Sri Aurobindo College of Dentistry

Indore, Madhya Pradesh

INDIA

MODULE PLAN

- TOPIC : ADVANCED IMAGING
- SUBJECT:OMDR
- TARGET GROUP: UNDERGRADUATE DENTISTRY
- MODE: POWERPOINT – WEBINAR
- PLATFORM: INSTITUTIONAL LMS
- PRESENTER: DR.PRAGYA SANGHI

ADVANCED IMAGING

PRESENTED BY- DR.PRAGYA SANGHI
(M.D.S)

INTRODUCTION

- The imaging modalities described in this chapter employ equipment and techniques that are beyond the routine needs of most general dental practitioners.
- Each of these techniques makes a tomographic image- that is, a slice through tissue- rather than a single projection image.
- The most versatile of these are computed tomographic scanning and MRI.
- Nuclear medicine, ultrasonography, and positron emission tomographic (PET) imaging are used for more specialized purposes.

COMPUTED TOMOGRAPHY

COMPUTED TOMOGRAPHY

- It is a radiographic technique that blends the concept of thin layer radiography (tomography) with computer synthesis of the image (computed).

HISTORY

- Initially called as CAT scan.
- First CT scanner in 1972. GODFREY HOUNSEFIELD
- Hounsfield and Cormack received the Nobel Prize in Medicine for their invention in 1979.

- Discovery of CT revolutionized medical imaging.

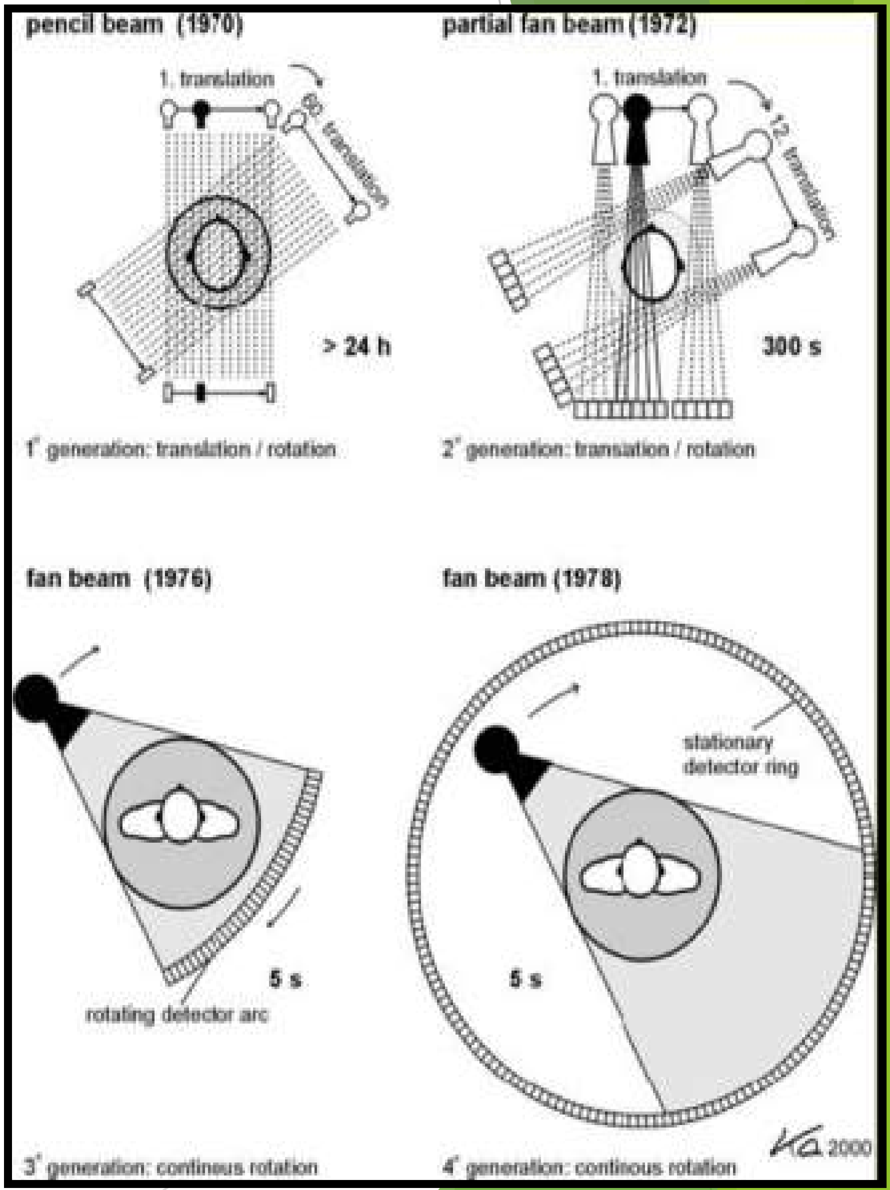
- Complex anatomic pattern of the skull bones and the jaws requires three dimensional visualization.

- Limitation of the conventional radiography is overcome by computed tomography.

- Involves combination of x-ray technology and computer technology.

Generations of CT machines

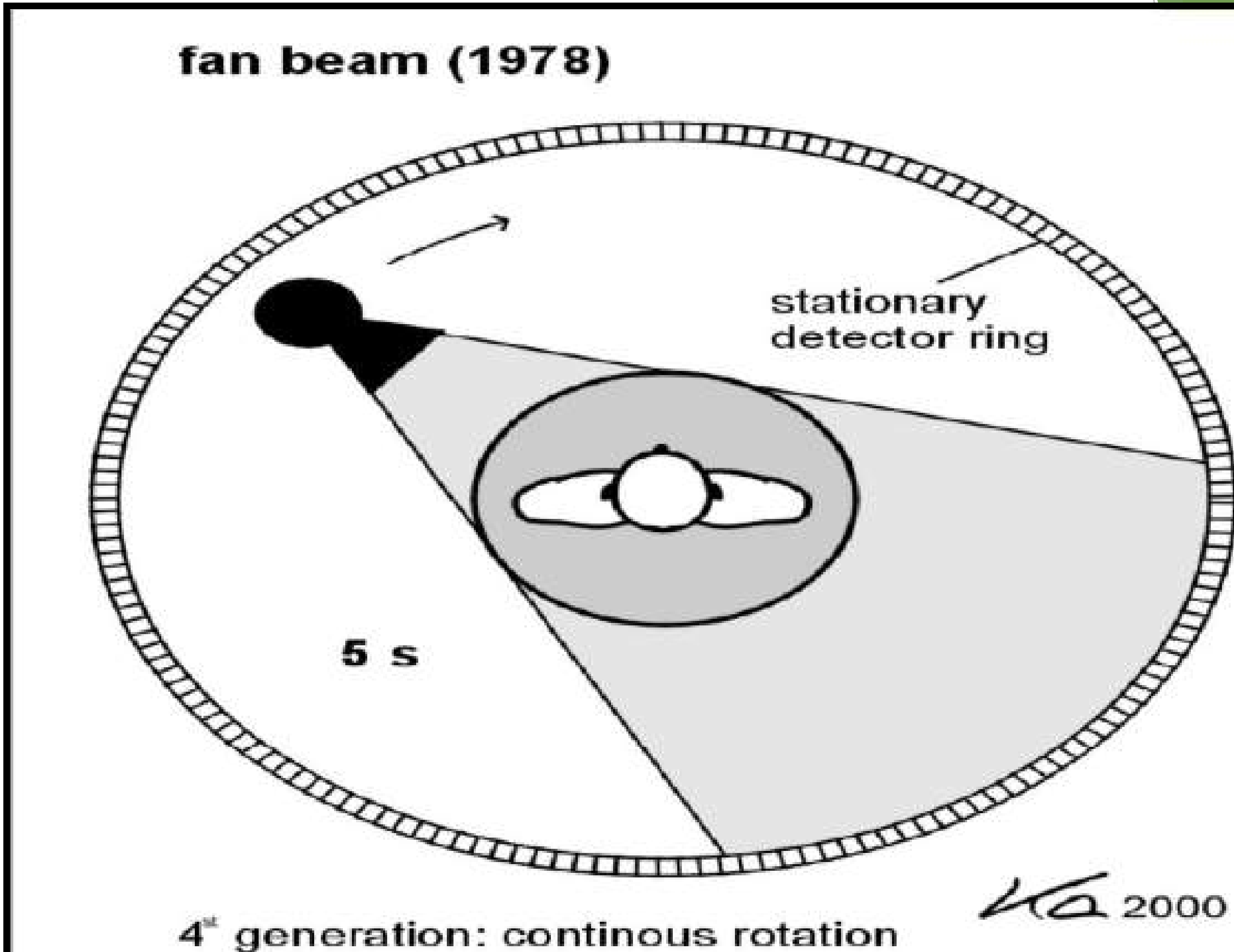
- First generation
- Second generation
- Third generation
- Fourth generation
- Spiral CT



Difference in all above generation is speed of scanning and movements of gantry.

- In first two generation there are
  - 1) Linear &
  - 2) Rotary movements

- In next two generation there is only one movement i.e rotary movement.


fan beam (1978)
stationary detector ring
5 s
2000
4st generation: continous rotation

5th generation

- Newer method
- X-ray tube moves continuously with patient moving with constant rate producing a spiral or helix around the patient.

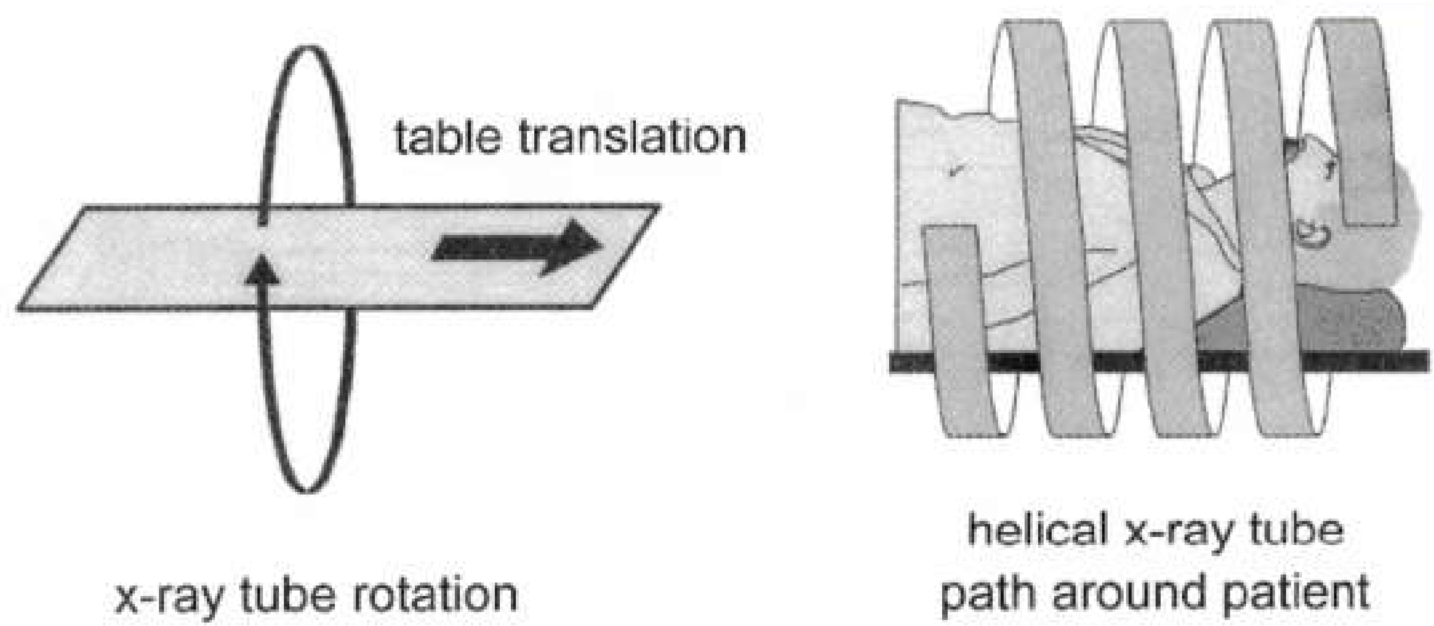


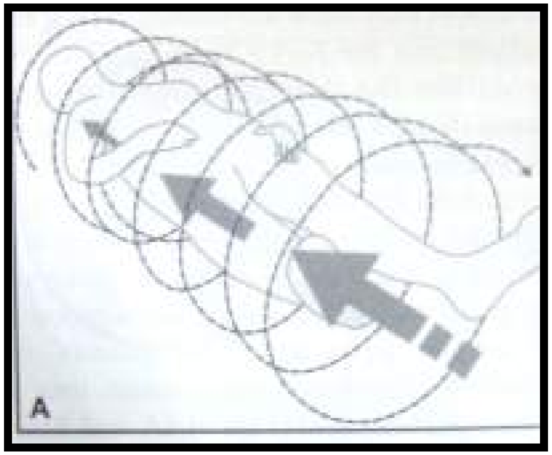
FIGURE 13-12. With helical computed tomographic scanners, the x-ray tube rotates around the patient while the patient and the table are translated through the gantry. The net effect of these two motions results in the x-ray tube traveling in a helical path around the patient.

