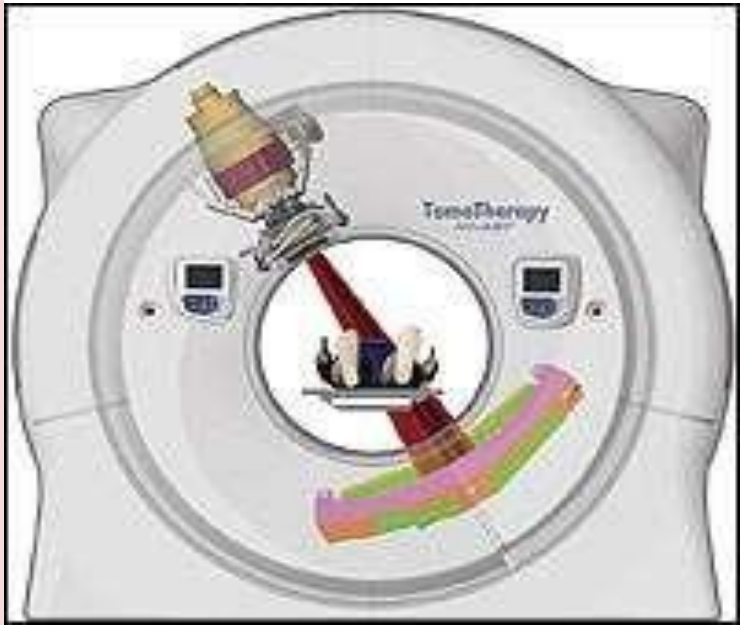
  -the **Scanner housing**.

  -heart of the CAT scanner,

  the X-ray Tube, as well as

  Detectors that generate

  and detect x rays

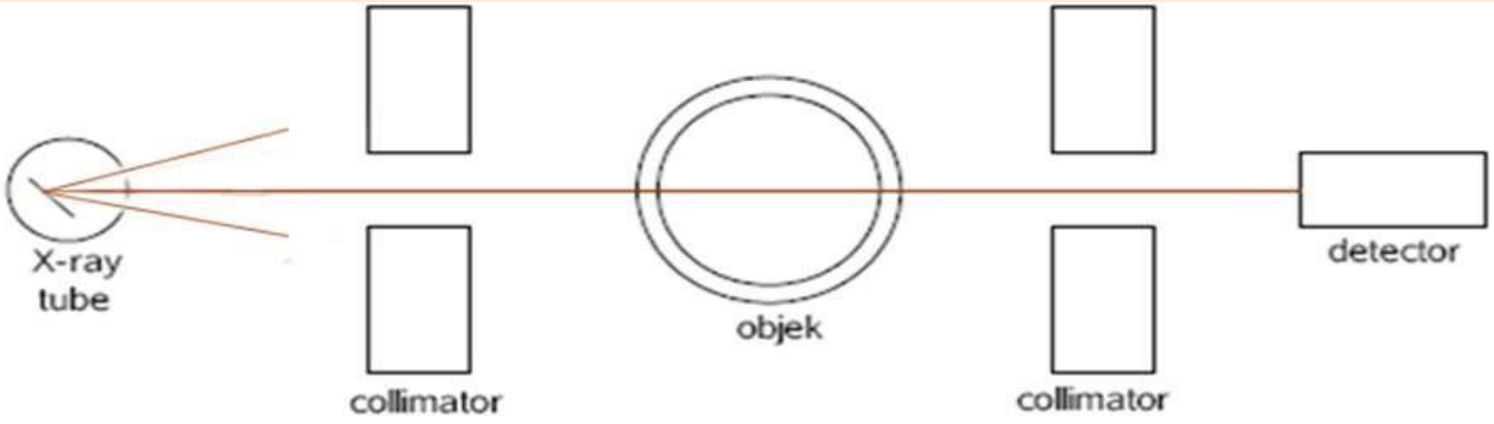


CT X-ray Tube

- Tubes operates with three phase or high frequency generators and rotating anode.
- Anode heat capacity: –3.5MHU upto 8MHU (Million Heat Unit)
- Operates at 120 kVp (Kilovolt Peak) and 200-800 mA (Milliamperage).
- High X-Ray output reduces the exposure time and improves image quality as well as decrease bone absorption.
- Focal spot size ranges from 0.5 to 2mm
- Low slice thickness result in higher spatial resolution and contrast, less partial volume artifact and higher patient dose.

