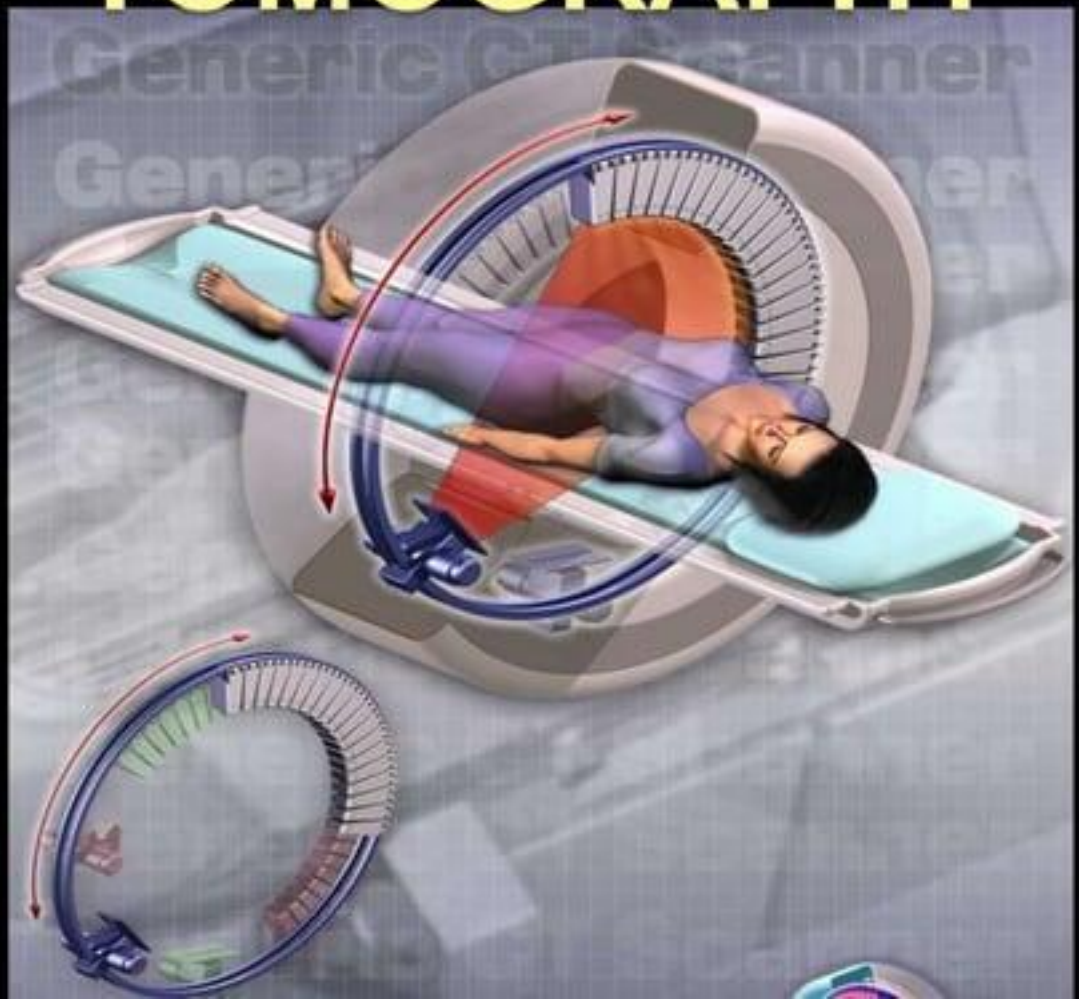
BASICS OF CT & MRI

COMPUTED TOMOGRAPHY



INTRODUCTION

OVER the last 40 years an array of imaging modalities has been developed that has enhanced the already versatile x-ray generating equipment and film used in conventional image production.

computed tomography was developed in the early to mid 1970s and is a radiographic technique for producing cross-sectional tomographic images.

Claimed to be 100 times more sensitive than conventional x-ray systems, it demonstrated differences between various soft tissues never before seen with x-ray imaging techniques.

HISTORY

- 1961-Oldendorff W.H recognized the potential of reconstruction tomography.
- 1963- Cornmark used a source and detector rotate around a non symmetrical phantom and a computed for processing the transmission data.
- 1972- Godfrey Hounsfield an engineer at EMI(Electrical musical instruments) limited, England announced the invention of a revolutionary imaging technique which he referred to as Computerized Axial Transverse Scanning..

- With this technique he was able to produce an axial cross-sectional image of the head using a narrowly collimated ,moving beam of X-rays.
- 1979-Cornmack and Hounsfield were awarded the Noble prize in Physiology and Medicine.
- From 1971to 1975 ,within a span of 4 years, four generation of scanner evolved, which yielded shorter times and better control over the patient's motion.
- In fifth generation CT scanner, scanning time is reduced to 16 milliseconds.
- 1998- CBCT was invented
-

Synonyms;

Computerized Axial Tomography

Computerized Reconstruction

Computerized Tomographic Scanning

Axial Tomography

Computerized transaxial Tomography

- **TOMOGRAPHY**

- *Tomography is a process by which an image layer of the body is produced, while the images of the structures above and below that layer are made invisible by blurring.*

Tomography may be classified into many types:

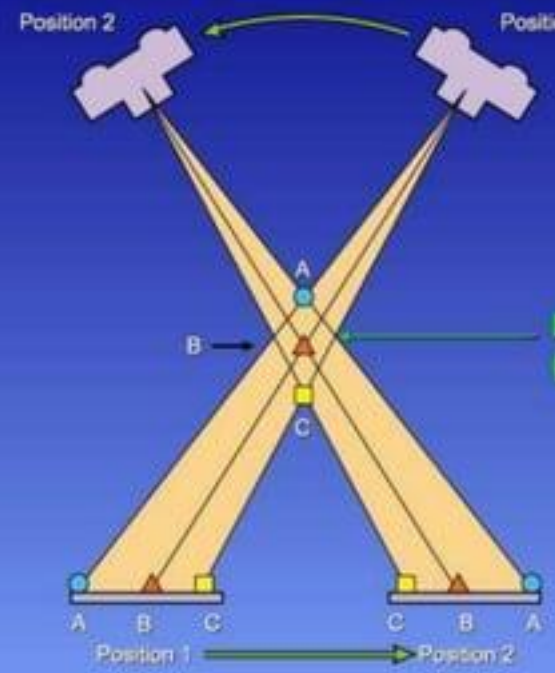
- Conventional Tomography
- Computed Tomography
- Three - dimensional C T
- Spiral Computed Tomography
- Emission Computed Tomography

Conventional Tomography

- *Tomography is a generic term, formed from the Greek words tomo (slice) and graph (picture) that was adopted in 1962 by the International Commission on Radiographic Units and Measurements to describe all forms of body section radiography.*

- *This is achieved by a synchronized movement of the film and the tube in opposite directions, about a fulcrum (i.e. the plane of interest in the patient's body). Objects closest to the film are seen most sharply and objects farthest away are completely blurred.*
- *The thickness of the image layer depends on the angle of rotation or the amount of movement of the tube.*
- *Some degree of image degradation also occurs within the image layer. The greatest amount of blurring is at the periphery of the image layer, and the sharpest image is at the center*

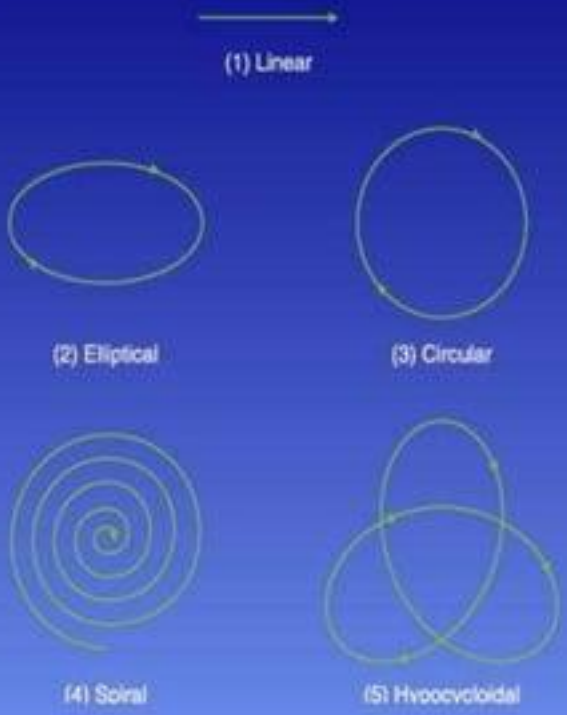
Tomographic Blurring Principle



Fulcrum or pivot point (objective plane)

- Only "B" (fulcrum) remains in same position on the IR

Tube Trajectories



5 basic types

Computed Tomography (CT)

- A computed tomographic image is a display of anatomy of a thin slice of body developed from multiple X-ray absorption measurements made around the body's periphery.