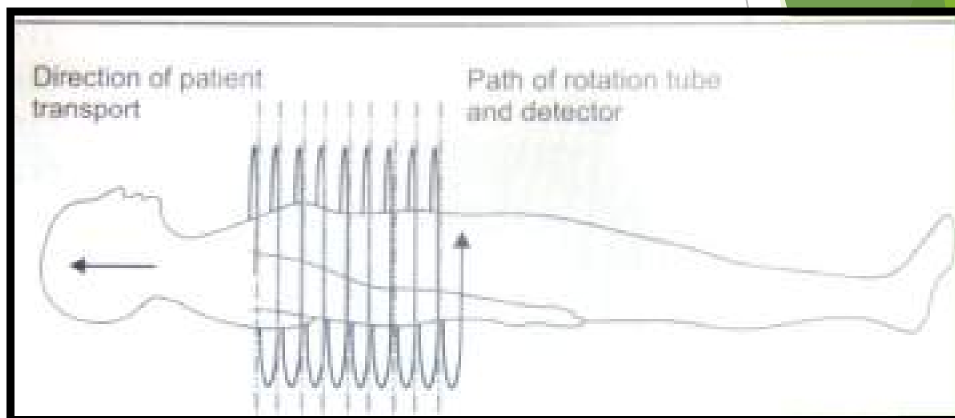
CT – 6th generation - helical or spiral CT

- Helical or spiral CT was introduced in early 1990, by Willi Kalender and Kazuhiro Katada.
- In older CT scanners the x-ray tube moved in a circular manner to take a slice, then the patient table would move ahead in the gantry for the next slice.
- In helical CT the x-ray source are attached to freely rotating gantry.
- During a scan the table moves the patient smoothly through the scanner .

- The name derives from the helical path traced out by the x-ray beam

- These major advantages led to the rapid rise of helical CT as the most popular type of CT technology.


A


Direction of patient
transport
Path of rotation tube
and detector

Advantages:

- Speed.
- Patient compliance is more.
- Allows optimal use of iv contrast enhancement.
- Decrease incidence of mis-registration between consecutive axial slices.

COMPUTED TOMOGRAPHY SYSTEM COMPONENTS

- The gantry,
- The computer
- The operating console

THE GANTRY

CT TABLE

CONSOLE

Gantry

- The gantry consists of the detector array.
- the x-ray source or tube.
- and the patient support.

TYPES OF DETECTORS

Two types

1. Scintillation crystals- Bismuth germanate crystals coupled with photomultiplier or sodium iodide crystals, are more efficient and has less afterglow.
2. Ionization chamber containing xenon gas under pressure, they have no afterglow but are slightly less efficient.

DETECTOR ARRAY

- The detector array contains numerous discrete detectors or cells.
- Each of these detectors acquires unique information for the scan and sends that information to the computer.

X-RAY SOURCE OR TUBE

- The x-ray source for most of the currently available CT scanners consists of an x-ray generator and an x-ray tube. The x-ray generator is designed to produce a high-milliampere (400 mA) beam at a nearly continuous rate.

- The large amount of heat generated through continuous beam production necessitates a large rotating anode and fairly large focal spot.

X-RAY SOURCE OR TUBE

- The x-ray beam is collimated before it traverses the patient (pre-patient collimation) and at the detector array (post-patient collimation).
- The pre-patient collimation decreases the radiation dose to the patient.
- The post-patient collimation reduces the amount of scatter radiation that contacts the detector array, improving the image.
- Coordination of the pre-patient and post-patient collimators determines the thickness of the slice.

ADVANTAGES OF CT

- Structural relationships of the hard and soft tissues can be obtained directly.
- DIFFERENCES BETWEEN tissues that differ in physical density by less than 1 % can be distinguished.
- Ability to rotate images and to add or subtract structural components permits relationship to be studied.
- Contiguous structures can be seperated and normal hidden surfaces examined in detail.

ADVANTAGES OF CT - contd

- Accurate linear and volumetric measurements can be made.
- Changes in linear and volumetric measurements can be determined by sequential scans.
- Eliminates superimposition of images of structures outside the area of interest.
- A single CT imaging procedure consisting of either multiple contiguous or one helical scan can be viewed as images in the axial, coronal or sagittal planes.

ADVANTAGES OF CT - contd

- Images can be enhanced with the injection of contrast medium.
- Images can be manipulated.
- Areas of interest in the image can be selectively enlarged.
- Combining consequtive CT images, three dimensional CT images of the object can be accurately reconstructed.

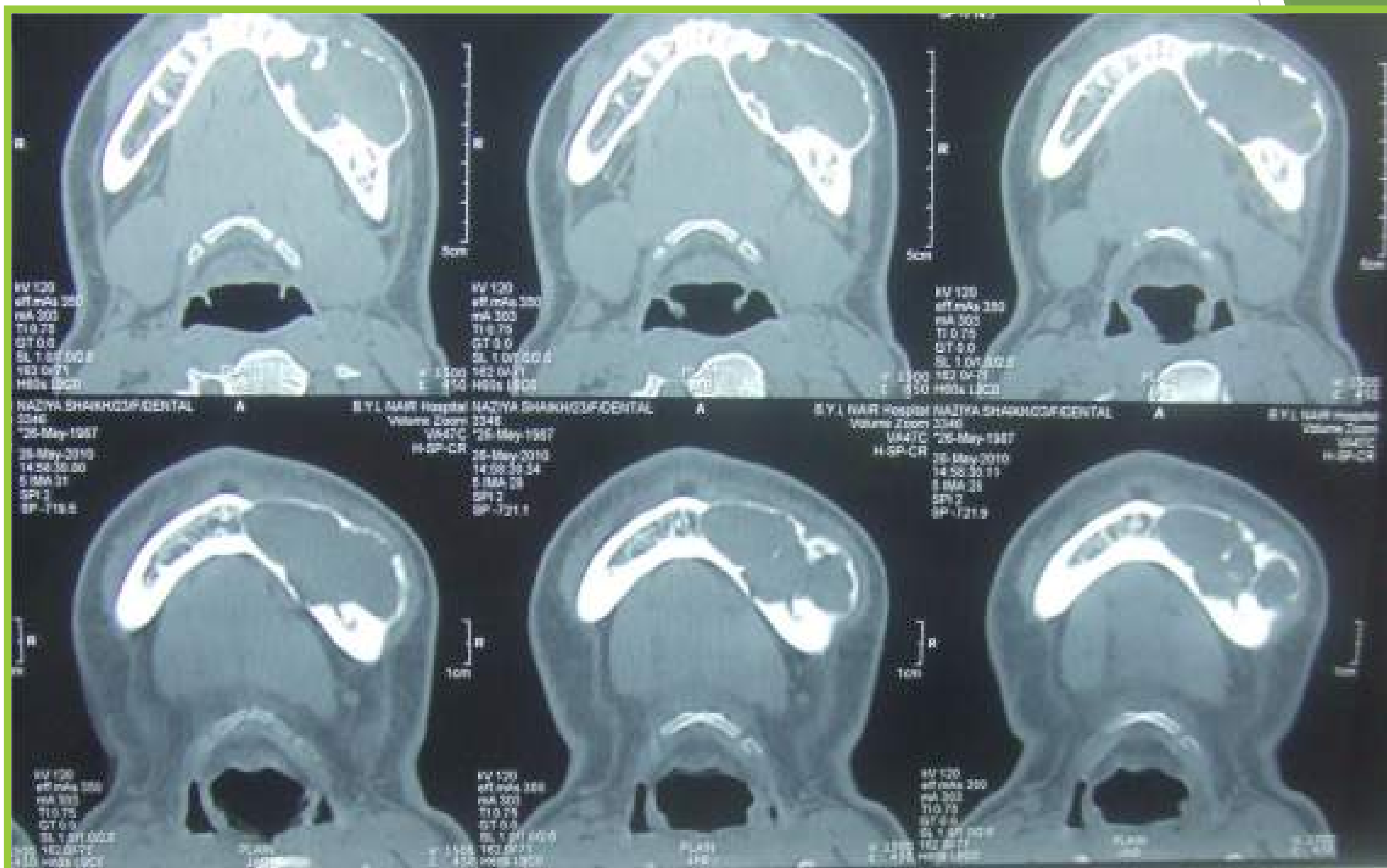
LIMITATIONS OF CT

- More blurring as compared to conventional radiographs.
- Metallic objects such as fillings produce marked streak artifacts across the CT image.
- Equipment is expensive.
- Inherent risk associated with contrast medium.