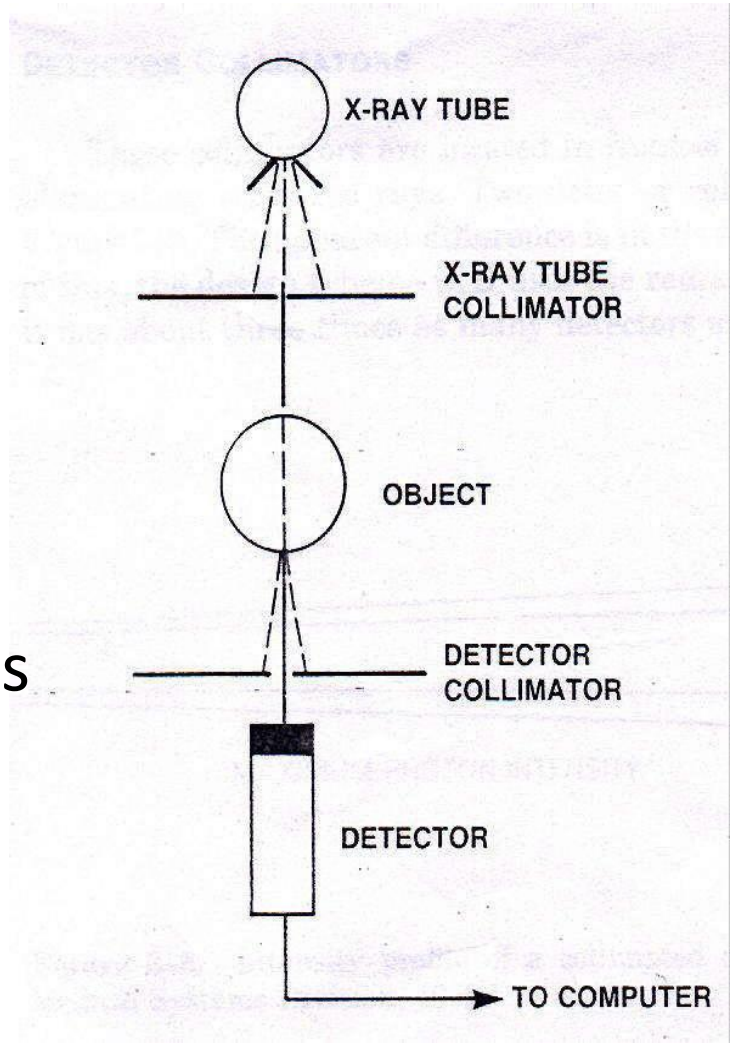
Collimator

- ✓ Thin fan shaped Collimator is used to reduce exposure.
- ✓ Postpatient collimator are also used to remove the scattered photons as well as control slice thickness that ranges from 1 to 3 mm.
- ✓ The x-ray beam is collimated at two points ,one close to the x-ray tube and the other at the detector. The collimator at the detector is the sole means of controlling scatter radiation. The collimators also regulate the thickness of the tomographic section (voxel length)



COLLIMATORS

- To decrease scatter radiation
- To reduce patient dose
- To improve image quality
- Collimator width determines the slice thickness



Detectors

Made up of multiple discrete cells or detectors .

Two types of detectors are used

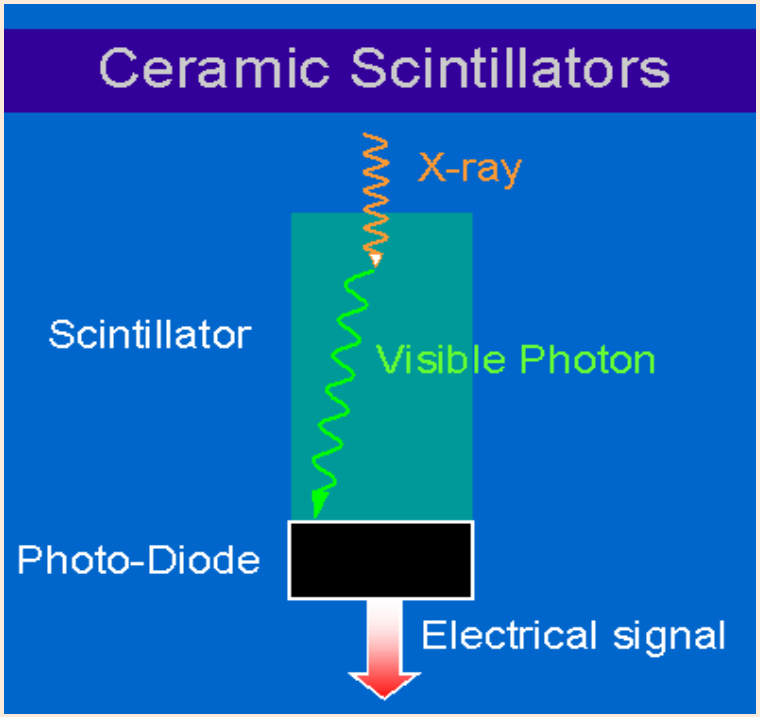
- ❖ Crystal Scintillation Detectors
- ❖ Gas Filled Detectors