- Computed tomography (CT) permits the imaging of thin slices of tissue in a wide variety of planes.
- Most CT is done in the axial plane, and many CT scans also provide coronal views; sagittal slices are less commonly used.

Slice thickness is usually

✓10 mm through the body and brain

✓ 5 mm through the head and neck, unless three dimensional reconstruction is anticipated.

✓ In such cases, the slice thickness is 1.0 to 1.5 mm in order to provide adequate data

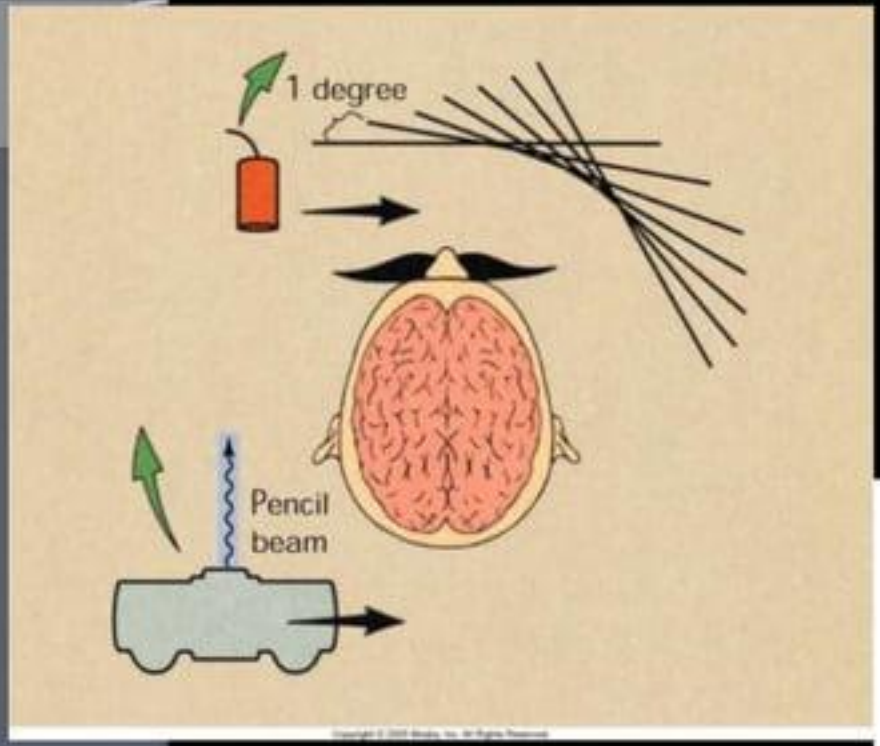
BASIC PRINCIPLE

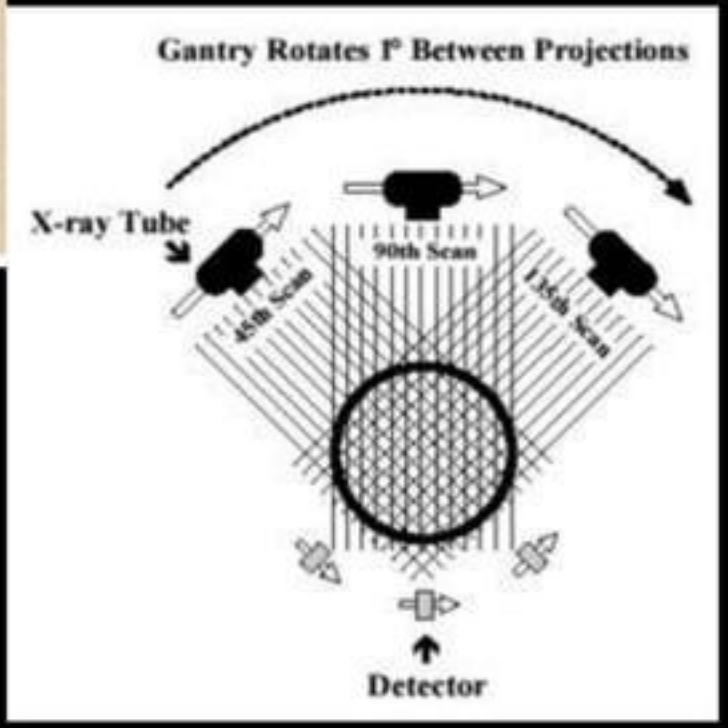
- *CT scanners use the X-rays to produce the sectional or slice images ,as in conventional tomography, but radiographic film is replaced by sensitive detectors. The detectors measure the intensity of the x-ray beam emerging from the patient and convert this into digital data which are stored and can be manipulated by a computer. This numerical information is converted into a gray scale representing different tissue densities ,thus allowing a visual image to be generated.*

CT Scanner Generations

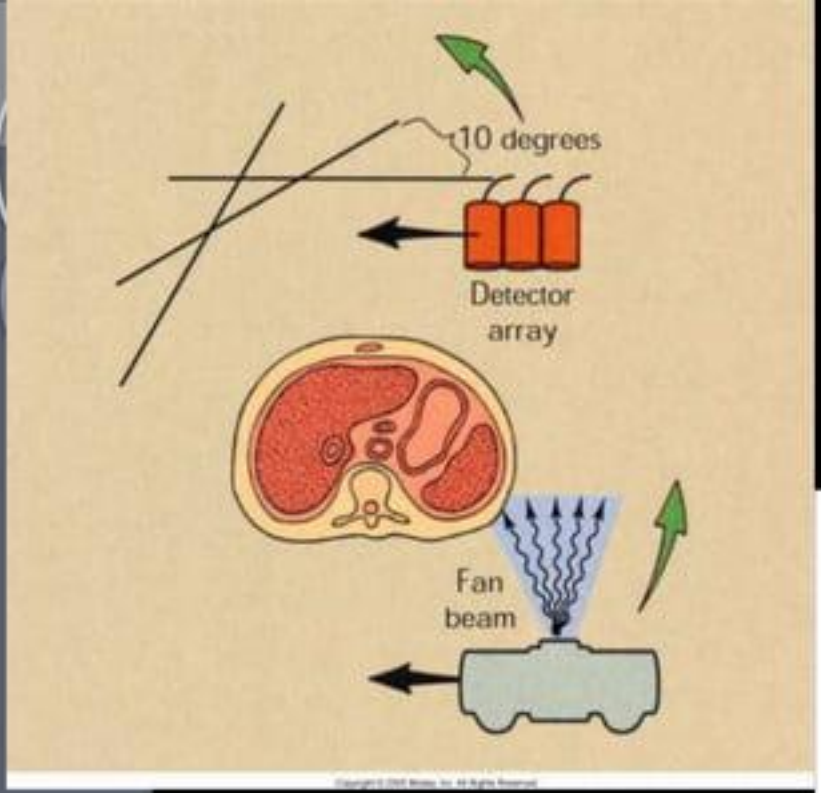
- **1. First generation (Rotate / Translate, pencil beam)**
- The original EMI unit was the first generation scanner. It was rotate/translate pencil beam system. Only two detectors were used, which measured transmission of X-ray through the patient for two different slices. That is two tomographic sections were taken simultaneously. It was designed specifically for evaluation of brain. In this unit head was enclosed in a water bath.
- The linear motion was repeated 180 times and after one linear movement ,gantry rotated 1 degree.
- X-ray beam was on during linear motion ,while off during rotation.
- The transmitted radiation was 160 times during each linear movement .
- Total no. of transmission-160x180= 28,800

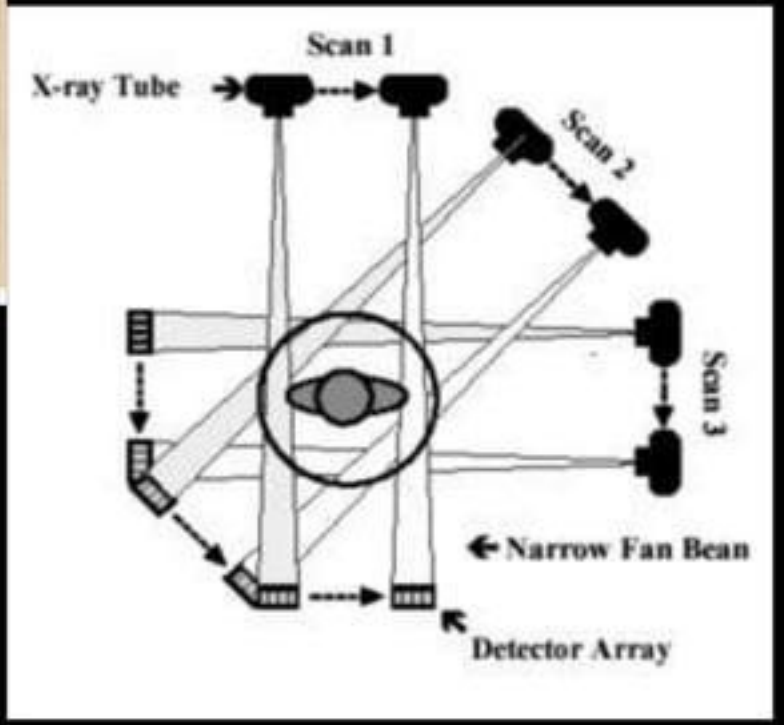
- Scan time was 4.5 to 5 min.
- Matrix was 80x80