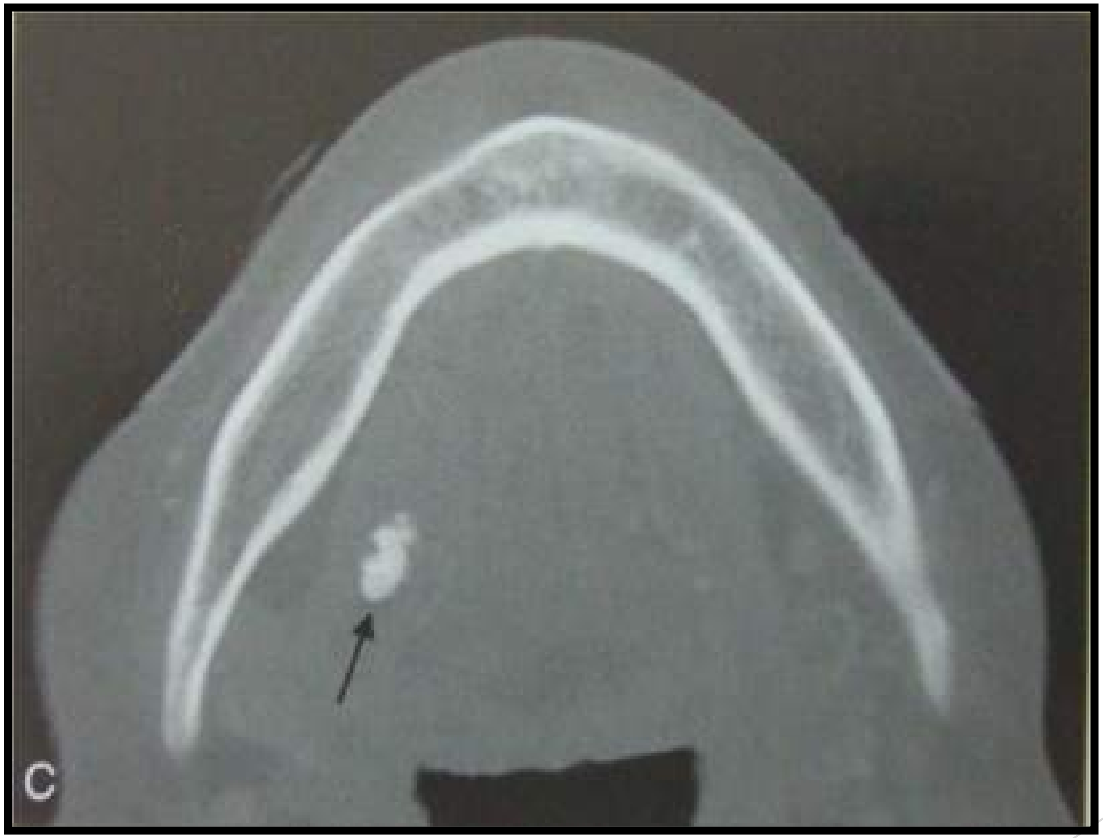
DENTAL APPLICATIONS FOR COMPUTED TOMOGRAPHY

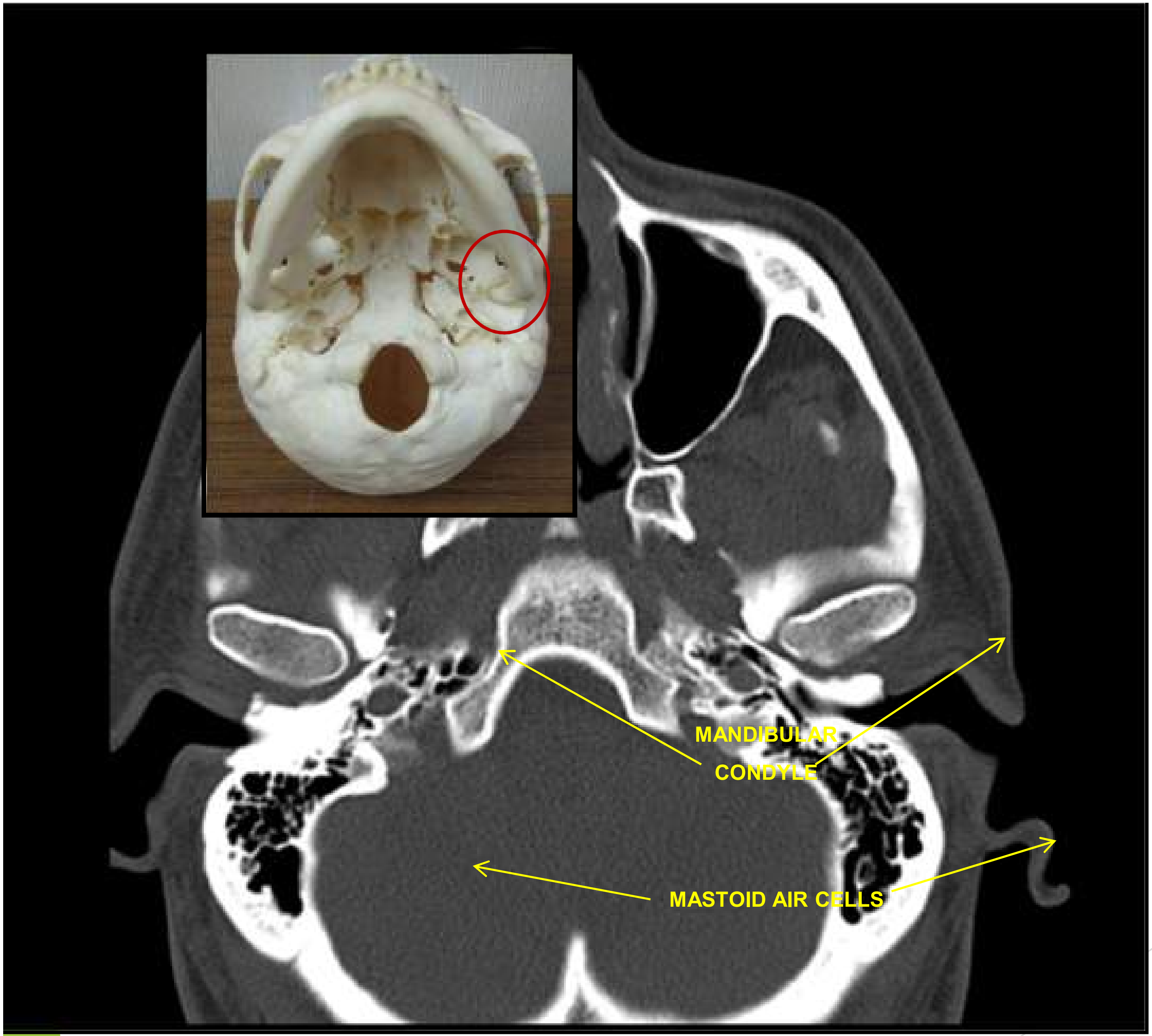
- Pathologic Processes
- Assessment of the Paranasal Sinuses
- Assessment of Trauma
- Assessment of the Temporomandibular Joint
- Implant Assessment
- Orthodontics & Orthognathic Surgery
- Assessment of impacted teeth
- Assess growth and development
- Assessment of airway analysis(in cases of mandibular advancement)

CT IMAGES OF AMELOBLASTOMA

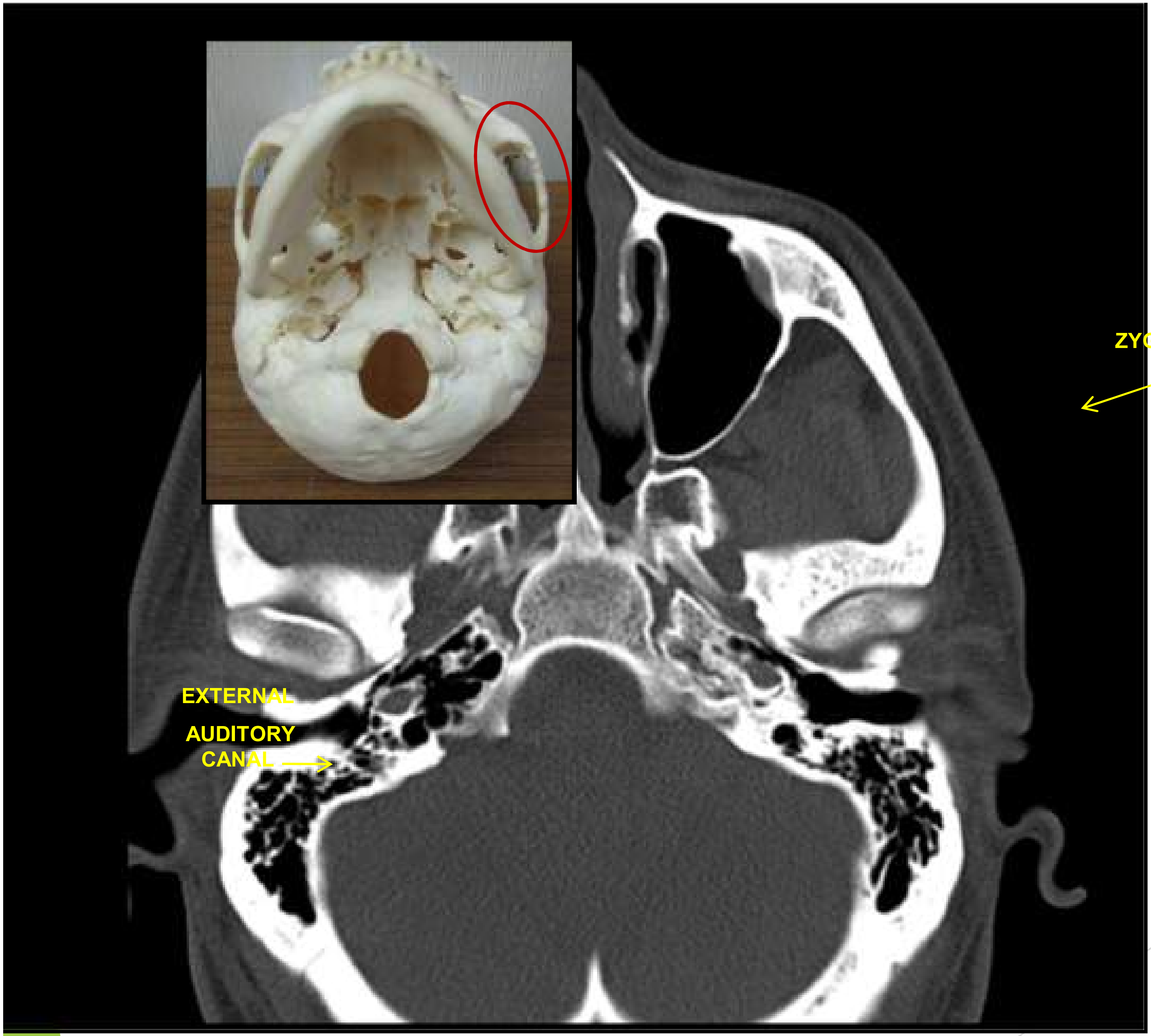

NAZIYA SHAIKH/23/F/DENTAL
B.Y.L NAIR Hospital
Volume Zoom
26-May-2010
kV 120
5cm
1cm