Scintillation Detectors

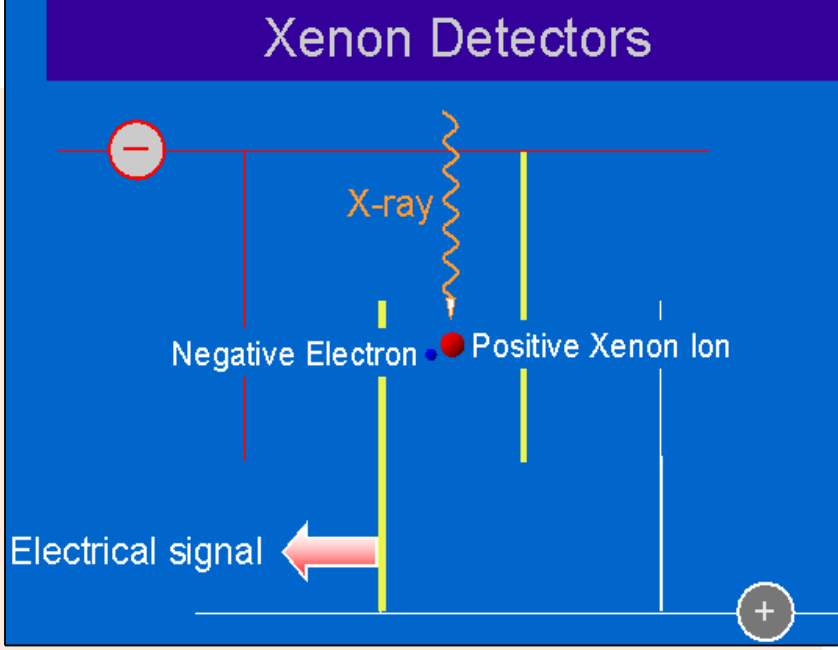
Coupled optically to photodiode

Materials Used

I. Sodium Iodide
II. Bismuth Germanium Oxide
III. Cesium Iodide
IV. Cadmium Tungstate



Gas Filled Detectors

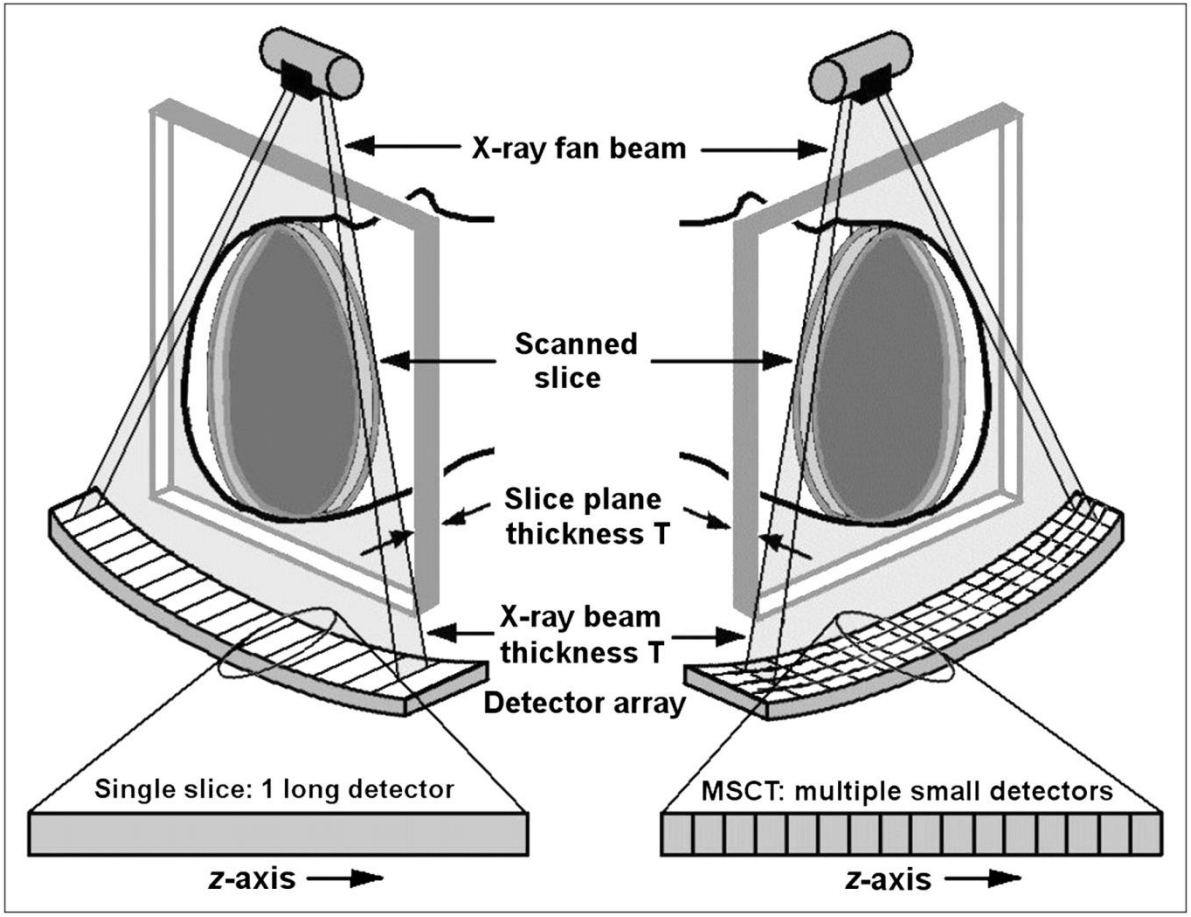


- Materials Used
  - Xenon
  - Krypton
  - Xenon + Krypton
- Have high atomic number, are inert, and display minimal after glow. The gas is contained under high pressure in the detector array.

Gas Filled Detectors	Scintillation Detectors
Sensitive face: 100% Detection Efficiency: 45%	Sensitive face: 50% Detection Efficiency: 90%

- Since 90% of 50 is 45, the output is same. The overall efficiency of both the detectors is same