1 degree
Pencil
beam


Gantry Rotates 1° Between Projections
X-ray Tube
90th Scan
45th Scan
135th Scan
Detector

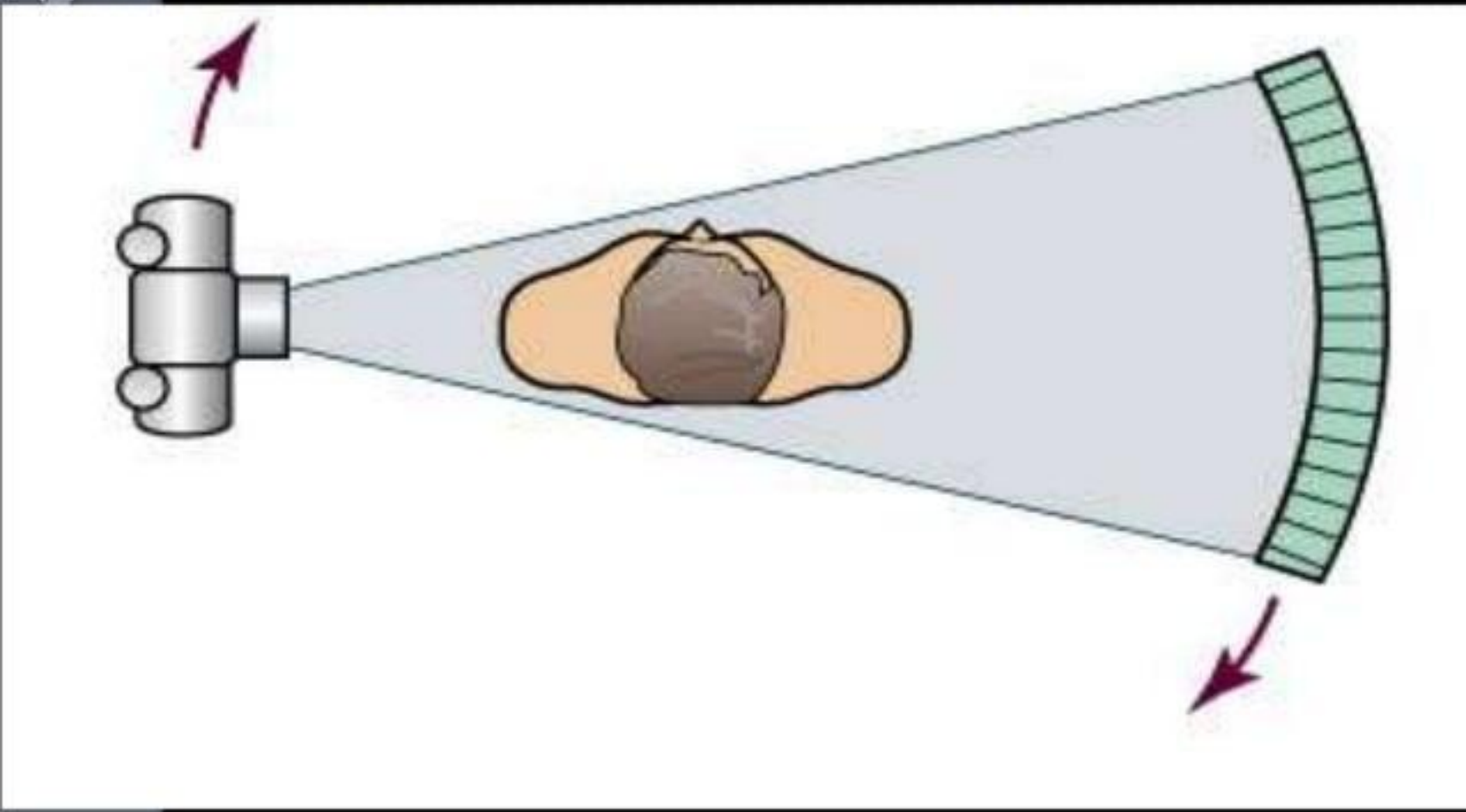
- **Second generation (Rotate / Translate, narrow fan beam)**
- Second generation scanner were also of translate-rotate type. These units were incorporated a linear array of 30 detectors. The use of 30 detectors increased the utilization of the X-ray beam by 30 times over the single detector used per slice in first generation systems. Source detector assembly intercepting a fan shaped (a narrow fan angle of 10°) beam rather than a pencil sized X-rays beam.
- Instead of moving 1 degree at the end of each linear scan ,the gantry rotates through a greater arc, upto 30 degree. So linear movement have to be repeated six times to cover 180 degree.
- Scan time was 10-90 sec.


10 degrees
Detector
array
Fan
beam


Scan 1
X-ray Tube
Scan 2
Scan 3
Narrow Fan Bean
Detector Array

- **Third generation (Rotate/rotate wide fan beam)**
- The translation motion of first and second generation was a major limitation because at the end of each translation, the translational inertia of X-ray tube/detector system had to be stopped; the whole system rotated and then the translation motion had to be restarted. This design could never have led to fast scanning.
- To overcome this limitation third generation scanners evolved. Third generation scanner uses increased number of detector (upto about 750 detector) and rotate-rotate system i.e. X-ray tube and detector array were rotated. The detector is aligned around an area of a circle whose centre is focal spot. X-ray beam is collimated into fan beam (fan angle was about 50°).
- Scan time was 2 to 10 sec.