CT SCAN IMAGE OF A SIALOLOITH





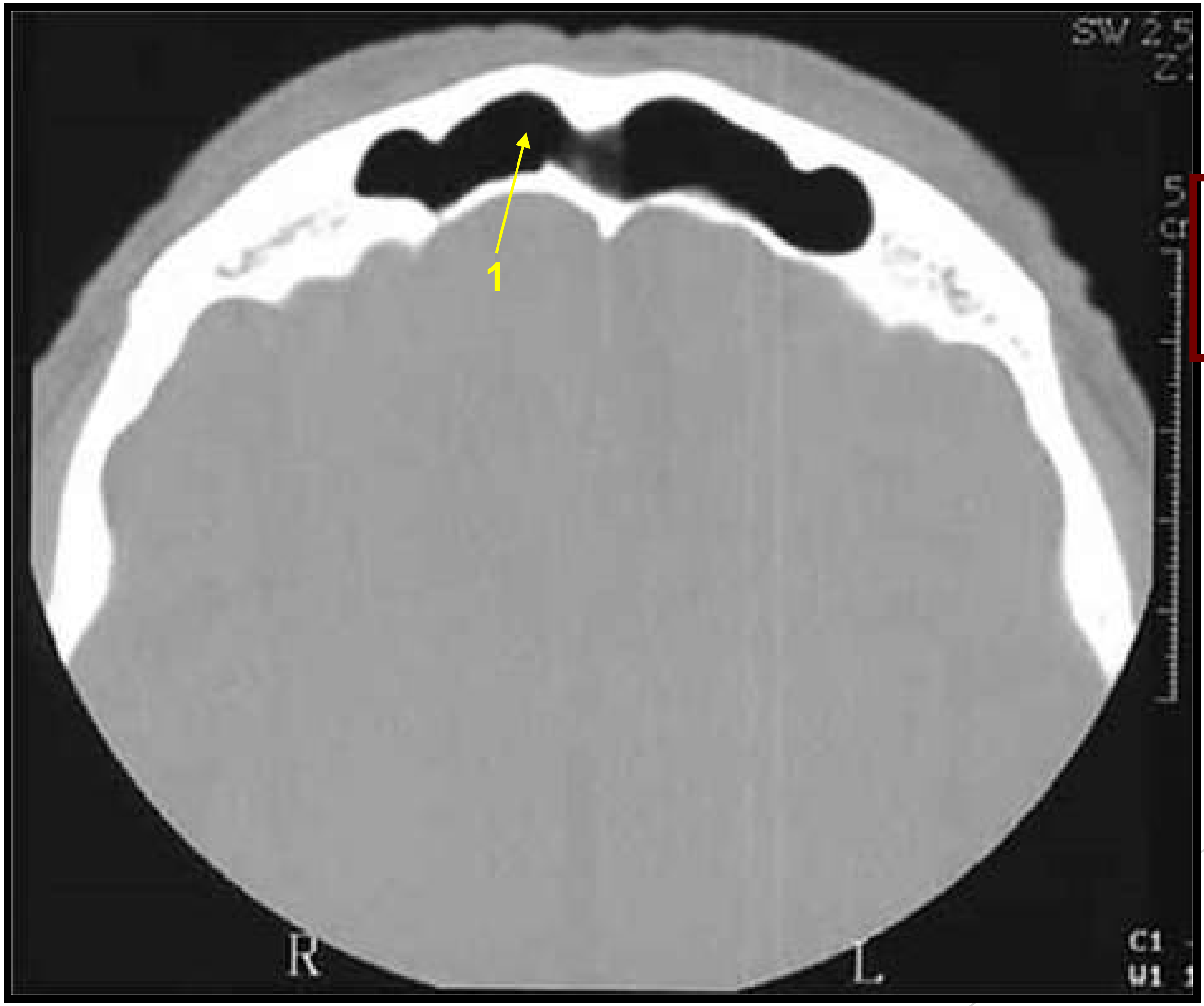
CT SKULL BASE



CT SKULL BASE

CT- SINUS

AXIAL VIEW



1. Frontal Sinus

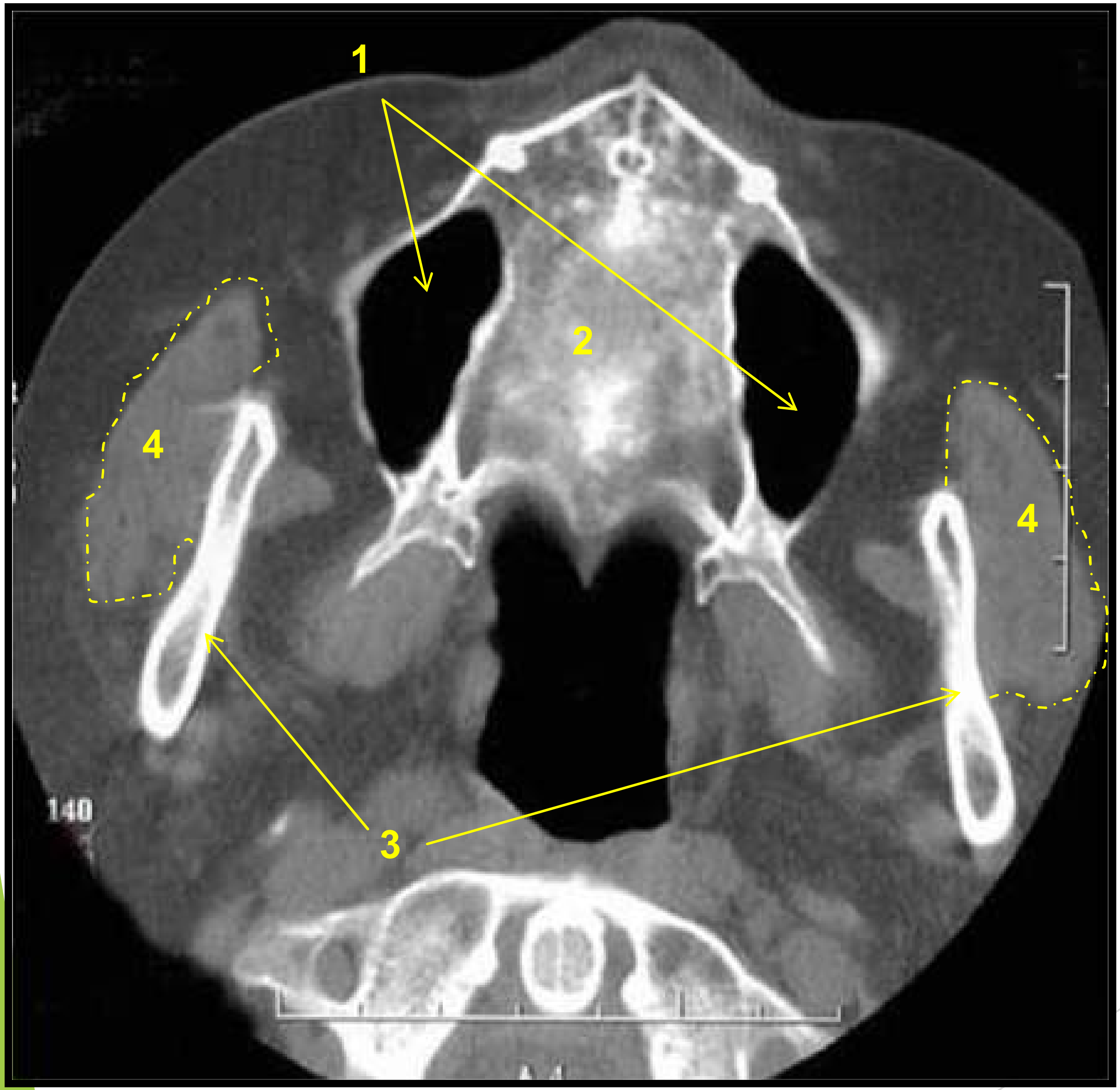
CT- SINUS

AXIAL VIEW

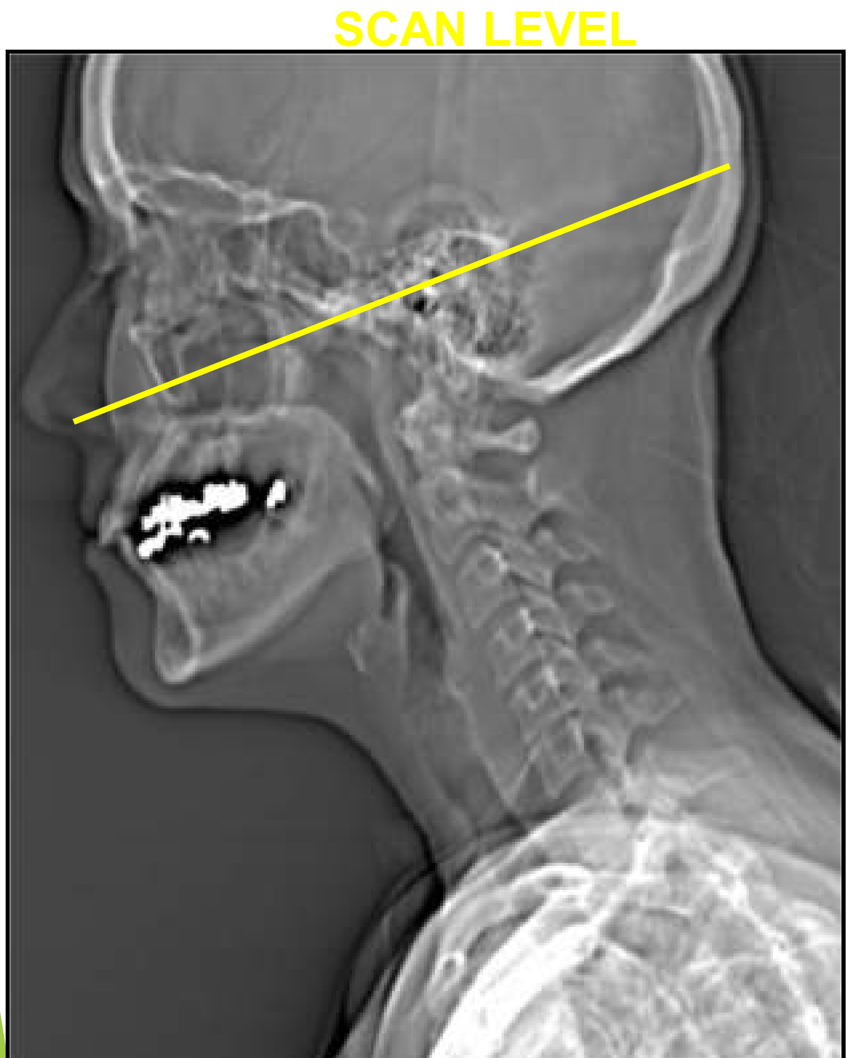
1. Ethmoid Sinus
2. Sphenoid Sinus
3. Carotid canal

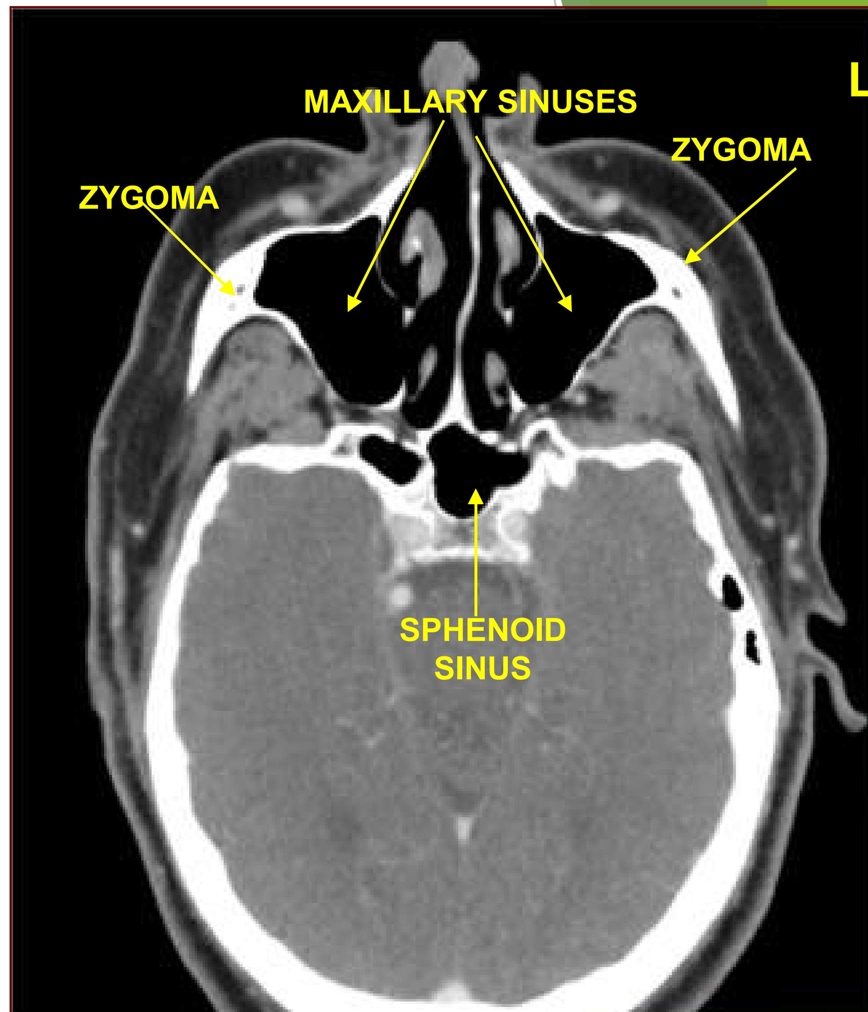
CT- SINUS

AXIAL VIEW

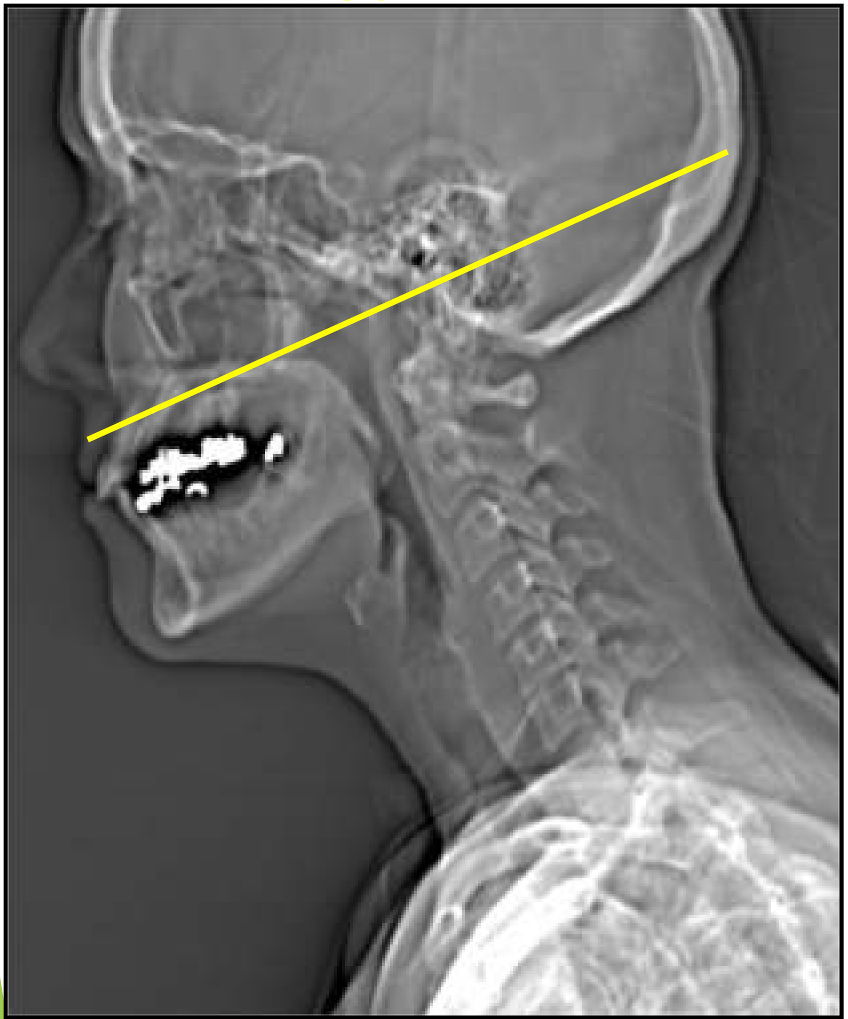


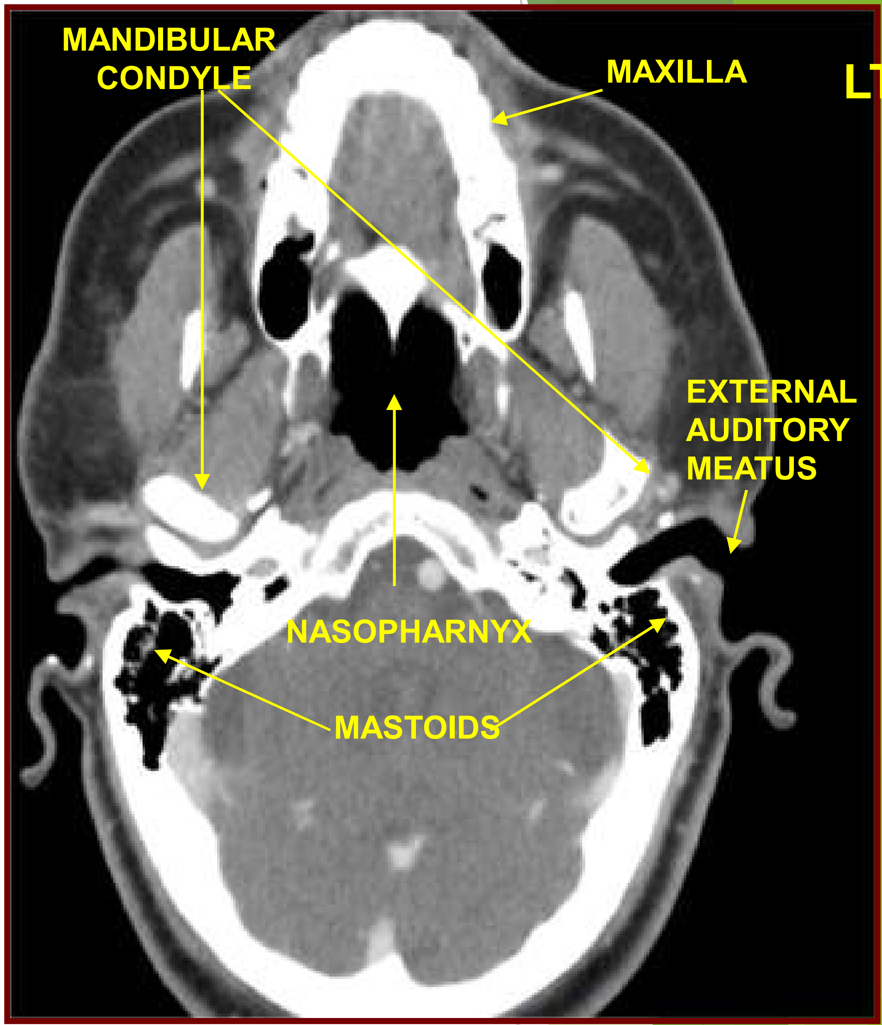
1. Maxillary Sinus
2. Hard Palate
3. Mandible
4. Masseter muscle