Multi Slice Detectors



Data Acquisition System

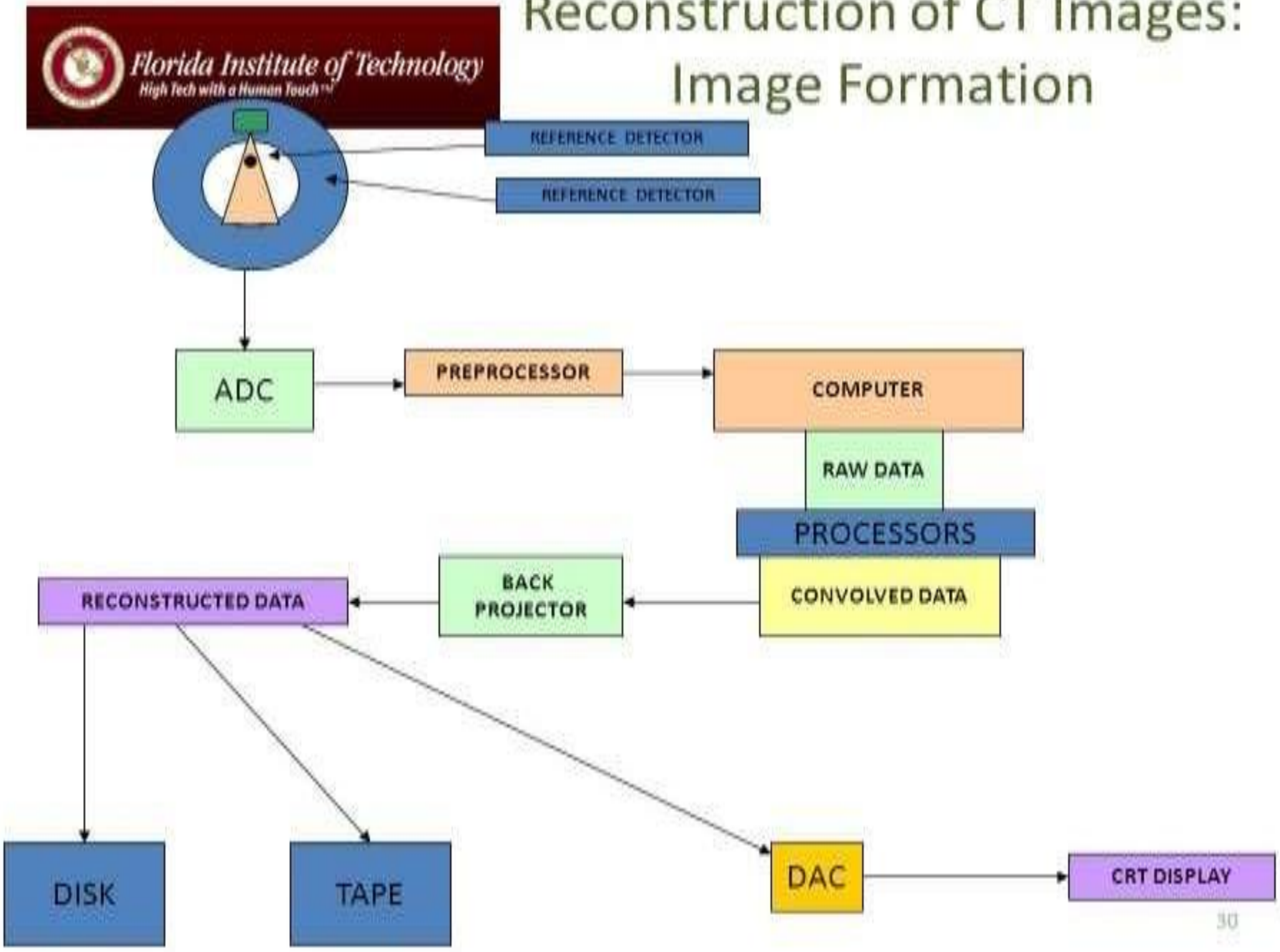
The DAS consists of the following parts

- X-ray photons come on the **dectector**
- 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.

Image Reconstruction

- After enough transmission measurements (detector)
- Sent to the computer for processing
- A software called **Fourier Slice Transform** is used.
- More than 250,000 reconstruction algorithms are used (example: algebraic reconstruction technique) to compute the image.

Reconstruction of CT Images: Image Formation



Operating Console

- ✓ It is master control center of the CT scanner.
- ✓ It is used to input all of the factors related to taking a scan.
- ✓ Typically, this console is made up of a **computer, a keyboard, and multiple monitors.**
- ✓ Often there are two different control consoles, one used by the CAT scanner operator, and the other used by the physician.

Scanning methods

1. **Digital projection**
    1. AP, PA, Lat or Oblique projection
    2. Surview, Scanogram
2. **Conventional CT**
    1. Axial -Start/stop
3. **Volumetric CT**
    1. Helical or spiral CT - Continuous acquisition

Digital Projection:

X-ray tube and detector remain stationary . Patient table moves continuously with X-rays “on” Produces an image covering a range of anatomy similar to a conventional X-ray image, e.g. flat plate of the abdomen .Image used to determine scan location.

Volume CT:

X-ray tube and detector rotate 360°. Patient table moves continuously with X-ray’s “on” Produces a helix of image information. This is reconstructed into 30 to 1000 images .

How does the procedure work?

- In many ways CT scanning works very much like other x-ray examinations.
- X-rays are a form of radiation—like light or radio waves—that can be directed at the body. Different body parts absorb the x-rays in varying degrees.
- In a conventional x-ray exam, a small amount of radiation is aimed at and passes through the body, recording an image on photographic film or a special image recording plate.
- Bones appear white on the x-ray; soft tissue, such as organs like the heart or liver, shows up in shades of gray and air appears black.