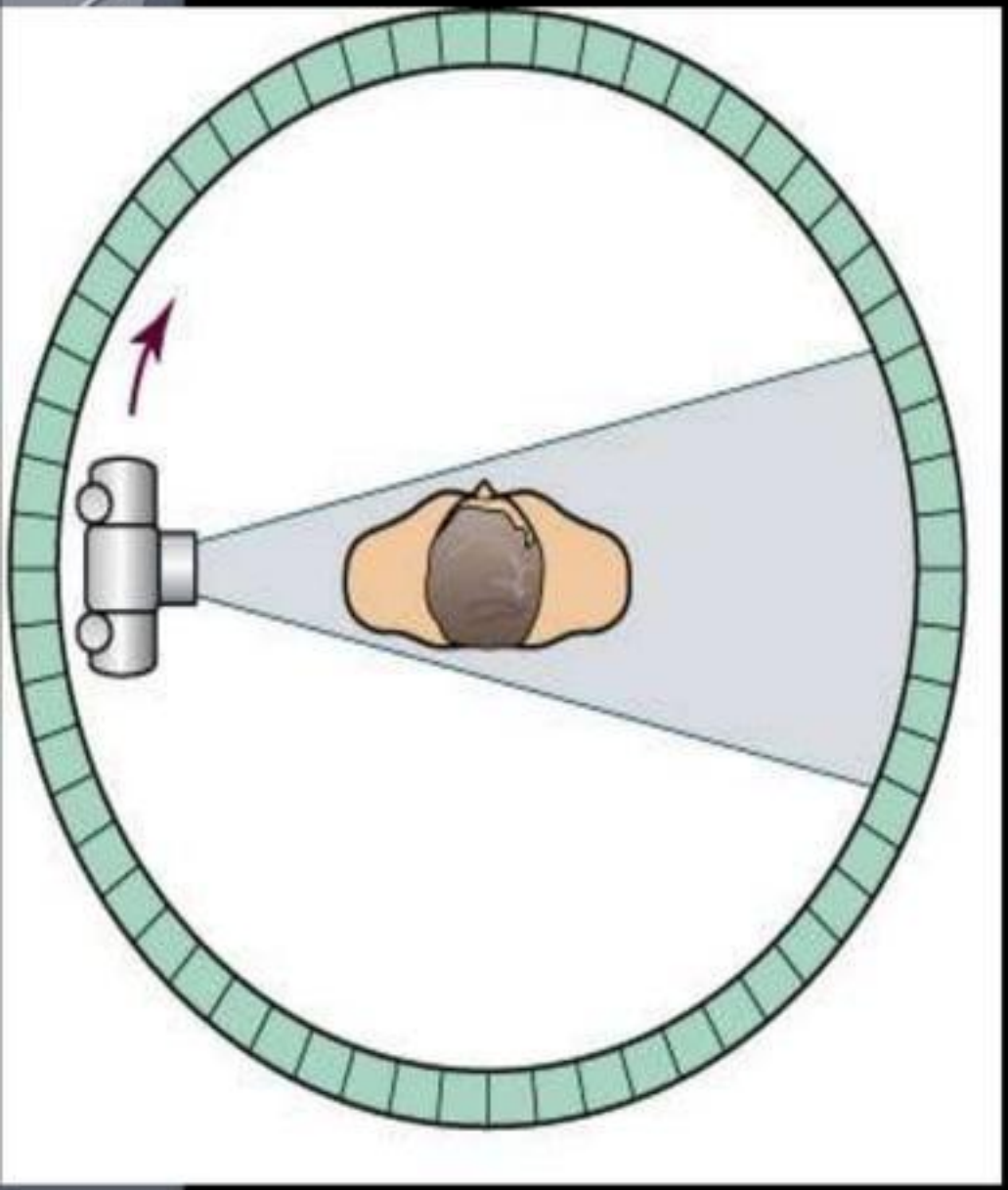
3rd generation configuration



- Cone Beam Radiology
- CBCT uses a round or rectangular cone – shaped x-ray beam centered on a two – dimensional x-ray sensor to scan a 360 degree rotation about the patient's head. During the scan a series of 360 exposures or projections, one for each degree of rotation, is acquired, which provide raw digital data for reconstruction of the exposed volume by computer algorithm.

- Depending on the equipment, scan time range from 17 sec to little more than 1 min.
- Multiplanar reformatting of the primary reconstruction allows for both three-dimensional and two-dimensional images of any selected plane to be made.
- Resolving power is four times that of CT
- Less expensive
- Radiation dose is 3-20 % that of conventional CT.

- **Fourth generation CT scanner (rotate /stationary)**
- Fourth generation CT scanner were designed to overcome the problem of electronic drift between many detectors used in the system so this design eliminated ring artifact.
- Fourth generation CT scanner uses rotate only motion. Huge tube rotated but the detector assembly does not. The detector forms a ring that completely surrounds the patient. The X-ray tube rotates in a circle inside the detector ring and X-ray beam was collimated to form a fan beam.
- Was not faster in principle than third generation.
- Easier detector calibration.



- 4th generation configuration

- **Fifth generation systems-**
- Developed by Dr. E Woods of Mayo Clinic. System consists of multiple rays tubes and detectors. Such a unit is primarily used to image 3D sections of the heart and reduces artifacts caused due to cardiac rhythm.

CT EQUIPMENT

The equipment consist of:

- Gantry containing x-ray *source, detectors and electronic measuring devices*
- *Motorized table- used to position the patient within gantry*
- *X-ray power supplies and controls*
- *Computer*
- *Viewing devices*


PHILIPS

X-RAY TUBES

- Radiation source for CT would supply monochromatic X-ray beam by which image reconstruction is simple and more accurate.
- Earlier models used oil-cooled, fixed – anode, relatively large (2x16mm)focal spot tubes at energies of about 120 kilovolt (constant potential) and 30mA. The beam was heavily filtered to move low energy photons and to increase the mean energy of the radiation.

- Most newer fan beam units have a diagnostic –type x-ray tube with a rotating anode and a much smaller focal spot ,in some units down to 0.6mm and generate X-rays in short bursts, or pulses. These tubes are air-cooled and operate at much higher currents, upto 600mA. They are (cathode-anode) perpendicular to the fan beam to avoid asymmetry in X-ray output because of the heel effect.

- Recently, special types of X-ray tubes have been developed for CT. These tubes are designed to withstand the very high heat loads generated when multiple slices are acquired in rapid sequence.

COLLIMATORS

- 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)

- **Detectors-**

1. Gas filled ion chamber detectors made of high pressure xenon.

   Capture about 50 % photons in the beam

2. Solid state detector

   commonly used, 80% efficient.

   Usually made of cadmium tungstate.

TECHNIQUE

- The process by which production of CT image occur is called scanning.
- The patient lies down with the part of the body to be examined within the circular gantry, housing the X-ray tube head and detector.
- The level of plane and thickness of the section to be imaged are selected and x-ray tube head rotates around the patient, scanning that section.
- As the tube head rotate around the patient each set of detector produces an attenuation or penetration profile of the region of the body being examined.

- These detectors produce electrical impulses that are pro-portional to the intensity of the X-ray beam emerging from the body

- That intensity is determined by various factors;

  1. the energy of the X-ray source,
  2. the distance between the source and the detector
  3. the attenuation of the beam by the material in the object being scanned.

- Penetration profile is stored in the computer, which calculates the density or absorption at points on a grid formed by the intersections of penetrating profiles.

- The CT image is a digital image, reconstructed by the computer, which mathematically manipulates the transmission data obtained from the multiple projections

- The image consists of a matrix of individual blocks called voxels (volume element).It consist of an array of individual points or pixels.

- The size of the pixel is determined by:
  - The geometry of the scan,
  - The frequency and spacing of measurements,
  - The number of penetration profiles and
  - The size of the x-ray source and detector

- Each pixel is assigned a CT number or Hounsfield unit(HU) between +1000 to -1000, depending upon the amount of the absorption within that block of tissue.

- Each number or pixel represents a calculation of the actual attenuation of the X-ray beam by materials with the body. It represents the absorption characteristics or linear attenuation coefficient of that particular volume of tissue in the patient.

- IMAGE RECONSTRUCTION
- Images are typically 512 x 512 or 1024 x 1024 pixels.
- Rapid image reconstruction done by

  Two-dimensional Fourier Analysis

  Filtered back projection

- CT numbers for various body tissues.

Absorber	CT number/HU
Bone (dense)	+400 to +1000
Soft tissues	+40 to +80
Water	0
Fat	-60 to -100
Lung	-400 to -600
Air	-1000

- *The computer can construct an image by printing the numbers or assigning different degree of greyness to each CT number. In some system ,the numerical values are translated into colours or brightness level that can be displayed on a television screen or printed on a paper.*

Image display-----In two basic mode

- As a paper printout of CT numbers
- As a gray scale image on a cathode ray tube or television monitor.

- WINDOW LEVEL AND WINDOW WIDTH
- These two variables enable the visual image to be altered by selecting the range and level of densities to be displayed.
- Window level-is the CT numbers selected for the centre of the range depending on weather the lesion under investigation is in the soft tissue or bone.
- Window width-is the range of CT numbers selected for various shades of grey.

- The contrast and brightness of the image may be adjusted as necessary although the images are usually viewed in two modes:
- Bone windowing and soft-tissue windowing.
- In Bone windowing, the contrast is set so that osseous structures are visible in maximal detail.
- With soft-tissue windowing, the bone looks uniformly white, but various types of soft tissues can be distinguished.

DISTORTION

A signal can contain errors or distortions that are repeatable (deterministic). For instance, if a patient moves during the acquisition step, parts of the anatomy may be blurred or in different positions from their true location. If the image reconstruction process requires linear and consistent data, but the measurements for some reason are not consistent, artifacts can arise that may result in lost information or spurious image features.

ARTIFACT

- Any discrepancy between the CT numbers represented in the image and the expected CT number based on the linear attenuation coefficient