SCAN LEVEL

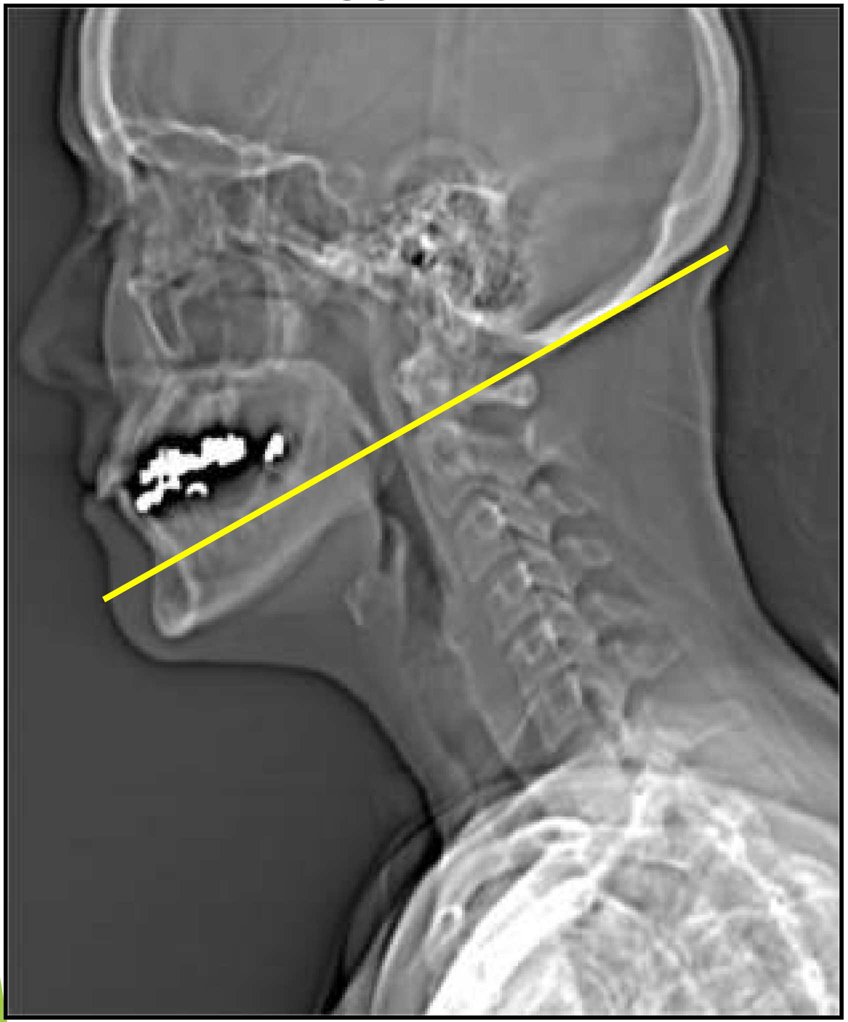

LT
MAXILLARY SINUSES
ZYGOMA
ZYGOMA
SPHENOID
SINUS

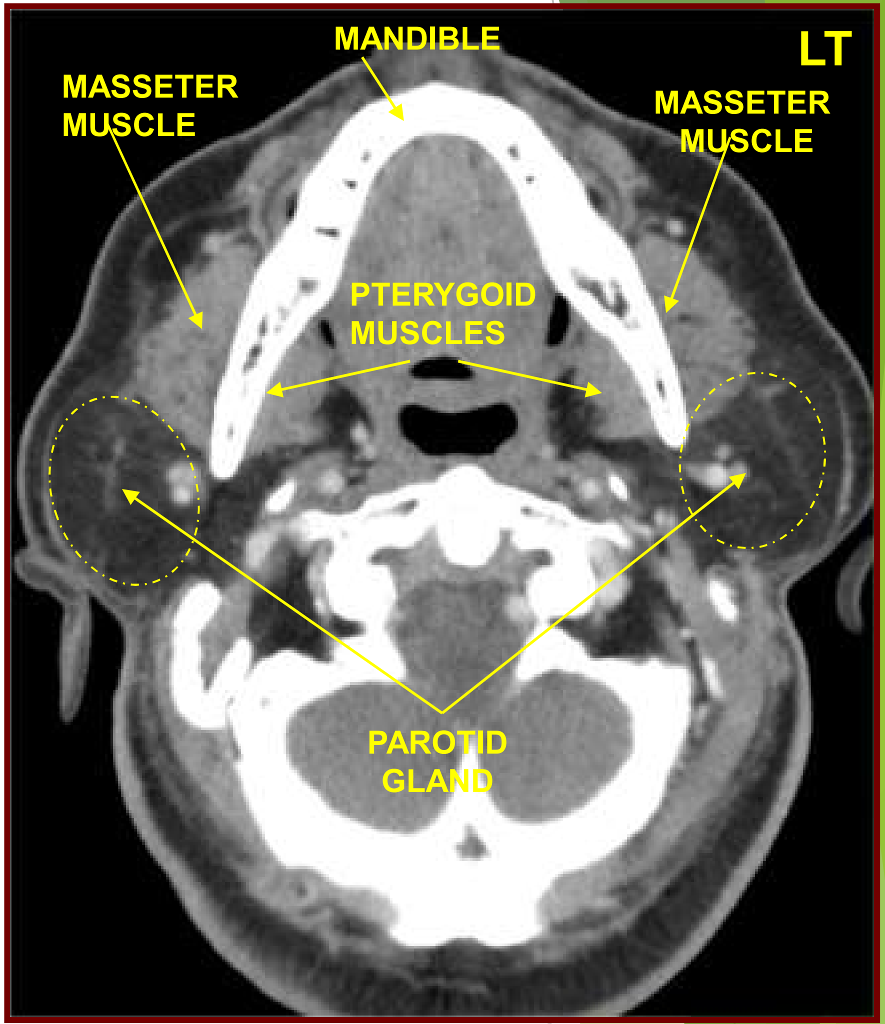
SCAN LEVEL



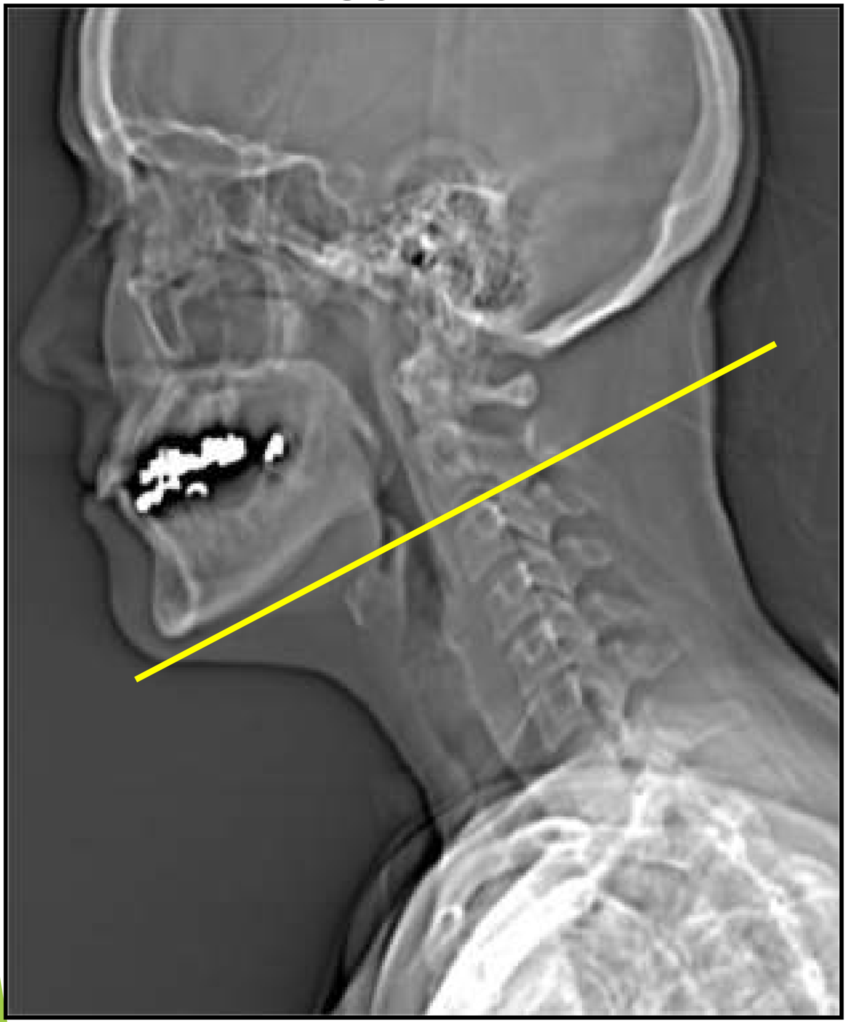

MANDIBULAR CONDYLE
MAXILLA
LT
EXTERNAL AUDITORY MEATUS
NASOPHARNYX
MASTOIDS

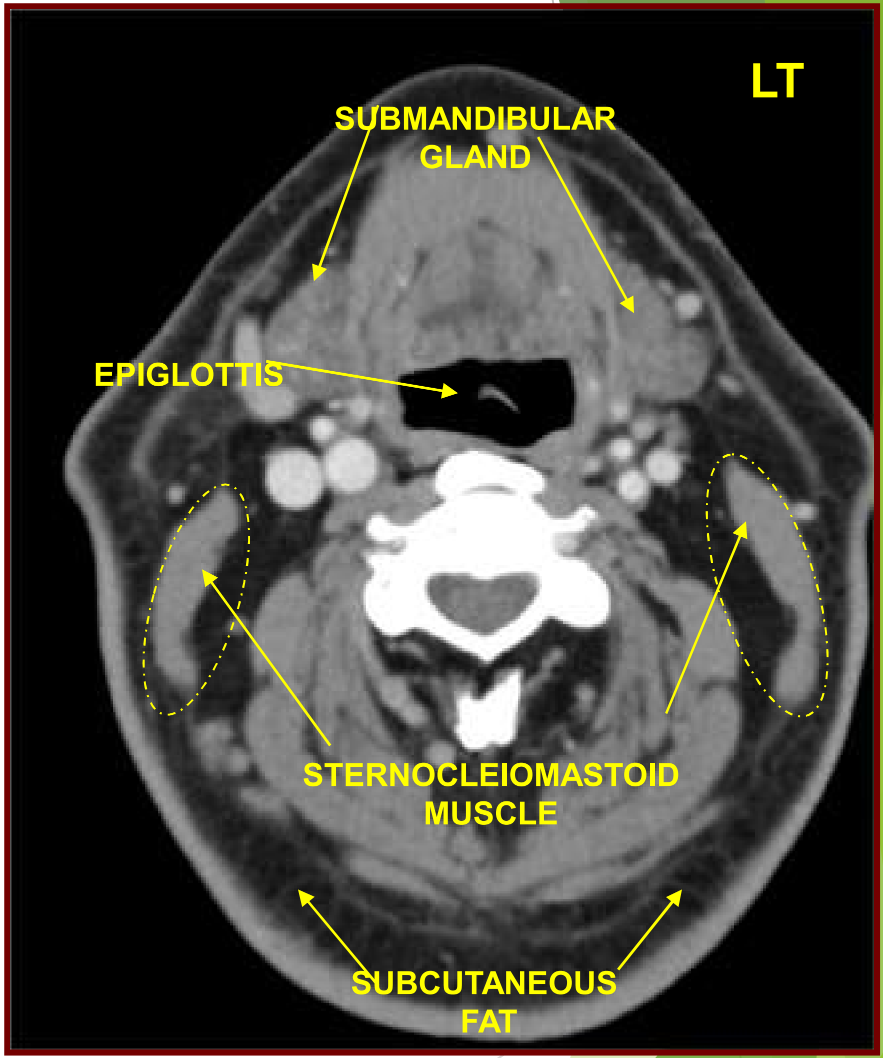
SCAN LEVEL



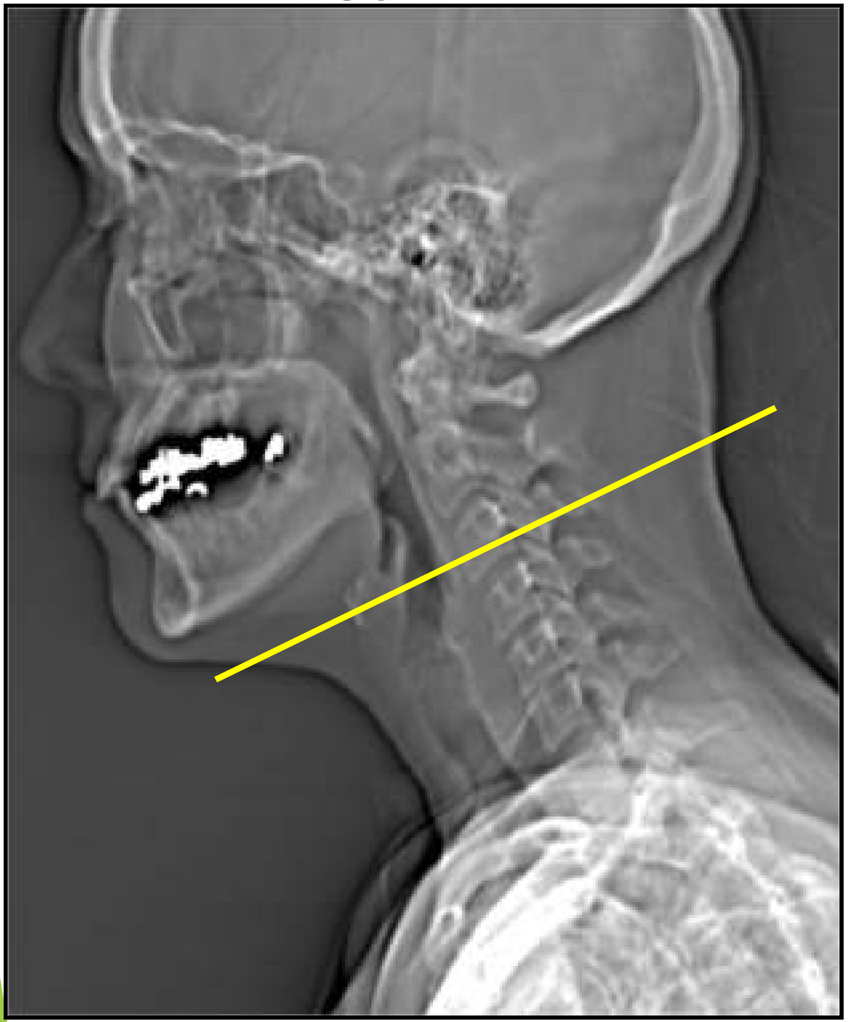

MANDIBLE
LT
MASSETER MUSCLE
MASSETER MUSCLE
PTERYGOID MUSCLES
PAROTID GLAND

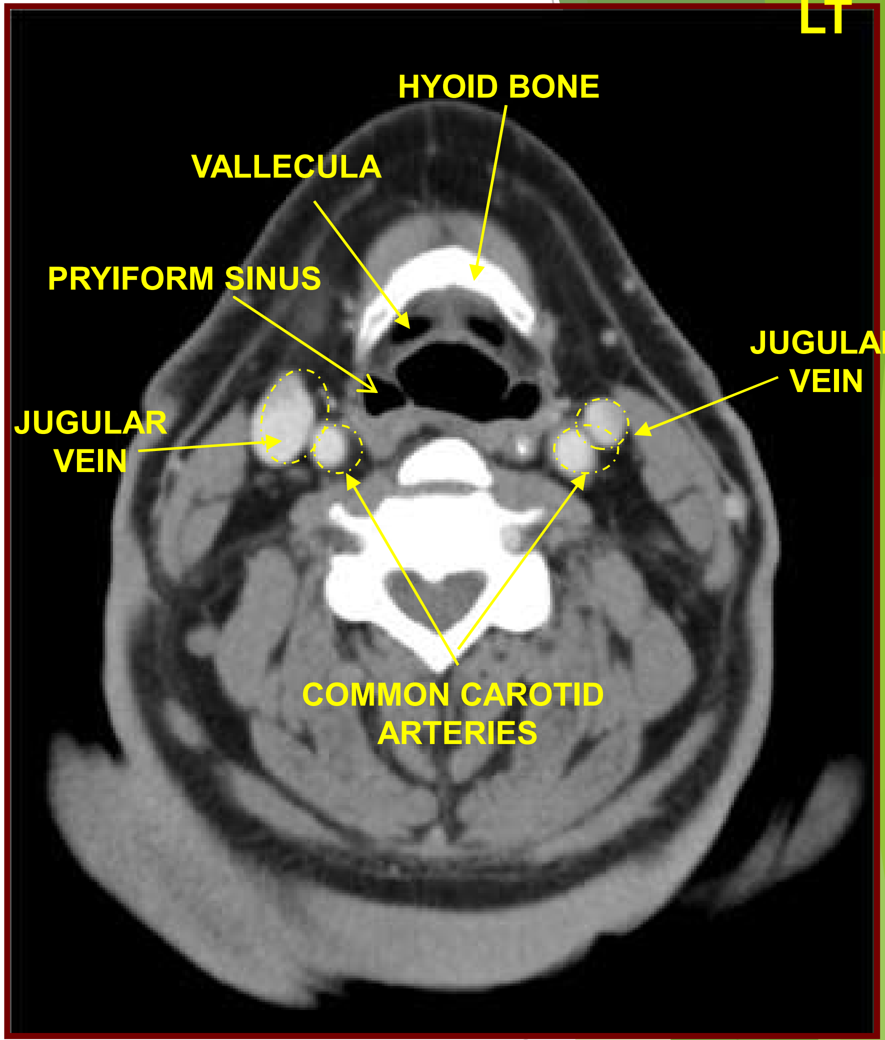
SCAN LEVEL



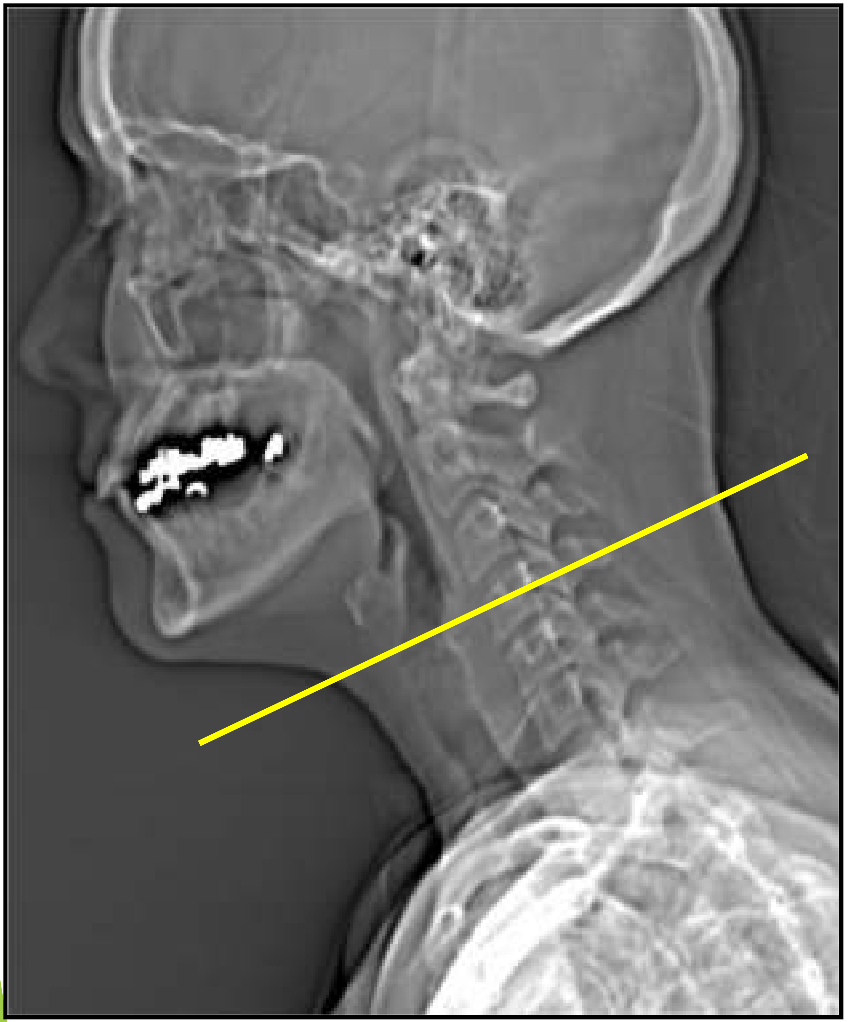