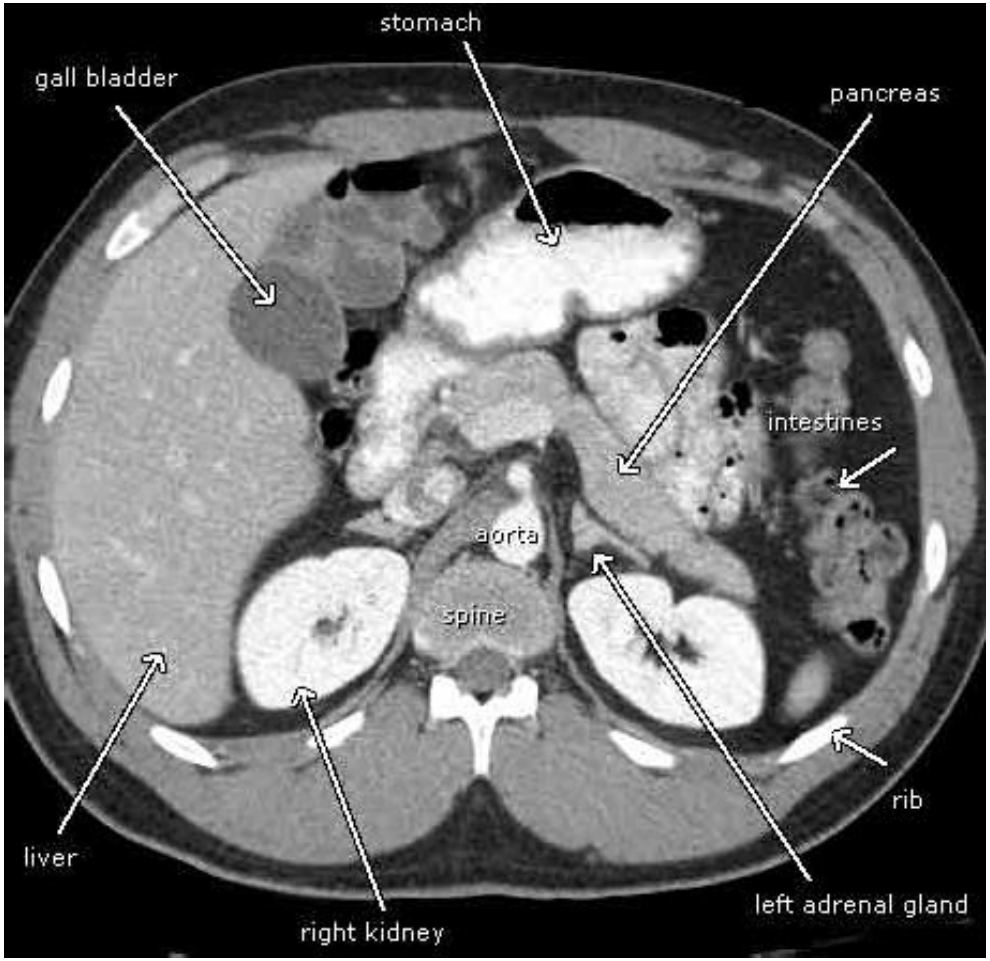
- With CT scanning, numerous x-ray beams and a set of electronic x-ray detectors rotate around patient, measuring the amount of radiation being absorbed throughout the body.

- At the same time, the examination table is moving through the scanner, so that the x-ray beam follows a spiral path.

- A special computer program processes this large volume of data to create two-dimensional cross-sectional images of your body, which are then displayed on a monitor.

- This technique is called helical or spiral CT.

CT slice through the mid-abdomen showing multiple normal-appearing organs



- CT imaging is sometimes compared to looking into a loaf of bread by cutting the loaf into thin slices.
- When the image slices are reassembled by computer software, the result is a very detailed multidimensional view of the body's interior.
- Refinements in detector technology allow new CT scanners to obtain multiple slices in a single rotation.
- These scanners, called multislice CT or multidetector CT, allow thinner slices to be obtained in a shorter period of time, resulting in more detail and additional view capabilities.

Body CT – 3D images

- 3-D images look like the "real thing."
- They can show details, such as broken bones.
- They are helpful in guiding surgeons before complex operations.

How is the CAT scan performed?

- The technologist begins by positioning patient on the CT examination table, usually lying flat on back or less commonly, on one side or on stomach.
- Straps and pillows may be used to help you maintain the correct position and to hold still during the exam.
- Depending on the part of the body being scanned, patient may be asked to keep hands over head.
- The X-rays flow from the rotating x-ray beams, then they passed through the body they detected on rotating x-ray detector.

- When x-ray passed through the body, the intensity of the x-rays changed according to the nature of body.
- When x-ray fall on the detector it produce Electrical signal according to the rays.
- The signal passed to the data ecquisition unit to store these signals temporarily.
- After this, the image re-construction unit receive these signal and process it, after processing signals it make 3-D (three dimensional) images of internal structure of the body.