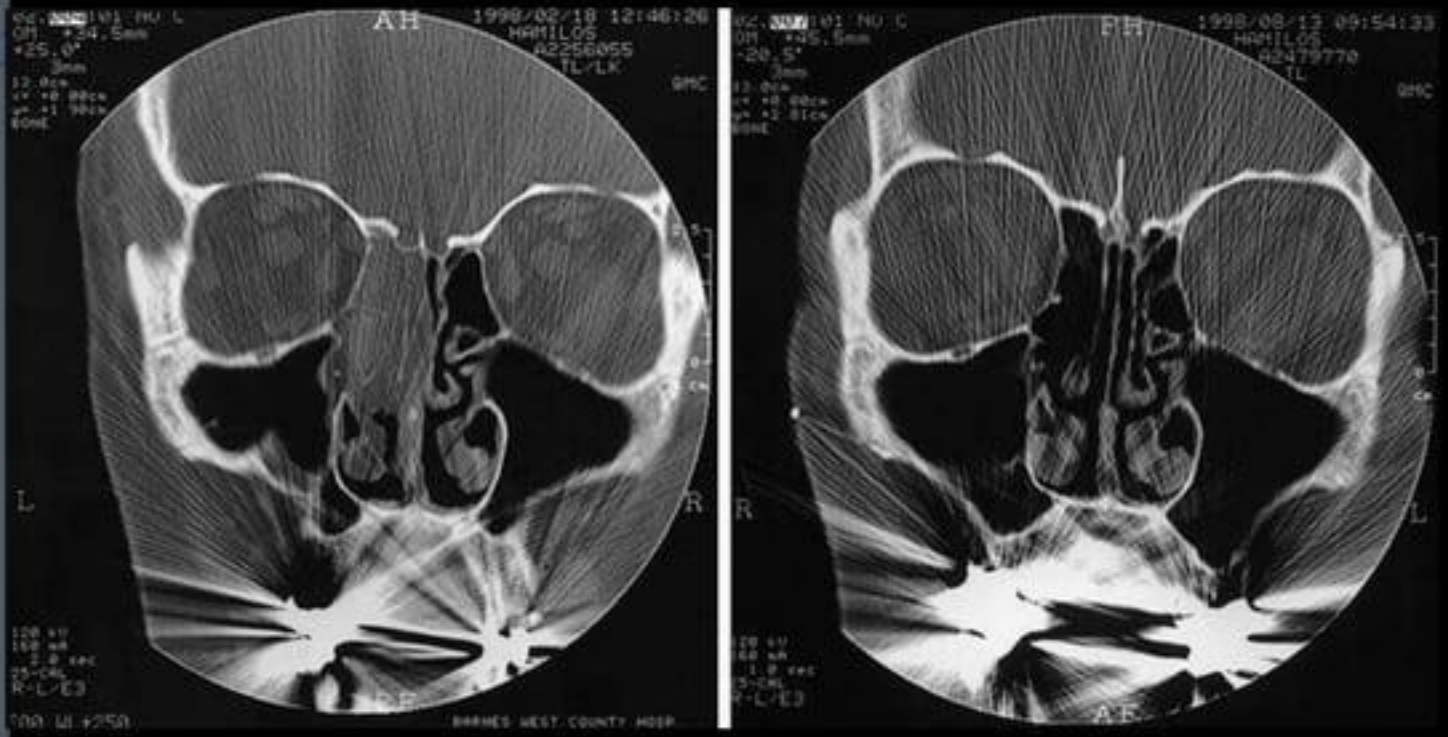
- IMAGE ARTIFACTS

1. Partial volume artifact
2. Beam hardening artifact
   - (due to absorption of low energy photon from the beam.)
3. Metal artifacts

METAL ARTIFACT

- MANIFEST AS "STAR STREAKING" ARTIFACT.
- CAUSED BY PRESENCE OF METALLIC OBJECTS INSIDE OR OUTSIDE THE PATIENT.
- METALLIC OBJECT ABSORBS THE PHOTONS CAUSING AN INCOMPLETE PROFILE

METAL ARTIFACT



- *CONTRAST MEDIA*
- *Is used to obtain a differential change in the attenuation values of normal and pathologic tissues so that recognition of pathology is facilitated. one can expect a large variety of contrast enhancement in pathological tissues due to tissue alterations, mainly related to differences in vascular contrast distribution volume and total distribution volume.*
- *Iodine based*
- *iodine monomers-*

  iothalmate, diatrizoate, metrizoate
- *Non ionic monomer like iopamidol ,iotrioxol*

- ***INDICATIONS***
- ***Intracranial diseases and trauma***
- ***Malignancy of jaws***
- ***Infection***
- ***Post-irradiation***
- ***Salivary gland***
- ***Temporomandibular joint***
- ***Implants***
- ***Fracture***
- ***Foreign body***
- ***Imaging of unerupted and displaced teeth, bone grafting.***

Advantages

- Cross-sectional imaging
- Superior contrast and resolution
- Geometric accuracy
- Images can be manipulated
- Axial tomographic sections are obtainable
- Images can be enhanced by the use of i.v contrast media, providing additional information.

Disadvantages

- Expensive
- Facilities are not widely available
- Very thin contiguous or overlapping slices may result in a high dose of radiation.
- Geometric miss
- Metallic objects such as fillings produce marked streak artifacts across the CT image.

Recent advances in CT

3 DIMENSIONAL CT-

- in this data obtained from CT scan is reformatted into 3D images.
- 3D CT requires that each voxel, shaped as rectangular parallel piped or rectangular solid be dimensionally altered into multiple cuboidal voxels. This process, called interpolation creates sets of evenly spaced cuboidal voxels (cuberilles) that occupy the same volume as the original voxel.
- The CT numbers of the cuberilles represent the average of the original voxel CT numbers surrounding each of the new voxel.
- Creation of these new cuboidal voxels allows the image to be reconstructed in any plane without loss of resolution by locating their position in space relative to one another.

- Ultrafast CT: I matron (San Francisco) has developed a CT scanner capable of acquiring the data upto 10 times faster than conventional CT. About 50msec is able to freeze cardiac and pulmonary motion, enhancing the quality without motion artifact.

- Spiral CT scanners: (discovered in 1989) in this while the gantry containing the x-ray tube and detectors revolve around the patient, the patient table continuously advances through the gantry. This results in the acquisition of a continuous spiral of data as the x-ray beam moves down the patient.

Advantage

- Improved multiplanar image reconstruction
- Reduced examination time(12sec vs 5 min)
- Reduced radiation dose(<75%)

Helical CT is now standard.

- In helical CT scanners, pitch refers to the amount of patient movement compared with the width of image acquired.

$$\text{Pitch} = \frac{\text{table travel per X-ray tube rotation}}{\text{image thickness}}$$

Multidetector helical CT (MDCT, multislice CT, or multirow CT)

- Introduced in 1998
- Widely used
- With this method ,anywhere from four to 64 adjacent detector arrays are used in conjunction with helical CT.
- Time for full cycle rotation-0.35sec.
- The quality of axial ,reformatted, and three dimensional images ,also improved with this as compared to single-slice machines.

Electron beam CT– recent development

- In this machine an electron gun generates an electron beam that is focused electrostatically on a fixed tungsten target circling halfway around the patient.
- The X-rays that are generated expose the detector array circling the other half of the patient.
- Because there are no moving parts ,an image may be acquired in less than 100 microseconds.
- This technique is primarily used for cardiac imaging to stop heart motion.

- Emission CT- is similar in principle to x-ray transmission CT .instead of section morphology ,it reflects physiological processes that concentrate the radionuclide in one or more organs or body compartments.

CBCT	CT
Less radiation dose	More
More time	Less
Images are of lower contrast	Higher
Slice thickness 0.1 mm	1-2 mm
Less expensive	More

SIGNIFICANCE OF CT IN MAXILLOFACIAL REGION

- Trauma
- Neoplasms
- Inflammatory processes
- TMJ disorders

Odontogenic infections

- Cellulitis- soft tissue swelling obliterating fat planes.
- Abscess- irregular zone of low density with a peripheral rim of contrast enhancement.
- Acute osteomyelitis- zone of increased contrast enhancement.
- Chronic osteomyelitis- destructive pattern with peripheral rim of contrast enhancement.

Carl W Hardin and RIC Harnsberger (1985) made use of CT in evaluation of infections and tumours involving the masticator spaces and found that CT is helpful in differentiating inflammation from frank abscesses.

Alan A Schwimmer et al (1988) emphasized the role of CT in the diagnosis and management of temporal and infratemporal space abscesses.

Sialadenitis

- CT is non-invasive, painless and less time-consuming.
- Non-contrast CT for detecting calculi.
- Contrast CT for abscess/cellulitis
- Salivary calculi seen as high density, non-contrast enhancing mass along the course of the duct.

Nick Bryan et al performed CT in 27 patients with salivary gland neoplasm and concluded that when CT is combined with the clinical information and laboratory findings, the overall specificity in identifying the tumour becomes 90%.

ODONTOGENIC CYSTS

- Appear as localized, expansile degenerative area having a fluid density throughout the lesion.
- Do not show contrast enhancement in contrast aided imaging (except Aneurysmal Bone Cyst).

John W Frame and Michael JC Wake evaluated mandibular keratocysts with CT and established that CT provides better methods of accurately displaying the margins of the keratocysts, the areas of bony perforation and any extension into soft tissues.

ODONTOGENIC TUMOURS

- Appear as an expansile lesion having a soft tissue density which show moderate enhancement in contrast aided imaging (except cemental tumours).
- Foci of cystic degeneration are commonly seen.
- Show breach in cortical plates.
- Foci of calcifications are noticed in maturing odontogenic tumours.

- Ameloblastomas- bicortical expansion, thinning and breach of bony walls, extension of tumour into adjacent soft tissue spaces.
- Focal cystic degenerations commonly seen in multilocular lesions.
- Plexiform ameloblastomas have high contrast enhancement due to high vascularity.
- Cystic ameloblastomas show a predominant fluid density.
- Malignant ameloblastomas have a grossly destructive pattern.
- Focal hyperdense areas suggesting calcifications maybe noticeable in Pindborg tumour.