LT
SUBMANDIBULAR GLAND
EPIGLOTTIS
STERNOCLEIOMASTOID MUSCLE
SUBCUTANEOUS FAT

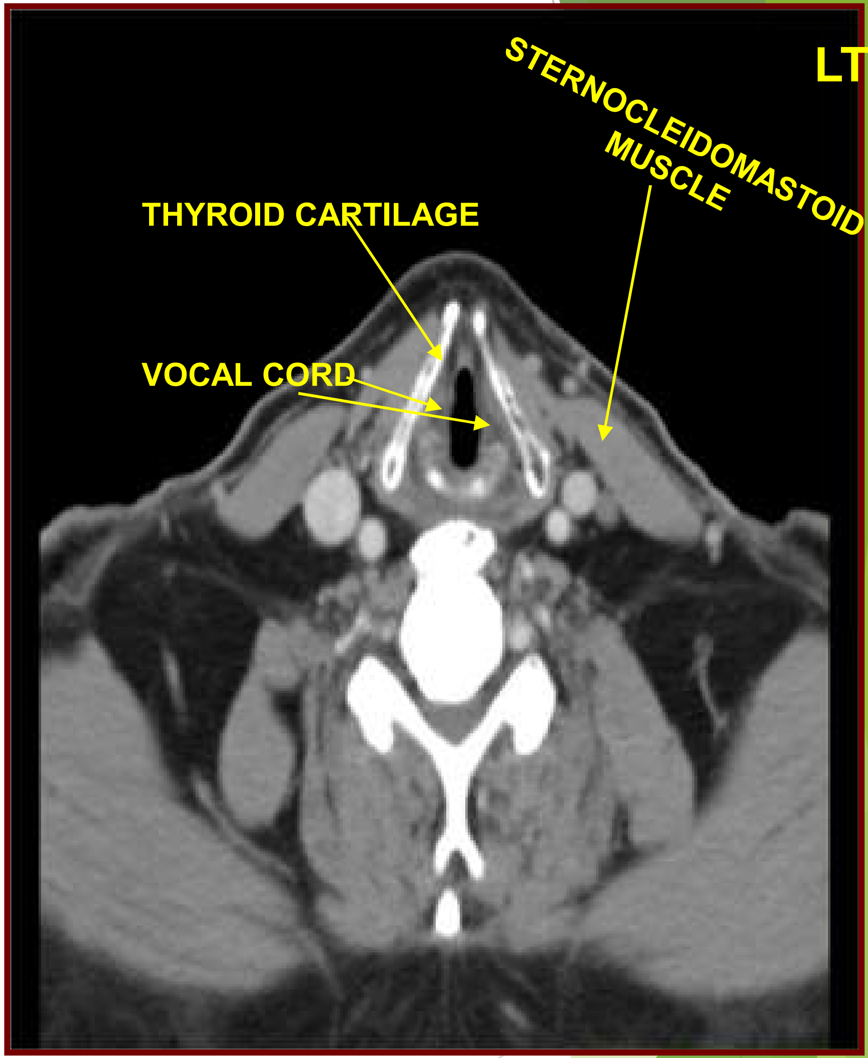
SCAN LEVEL



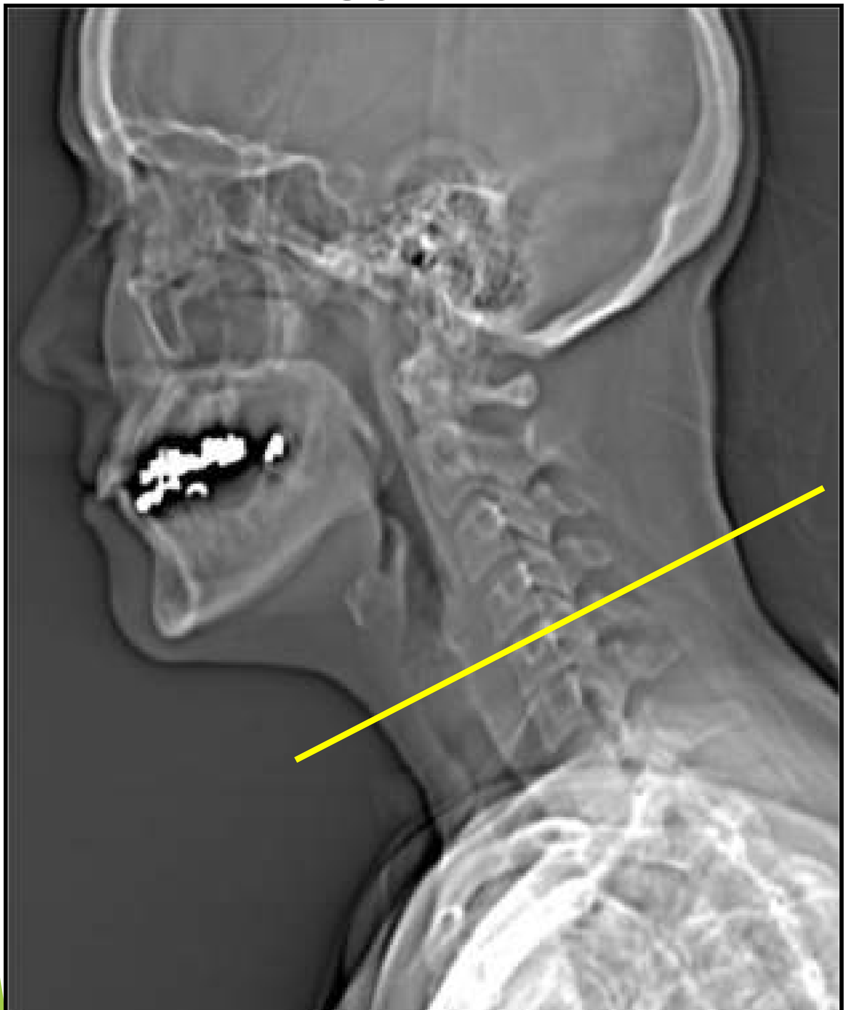

LT
HYOID BONE
VALLECULA
PRYIFORM SINUS
JUGULAR VEIN
JUGULAR VEIN
COMMON CAROTID ARTERIES

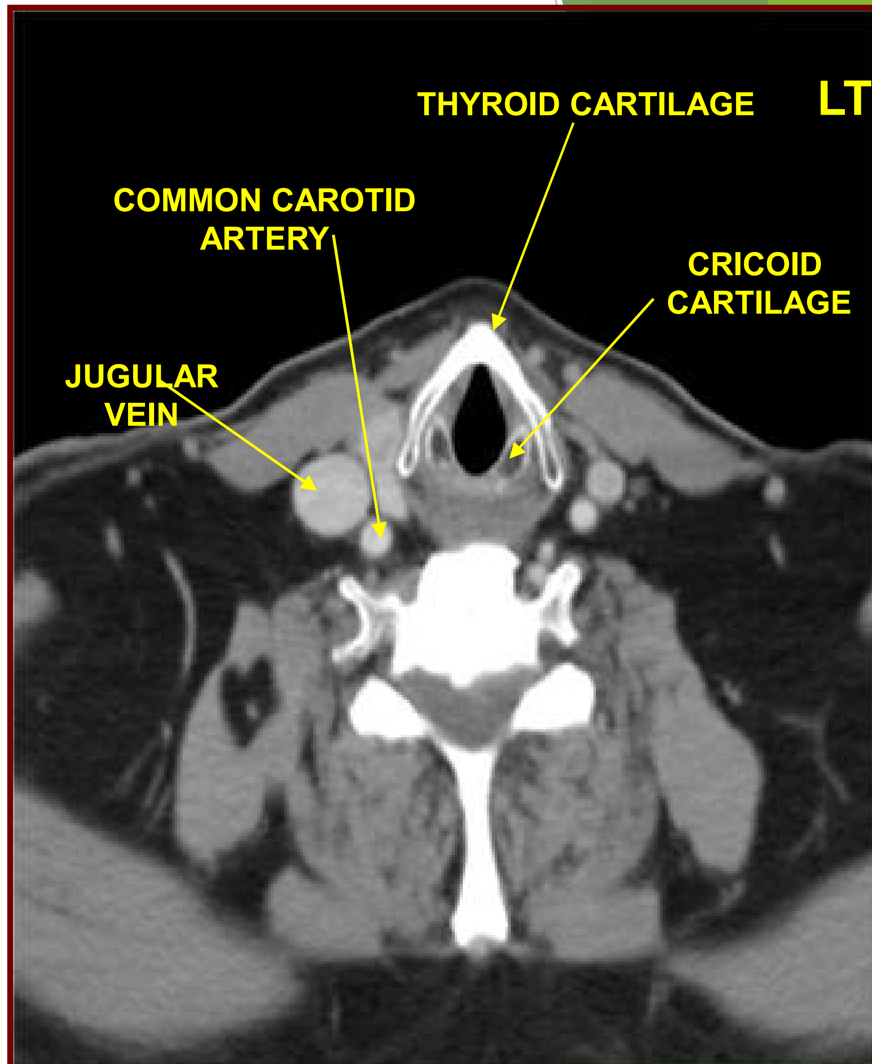
SCAN LEVEL



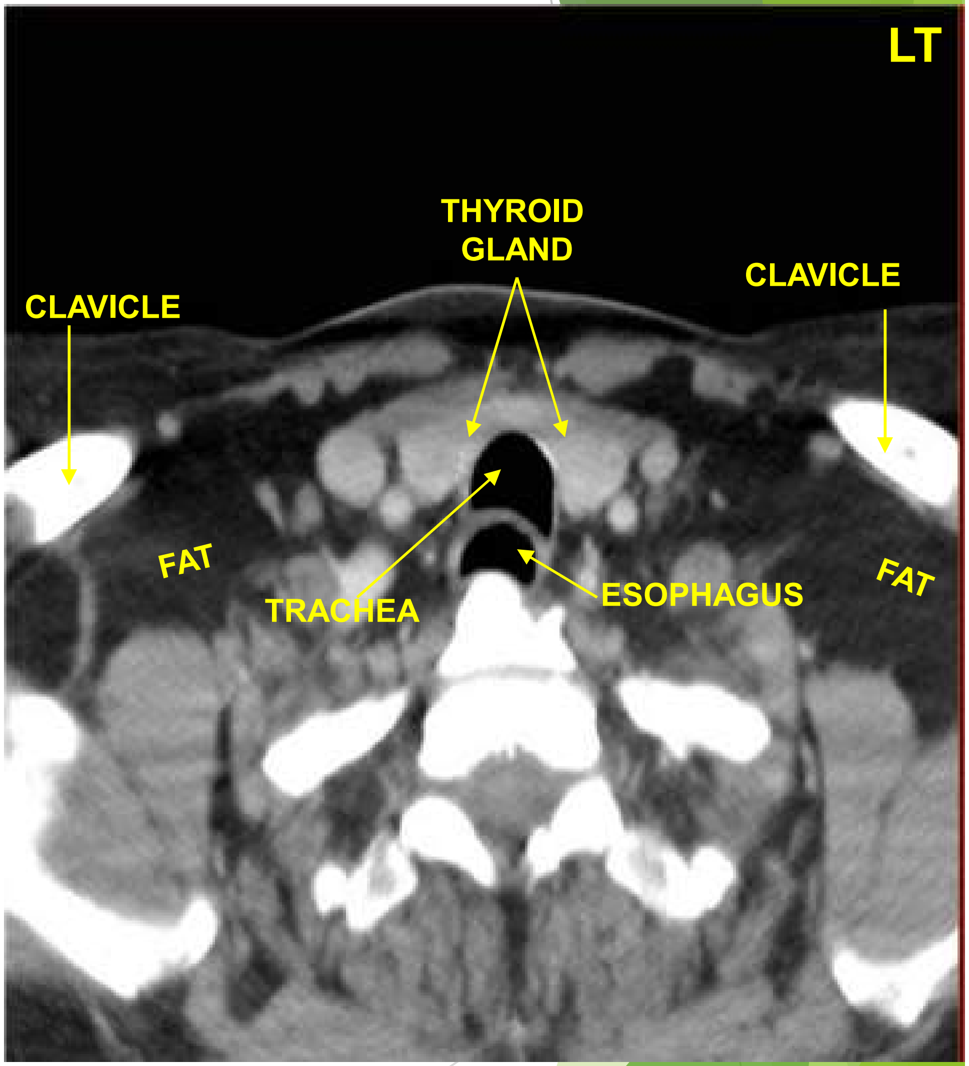

LT
STERNOCLEIDOMASTOID MUSCLE
THYROID CARTILAGE
VOCAL CORD

SCAN LEVEL

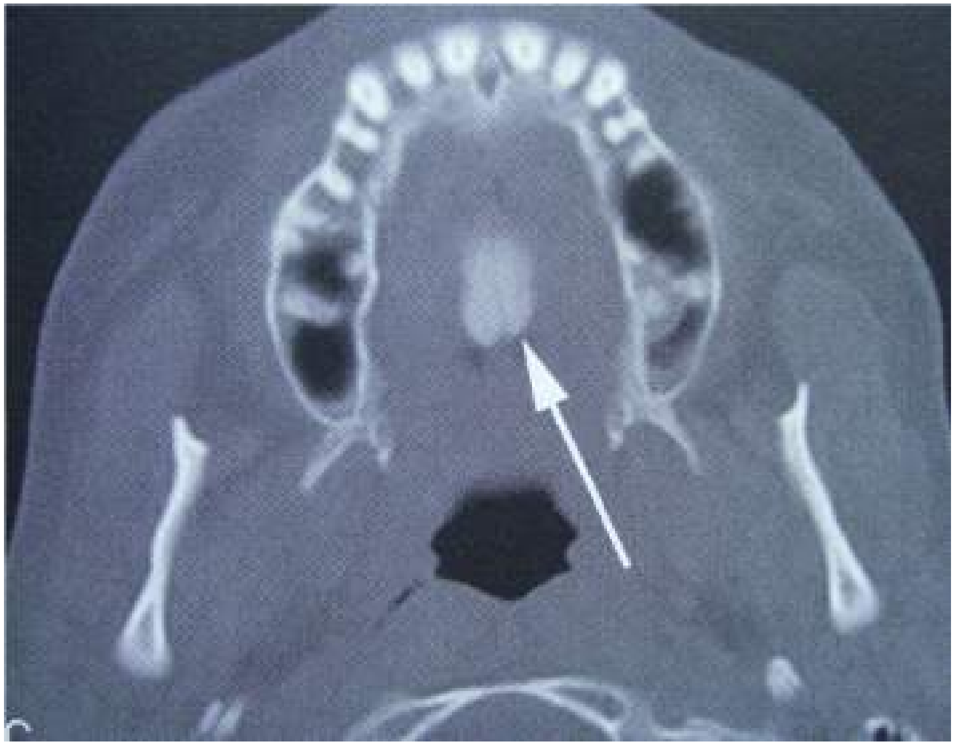



THYROID CARTILAGE
LT
COMMON CAROTID
ARTERY
CRICOID