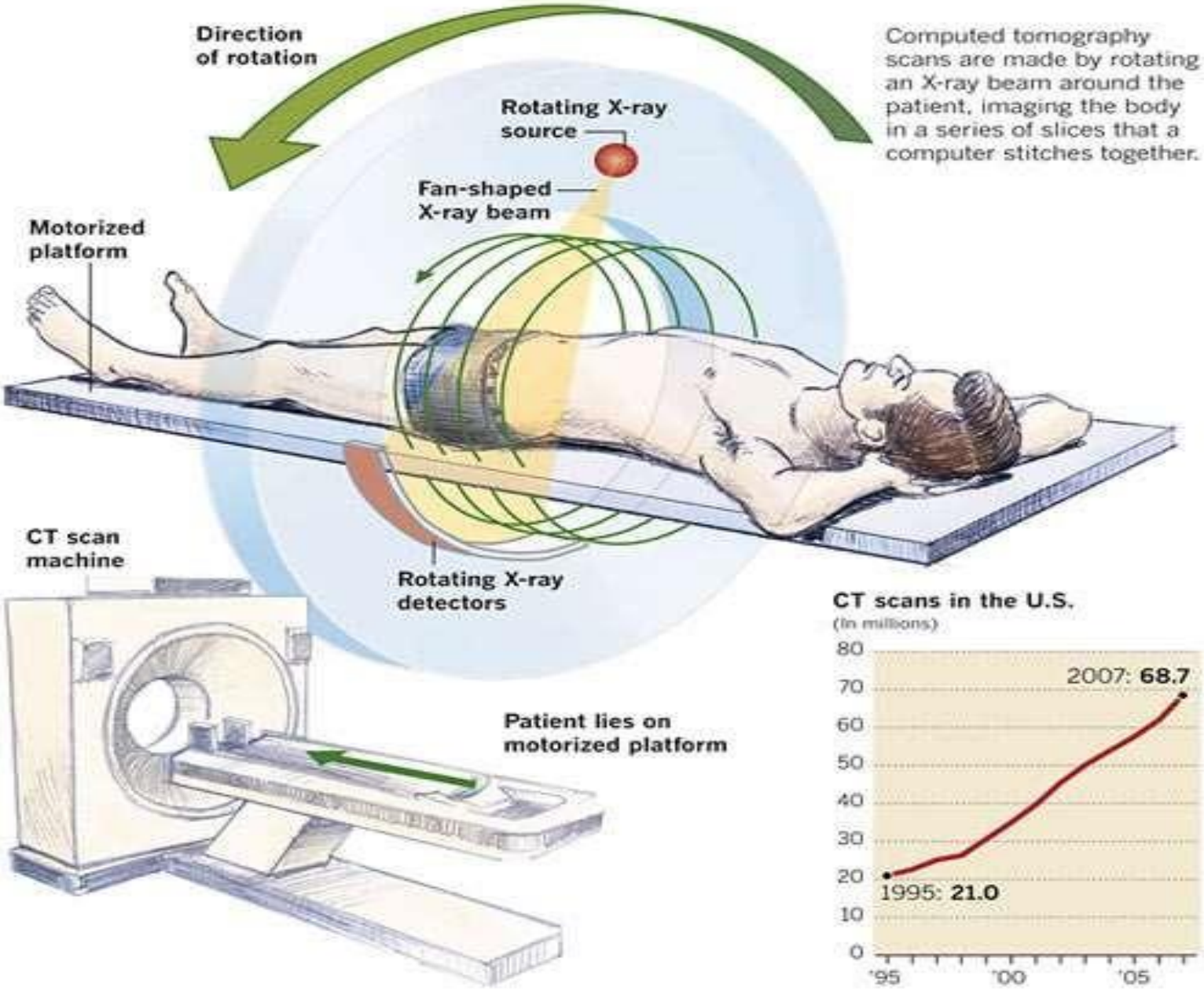
- These 3D images sent to the Computer for more processing.
- After this we can print out these images as hard form on x-ray sheets

- If contrast material is used, it will be swallowed, injected through an intravenous line (IV) or administered by enema, depending on the type of examination.
- Next, the table will move quickly through the scanner to determine the correct starting position for the scans.
- Then, the table will move slowly through the machine as the actual CT scanning is performed.
- Depending on the type of CT scan, the machine may make several passes.
- Patient may be asked to hold breath during the scanning.

- Any motion, whether breathing or body movements, can lead to artifacts on the images.
- This is similar to the blurring seen on a photograph taken of a moving object.
- When the examination is completed, patient will be asked to wait until the technologist verifies that the images are of high enough quality for accurate interpretation.
- The CT examination is usually completed within 30 minutes. The portion requiring intravenous contrast injection usually lasts only 10 to 30 seconds.