Osborn et al (1982) made a study, on imaging of several mandibular tumours and established their osseous and soft tissue extensions. CT was found valuable in excluding the involvement of mandible by primary osseous and soft tissue lesions of adjacent areas.

MALIGNANCIES

- Seen as predominantly destructive lesions interspersed with focal high contrast enhancement areas.
- Invasive lesions show no/minimal expansion.
- Demarcation from surrounding soft tissue is difficult without contrast aided imaging.
- Reparative lesions like central giant cell granulomas also manifest as destructive, contrast enhancing lesions showing minimal or no expansile pattern.

Close LG et al (1986) found a critical factor in the pretreatment evaluation of patients with carcinoma of the oral cavity or oropharynx, the presence or absence of bony invasion. CT was more specific than conventional X-ray films in detecting bone invasion.

Mark A Cohen and Yancu Hertzanu (1988) in their study on CGCG using CT, conventional tomogram and conventional radiographs, proved CT to be superior in clearly demonstrating the soft tissue mass of lesion, its extension into adjacent structures and bony destruction.

Fibro-osseous lesions

- CT pattern depends on the maturative stage of lesion.
- Cemental lesions are distinguished based on the continuity of the lesions with the roots of the tooth and the periodontal ligament space, separating the lesion from the bony alveolus.

Ariji Y et al (1994) studied cases of florid cemento-osseous dysplasia with conventional radiography and CT and observed thin, low density areas around high density masses with expansion of buccal and lingual cortical plates. CT was able to give additional information by identifying the density of these masses which ranges from 772-1582 HU. These values were suggestive of cementum or cortical bone.

MAXILLARY LESIONS

- Maxillary lesions share similar pictures in contrast to mandibular lesions which make this difficult to distinguish them.

Brenna Betti N, Bruno E et al (1993) For early diagnosis of the maxillary antrum carcinoma, besides a conventional radiographic test, also of more specific analysis, as the computed tomography and radio therapy.

Colin P and Hodson N. Thirty-two patients with histologically proved malignant disease involving the paranasal sinuses were studied by CT. Significantly greater tumor extent was demonstrated by CT than by conventional methods.

TMJ

- CT helps identify the bony changes in the TMJ like destruction of the condylar head, wearing of articular elements, traumatic lesions within and outside the capsule.
- Advantageous over arthrography as it is a painless procedure with superior resolution.

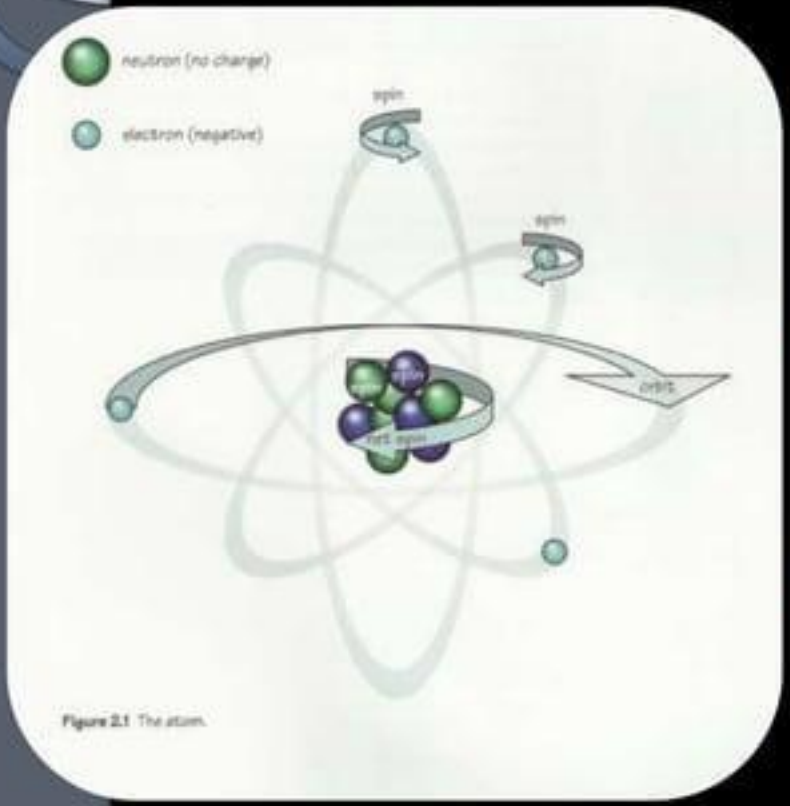
conclusion

- CT scan has made a major impact on the practice of dentistry, particularly in oral and maxillofacial diagnosis, surgery and management of a wide variety of oral lesions. Advances in computer softwares already allow 3 D visualization of anatomy and pathology, but further improvement in clinical performance is expected.

MAGNETIC RESONANCE IMAGING

- Here, radiant energy is in the form of radiofrequency wave rather than X-ray.
- Father of MRI- *Felix Bloch*

TYPES OF ATOMIC MOTION



1. The electron orbits the nucleus
2. The electron spins on its own axis
3. *****The nucleus spins on its own axis*****

MRI USES THE HYDROGEN ATOM

- 1 electron orbits the nucleus
- The nucleus contains no neutrons but contains 1 proton

∴ THE HYDROGEN NUCLEUS HAS A NET POSITIVE CHARGE

- Hydrogen nucleus is a spinning, positively charged particle

LAW OF ELECTROMAGNETISM

- A charged particle in motion will create a magnetic field
- The postitively charged, spinning hydrogen nucleus generates a magnetic field

WHY HYDROGEN?

- Very abundant in the human body-H_20
- Has a large magnetic moment

MAGNETIC MOMENT

The tendency of an MR active nuclei to align its axis of rotation to an applied magnetic field

MR ACTIVE NUCLEI

odd # protons

or

odd # neutrons

or

BOTH

e.g. Hydrogen^{1}, Carbon^{13}, Nitrogen^{15}, Oxygen^{17}, Fluorine^{19}, Sodium^{23}, Phosphorus^{31}

STABLE ATOMS

protons = # electrons

IONS

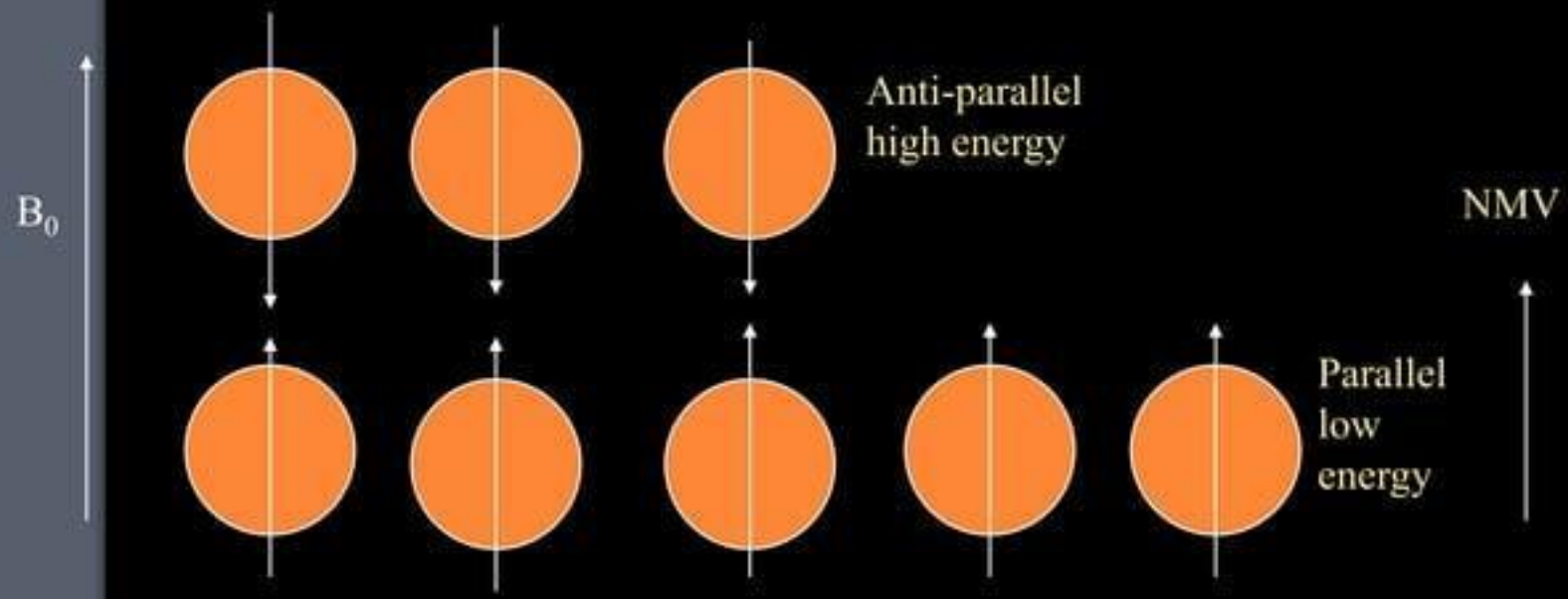
protons ≠ # electrons

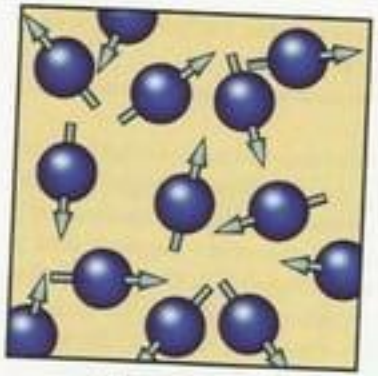
When a body is placed into the bore of the scanner, the strong magnetic field will cause the individual hydrogen nuclei to either:

A) ALIGN **ANTI-PARALLEL** TO THE MAIN MAGNETIC FIELD (B_0)

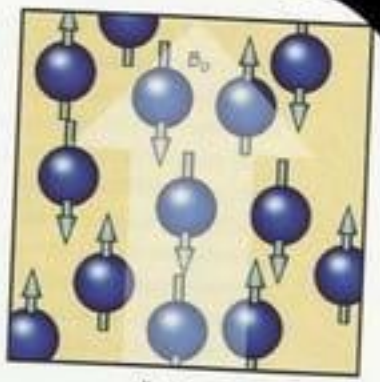
OR

B) ALIGN **PARALLEL** TO THE MAIN MAGNETIC FIELD (B_0)



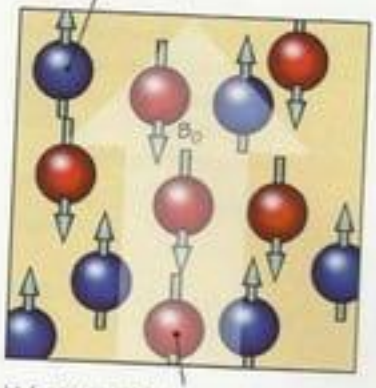


random alignment
no external field



alignment
external magnetic field

Figure 3.1 Alignment: classical theory.



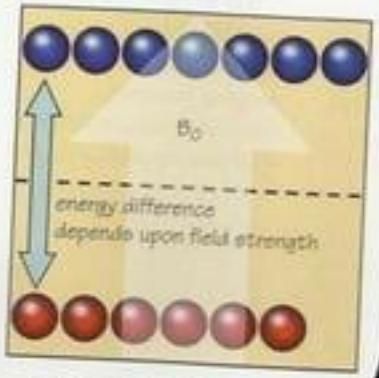
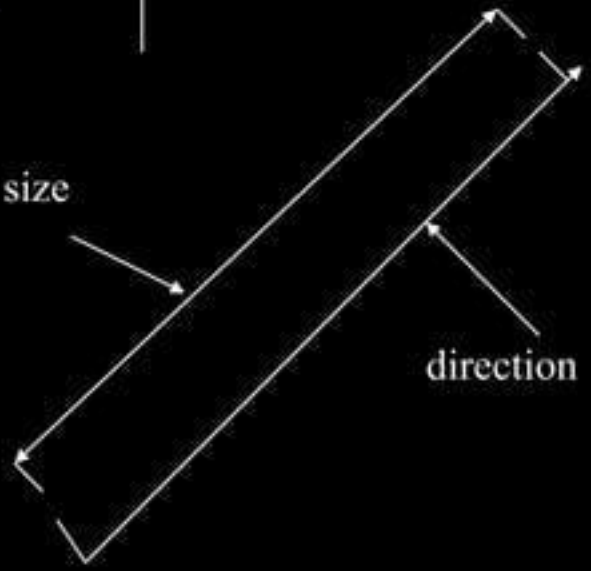


Figure 3.2 Alignment: quantum theory.

NET MAGNETIZATION VECTOR

- An excess of hydrogen nuclei will line up parallel to B_0 and create the NMV of the patient



The magnetic vector

THE NUCLEI WILL ALSO PRECESS…

PRECESSION

- Due to the influence of B_0, the hydrogen nucleus "wobbles" or precesses (like a spinning top as it comes to rest)
- The axis of the nucleus forms a path around B_0 known as the "precessional path"

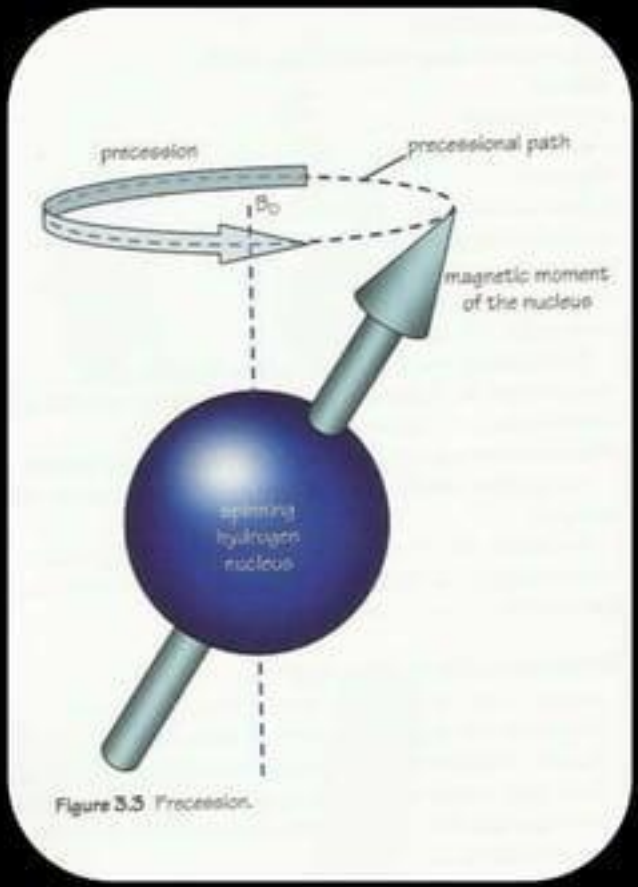
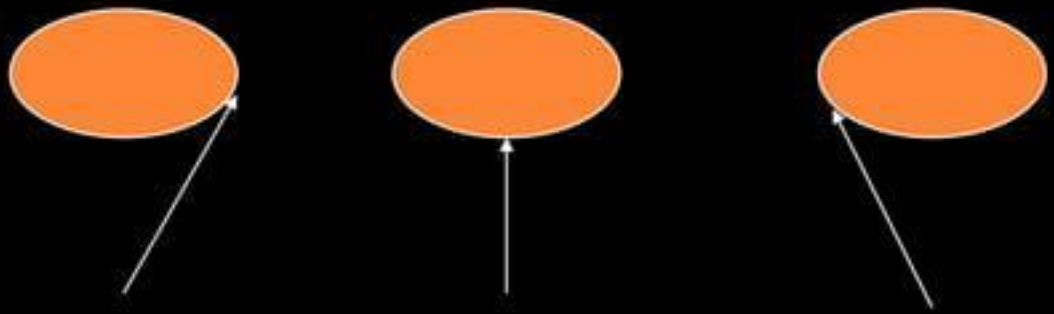


Figure 3.5 Precession.

PRECESSION

- The speed at which hydrogen precesses depends on the strength of B_0 and is termed the "precessional frequency"
- The precessional frequency of hydrogen in a 1.5 Tesla magnetic field is 63.86 MHz
- The precessional paths of the individual hydrogen nucleus' is random, or "out of phase"



- The spinning protons wobble or "precess" about that axis of the external Bo field at the precessional, Larmor or resonance frequency.
- Magnetic resonance imaging frequency

$$\omega = \gamma B_o$$

where γ is the gyromagnetic ratio

The resonance frequency ω of a spin is proportional to the magnetic field, B_o.