CARTILAGE
JUGULAR
VEIN

SCAN LEVEL


LT
THYROID
GLAND
CLAVICLE
CLAVICLE
FAT
TRACHEA
ESOPHAGUS
FAT

Torus palatinus



Osteosarcoma

MAGNETIC RESONANCE IMAGING (MRI)

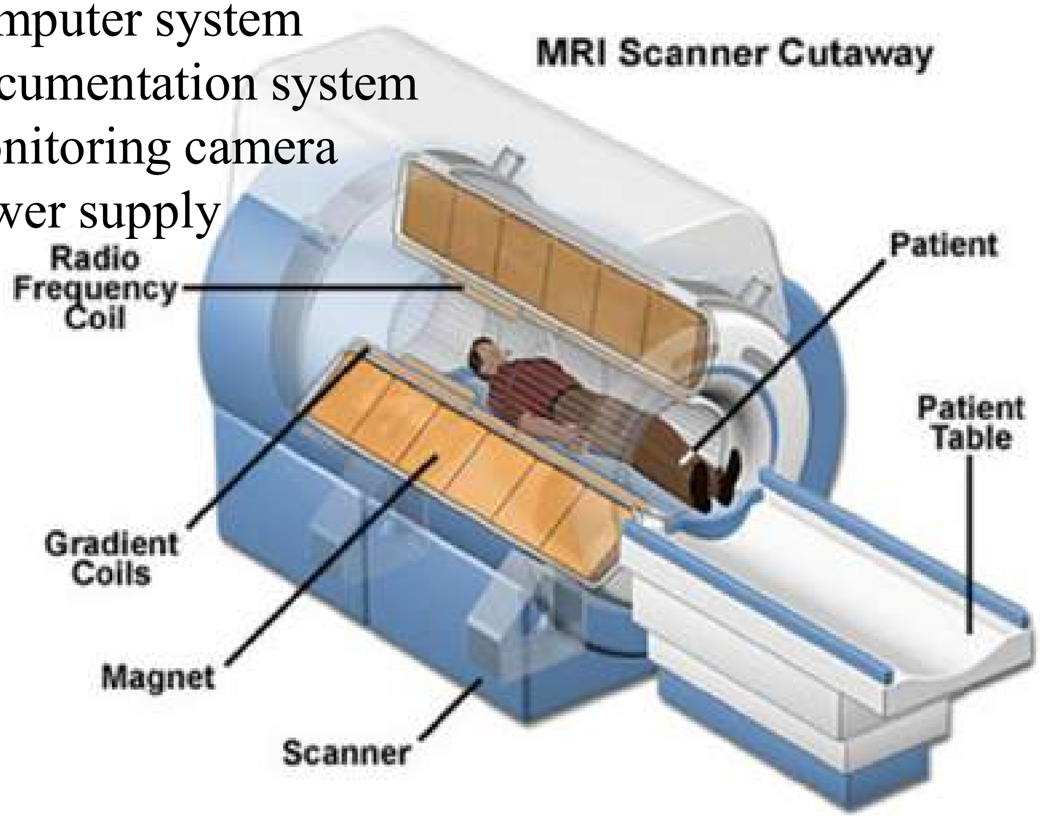
HISTORY

- Lauterbur described the first MR image in 1973, and Mansfield further developed use of the magnetic field and the mathematical analysis of the signals for image reconstruction.
- MR imaging was developed for clinical use around 1980, and Lauterbur and Mansfield were awarded the Nobel Prize in Physiology or Medicine in 2003.