Anatomy of a CT scan

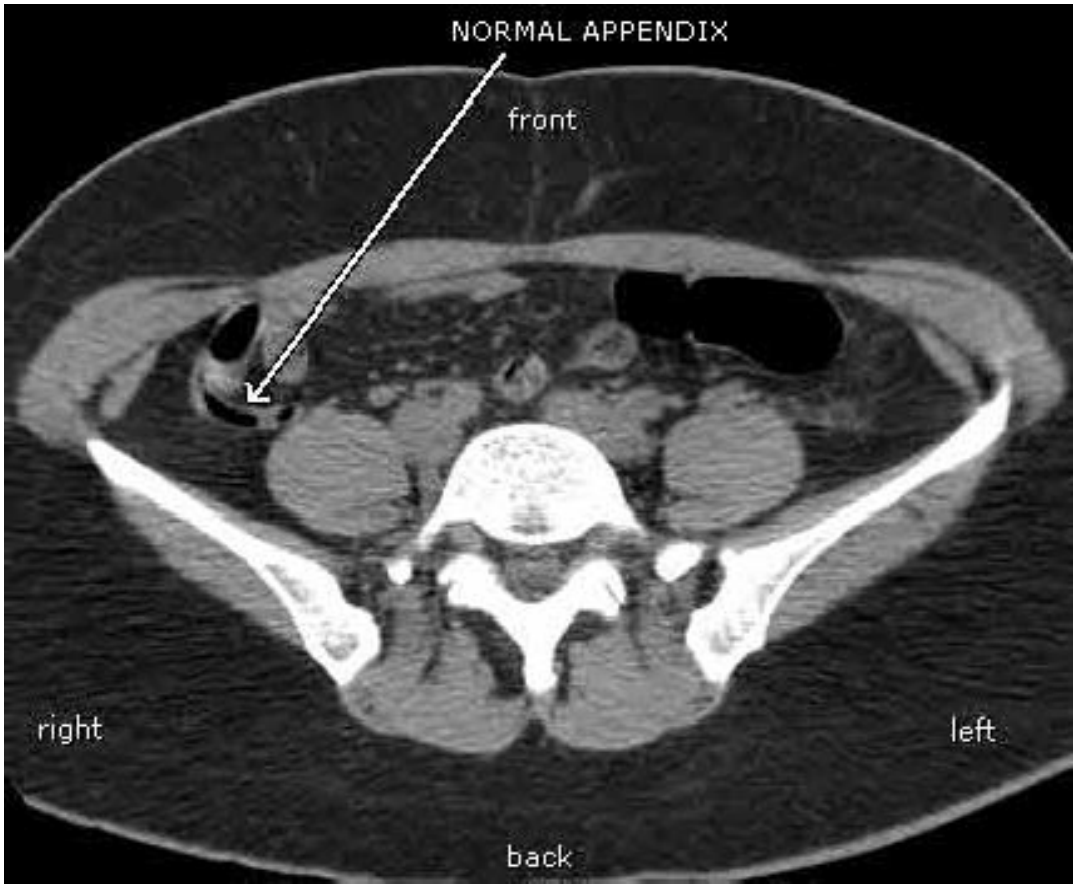
CT scanners give doctors a 3-D view of the body. The images are exquisitely detailed but require a dose of radiation that can be 100 times that of a standard X-ray.



Computed tomography scans are made by rotating an X-ray beam around the patient, imaging the body in a series of slices that a computer stitches together.

CT scans in the U.S.

(In millions)



- CT scan of a normal appendix in the right lower abdomen.
- The appendix normally connects with the right colon and contains air (this appears black on the scan).
- Air in the appendix excludes appendicitis since this means that the appendix is not obstructed or inflamed.

- Appendicitis: The appendix (A) is distended and inflamed.
- In this patient the appendix has not yet ruptured

Interpretation of a CT scan

Radiologist reading CT on a computer monitor

- Most radiologists look at CT images on computer monitors.
- It takes a lot of training and experience to interpret CT scans.
- A board certified radiologist is a physician qualified to independently prescribe, supervise and interpret a CT exam.

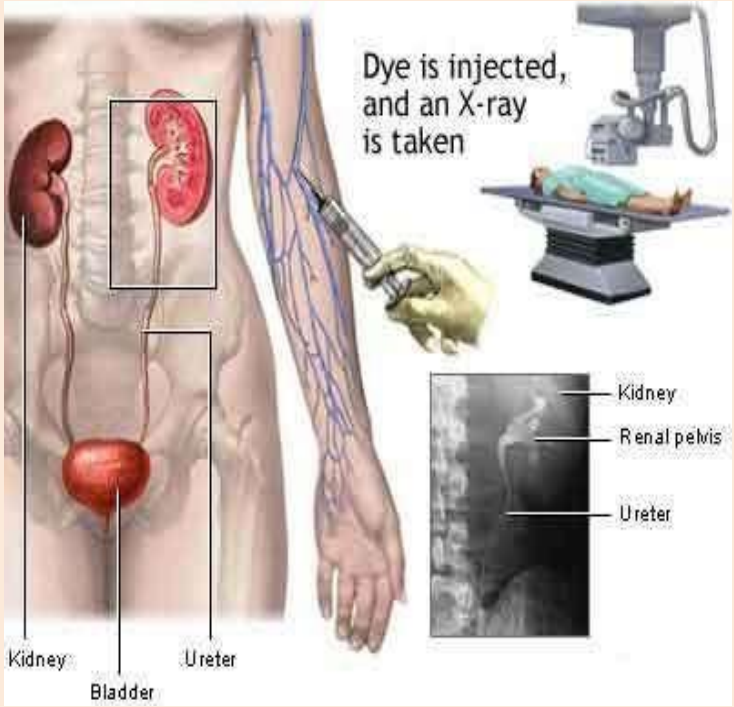
Contrast agents

CT contrast is used to make specific organs, blood vessels and/or tissue types "stand out" with more image contrast to better show the presence of disease or injury.