WE NEED THEM TO BE "IN-PHASE" OR TO RESONATE…

RESONANCE

Occurs when an object is exposed to an oscillating perturbation that has a frequency close to its own natural frequency of oscillation

RADIOFREQUENCY ENERGY

- Follows the Law of Electromagnetism (charged particles in motion will generate a magnetic field)
- Magnetic field known in MR as B_1
- Applied as a "pulse" during MR sequences
- The RF pulse is applied so that B_1 is 90° to B_0

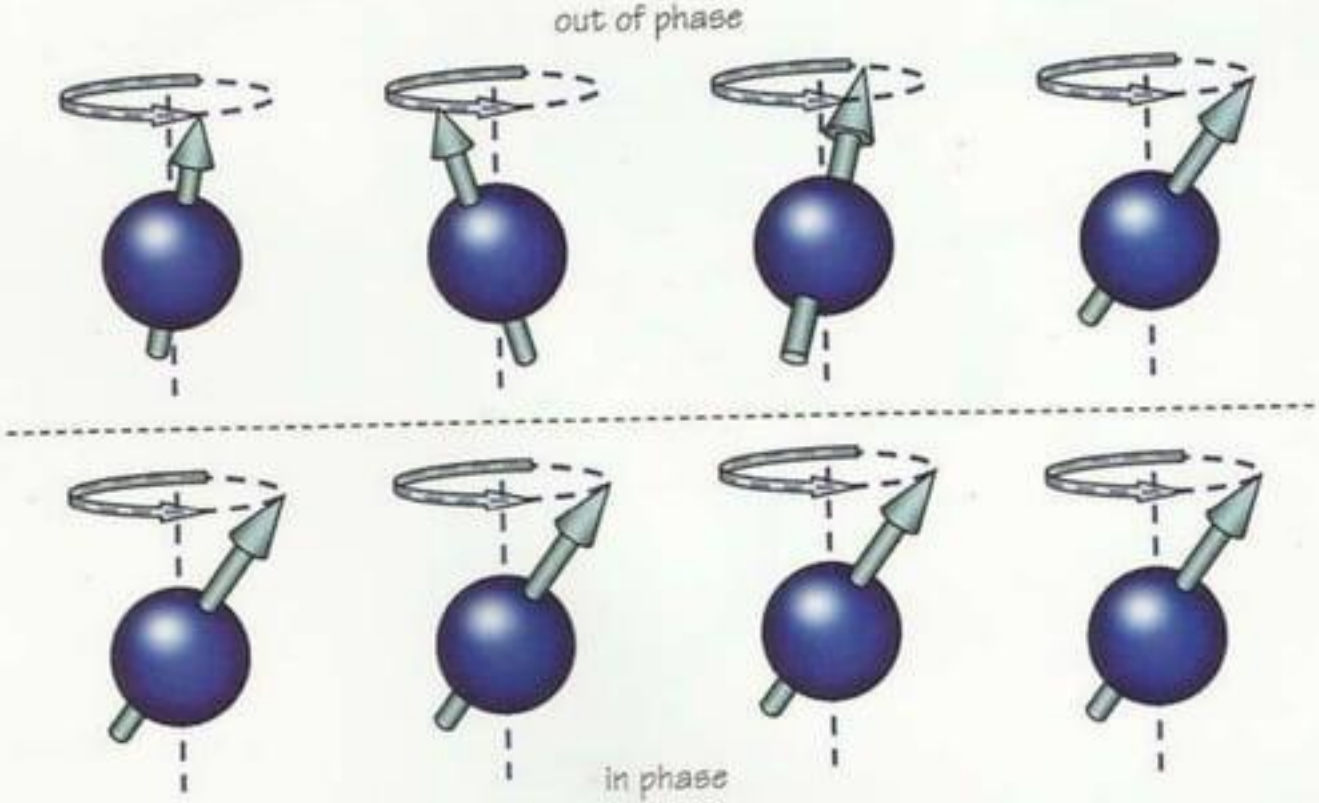
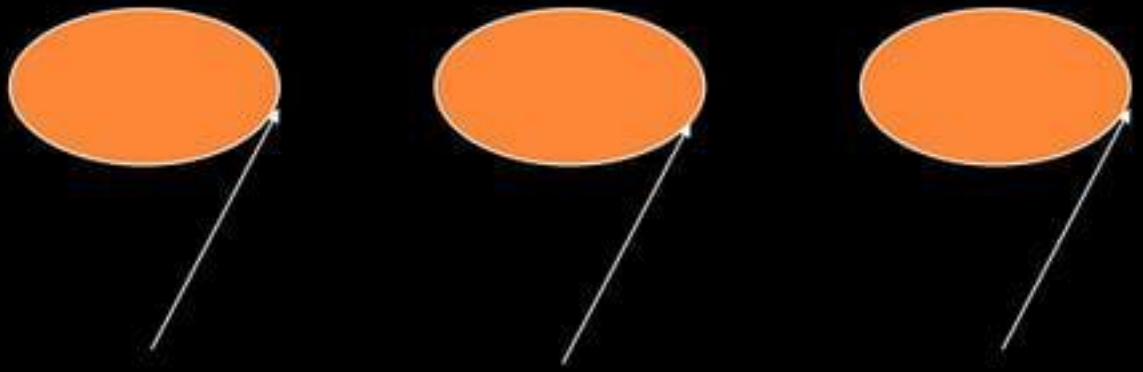


Figure 3.4 Coherent and incoherent phase positions.

DURING RESONANCE…

1) The hydrogen atoms begin to precess "in phase"



2) The hydrogen atoms align with the RF's magnetic field (B_1) and they flip!!

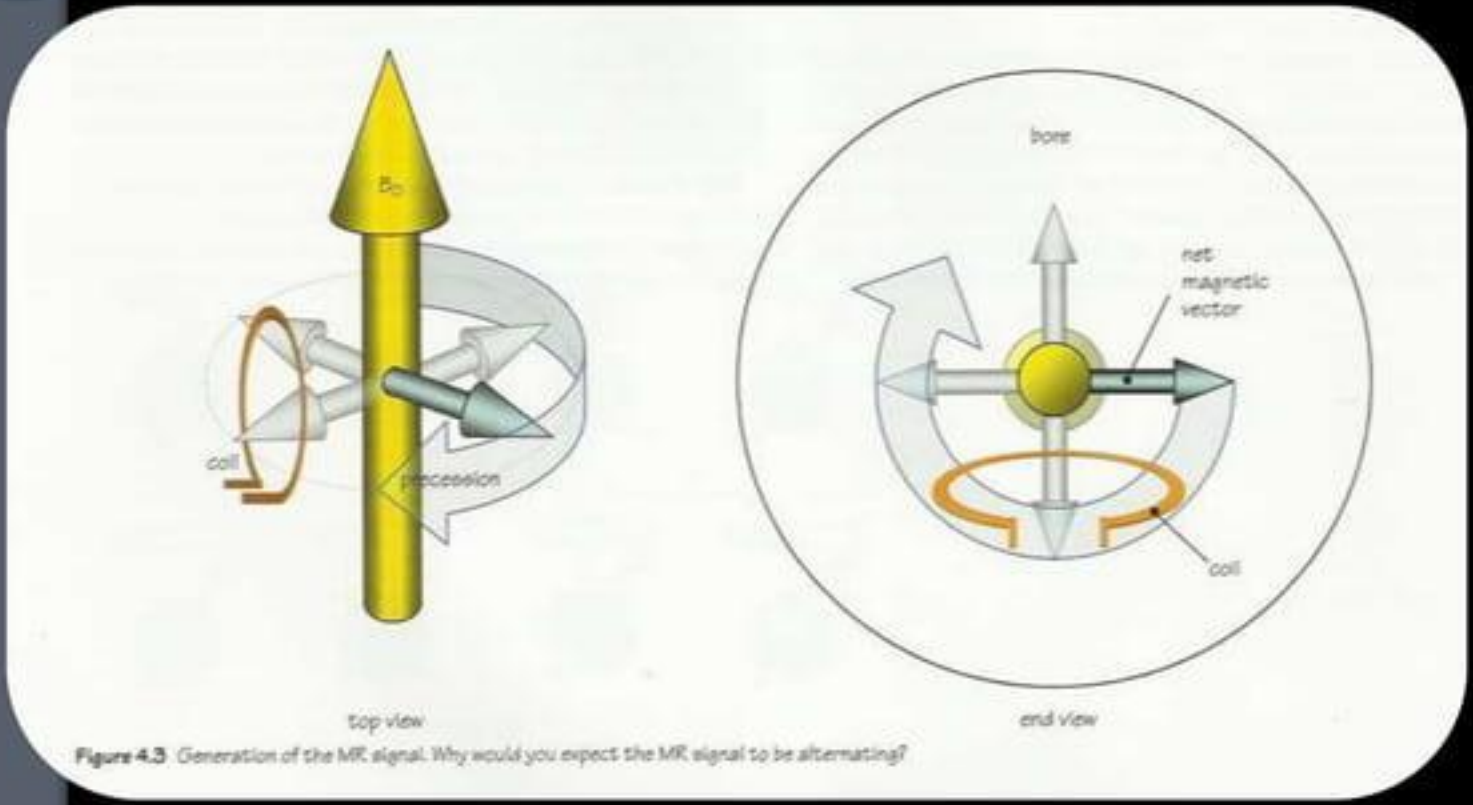


Figure 4.3 Generation of the MR signal. Why would you expect the MR signal to be alternating?