Route of contrast agent used in CT

1. Intravenous injection
2. Orally
3. Rectally
4. Intra articular

    - Arthrography or inhaled



COMPOUNDS USED:

Iodide compound contrast

a) Diatrizole (urograffin hypaque) 1500 moSml/kg
b) Metrizoate (Isopaque) 1500
c) Iothalamate (Conray) 1500

Ionic -- LOCM

a) Loxaglate (hexabrix) 490

None Ionic – LOCM

I. Iopamidole (Niopam , Isovue) 470
II. Iohexol (Ominpaque) “
III. Iomeprol (Iomeron) “
IV. Ioversol (Optiray) “
V. Iopromide (Ultravist) “

None Ionic – ISO

1. Iotrolan (Isovist)
2. Iodixanol (visipaque)

Barium compound contrast

1. Baritop 100 (100% all part of GIT)
2. EPI -C (150% large bowel)
3. E-Z HD (250 % esophagus , stomach and duodenum)
4. E-Z paque (100% small bowel
5. Polibar (115% large bowel)
6. Polibar rapid (100% large bowel)
7. Water -soluble 20 ml {Urograffin 150 , gastromiro }
8. Barium suspension – low density (2% w/v

- Once the iodine/barium contrast has been injected into the blood stream, it circulates through the heart and passes into the arteries, through the body's capillaries and then into the veins and back to the heart.
- As CT images are being acquired, the CT's x-ray beam is attenuated (weakened) as they pass through the blood vessels and organs flush with the contrast. This causes the blood vessels and organs filled with the contrast to "enhance" and show up as white areas on the x-ray or CT images. The kidneys and liver eliminate the contrast media from the blood.
- Toxicity may occur rarely that include flushing , nausea , metal taste in moth , peripheral burning , rigors urticaria , warm , pain , abdominal pain, bronchospasm, none cardiac pulmonary edema, arrhythmias, hypotension, nephrotoxicity, CIN , hematological crisis in sickle cell patient, neurotoxicity , thyroid diseases.

Some common uses of CT Scan

- one of the best and fastest tools for examining the chest, abdomen and pelvis
- it provides detailed, cross-sectional views of all types of tissue.
- used to examine patients with severe injuries from incidents such as a motor vehicle accident.
- performed on patients with acute symptoms such as abdominal pain or difficulty breathing.

- Severe injuries from incidents such as a motor vehicle accident.
- Detecting many different cancers and its size, precise location and the extent of the tumor's involvement with other nearby tissue.
- Detection, diagnosis and treatment of vascular diseases
- To assess for pulmonary embolism/ abdominal aortic aneurysms (AAA).
- Valuable in diagnosing and treating spinal and cranial problems

- often the best method for detecting many different cancers, including lung, liver, kidney and pancreatic cancer, since the image allows a physician to confirm the presence of a tumor and measure its size, precise location and the extent of the tumor's involvement with other nearby tissue.

- invaluable in diagnosing and treating spinal problems and injuries to the hands, feet and other skeletal structures because it can clearly show even very small bones as well as surrounding tissues such as muscle and blood vessels.

For children

CT imaging is more often used to evaluate:

- lymphoma
- neuroblastoma
- kidney tumors
- congenital malformations of the heart, kidneys and blood vessels
- cystic fibrosis
- complications of acute appendicitis
- complications of pneumonia
- inflammatory bowel disease
- severe injuries

Physicians often use the CT examination to:

- quickly identify injuries to the lungs, heart and vessels, liver, spleen, kidneys, bowel or other internal organs in cases of trauma.
- guide biopsies and other procedures such as abscess drainages and minimally invasive tumor treatments.
- plan for and assess the results of surgery, such as organ transplants or gastric bypass.
- stage, plan and properly administer radiation treatments for tumors as well as monitor response to chemotherapy.
- measure bone mineral density for the detection of osteoporosis.

BENEFIT VS RISK OF CT SCAN

Benefits

- Painless, noninvasive and accurate.
- Ability to image bone, soft tissue and blood vessels all at the same time.
- Provides very detailed images of many types of tissue
- Fast and simple; in emergency cases, they can reveal internal injuries and bleeding quickly enough to help save lives.
- Cost-effective imaging tool for a wide range of clinical problems.
- Less sensitive to patient movement than MRI and CT can be performed if you have an implanted medical device of any kind, unlike MRI.
- Provides real-time imaging, making it a good tool for guiding minimally invasive procedures such as needle biopsies and needle
- Diagnosis may eliminate the need for exploratory surgery and surgical biopsy.
- No radiation remains in a patient's body after a CT examination.
- Usually have no immediate side effects.

Risks

- Slight increase in cancer from larger amounts of radiation, such as from radiation therapy.

- Not recommended for pregnant women unless medically necessary because of potential risk to the baby.

- Manufacturers of intravenous contrast indicate mothers should not breastfeed their babies for 24-48 hours after contrast medium is given.

- Rare risk of serious allergic reaction to contrast materials exist, so radiology department should be well-equipped to deal with them.

Limitations of CT Scanning of the Body

- Soft-tissue details in areas such as the brain, internal pelvic organs, and joints (such as knees and shoulders) can often be better evaluated with magnetic resonance imaging (MRI).
- In pregnant women, while CT can't be performed safely, other imaging exams not involving radiation, such as ultrasound or MRI, is preferred if they are likely to be as good as CT in diagnosing your condition.
- A person who is very large may not fit into the opening of a conventional CT scanner or may be **over the weight limit—usually** 450 pounds—for the moving table

Advntages of CT-scan over X-ray

Traditional X-rays suffer from their inability to give any perception of depth to the physician. This is because the X-ray can only picture the average density of any tissue in front of the X-ray film. A CT Scan gets around this limitation in three ways:

- Instead of using a broad beam of X-rays, a CT Scan uses a very narrowly focused beam of X-rays that can only penetrate straight through the body in a straight line to the detector.
- The X-ray source is rotated around the body so that the X-rays pass through the entire structure in both directions.
- A computer is used to reconstruct the intensity of the X-rays into an image showing the density of any point of the plane through which the X-rays passed.

ANY QUERIES