- To make an MR image, the patient is first placed inside a large magnet.
- This magnetic field causes the nuclei of many atoms in the body, particularly hydrogen, to align with the magnetic field.
- The scanner directs a radiofrequency (RF) pulse into the patient, causing some hydrogen nuclei to absorb energy (resonate).
- When the RF pulse is turned off, the stored energy is released from the body and detected as a signal in a coil in the scanner.
- This signal is used to construct the MR image—in essence, a map of the distribution of hydrogen.

Main components are:

- ❑The magnet which is a key element of the MRI system
- ❑Computer system
- ❑Documentation system
- ❑Monitoring camera
- ❑Power supply



Let us start with a general overview of MRI

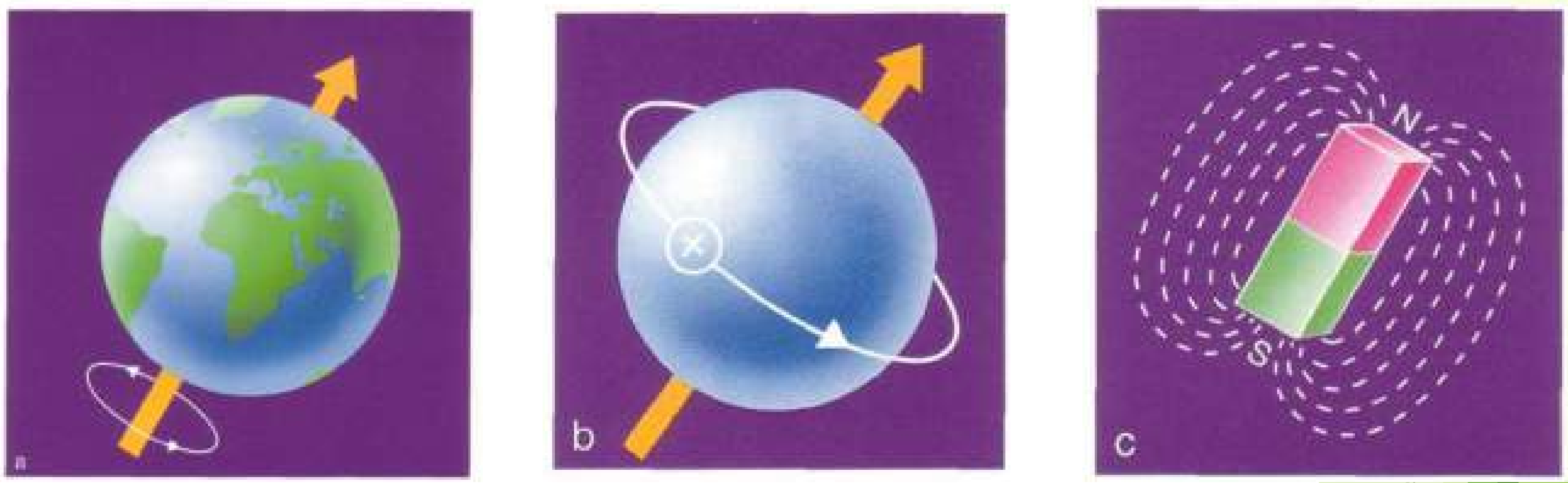
Steps of an MR examination can be described quite simply:

- ✓ The patient is placed in a magnetic field,
- ✓ A radio wave is sent in,
- ✓ The radio wave is turned off,
- ✓ The patient emits a signal, which is received and used for
- ✓ Reconstruction of the image.

PROTONS

- Individual protons and neutrons (nucleons) in the nuclei of all atoms possess a spin, or angular momentum.
- In nuclei having equal numbers of protons and neutrons, the spin of each nucleon cancels that of another, producing a net spin of zero.
- However, nuclei containing an unpaired proton or neutron have a net spin.
- Because spin is associated with an electrical charge, a magnetic field is generated in nuclei with unpaired nucleons, causing these nuclei to act as magnets with north and south poles (magnetic dipoles) and having a magnetic moment.

Protons



What happens to the protons, when we put them into an external magnetic field?

- The protons - being little magnets - align themselves in the external magnetic field.
- Two states are possible: **spin-up**, which parallels the external magnetic field, and **spin-down**, which is antiparallel with the field.

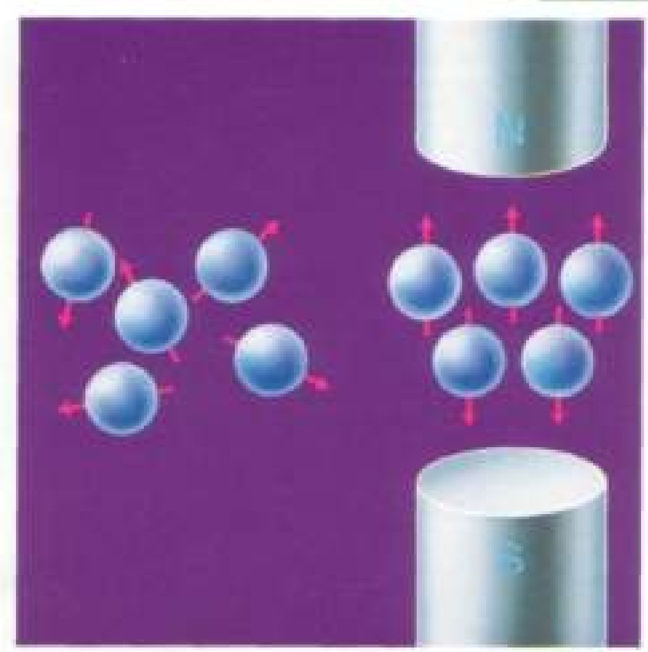
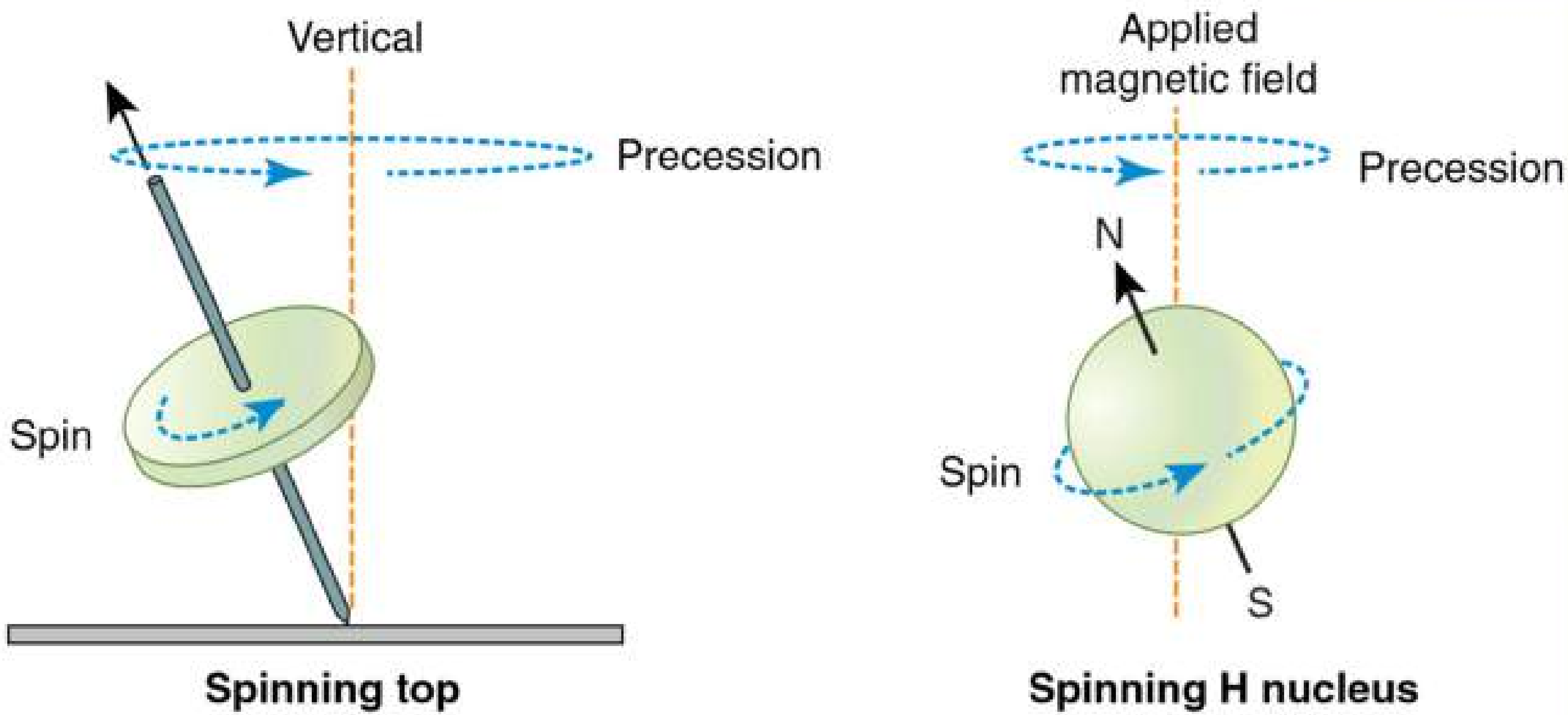


Figure: When protons are exposed to a strong external magnetic field, are aligned in only two ways, either parallel or antiparallel to the external magnetic field

PRECESSION

- The magnetic moments of hydrogen nuclei in a magnetic field do not align exactly with the direction of the magnetic field.
- Instead, the orientations of the axes of spinning protons actually oscillate with a slight tilt from a position absolutely parallel with the flux of the external magnet.
- This tilting of the spin axis, called precession, is similar to a spinning toy top, which rotates around an upright position as it slows down.
- Similarly, the presence of the magnetic field causes the axis of the spinning proton to wobble (or precess) around the lines of the applied magnetic field.
- The rate or frequency of precession is called the precessional frequency, resonance frequency, or Larmor frequency.

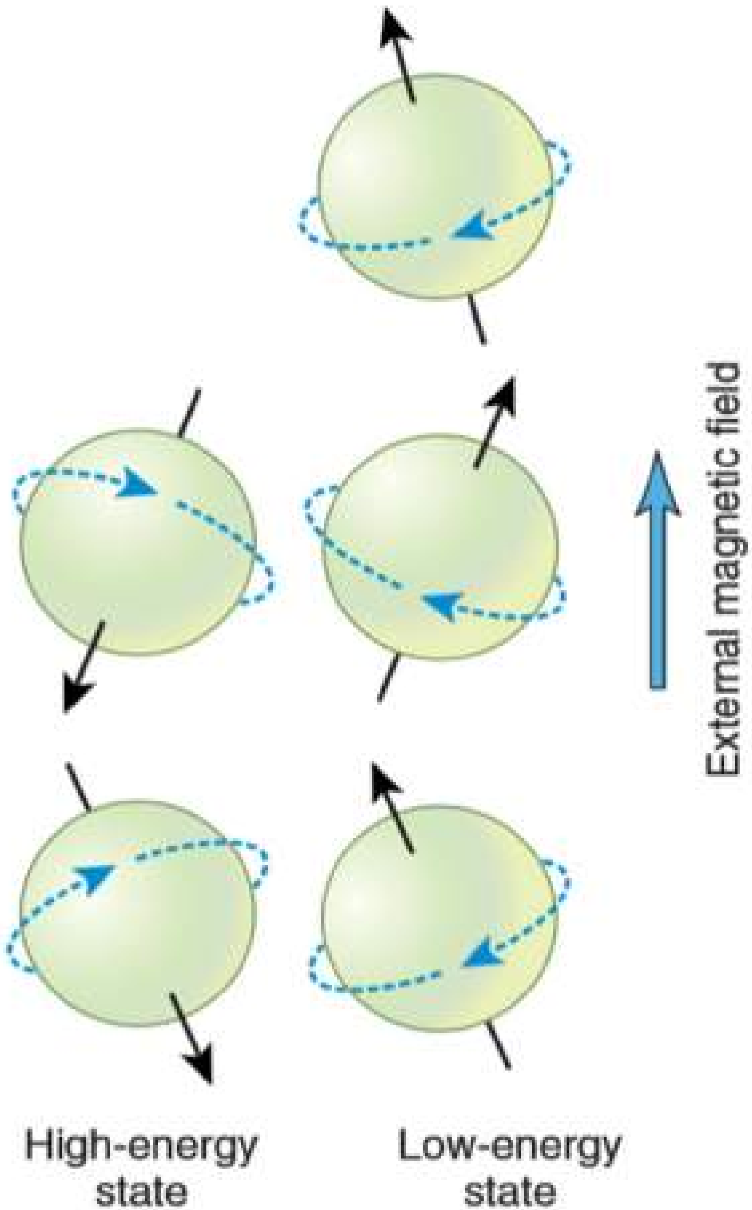
- The precessional frequency depends on the species of nucleus (i.e., hydrogen nucleus or other) and is proportional to the strength of the external magnetic field.
- The magnetic field in an MR scanner is provided by an external permanent magnet.
- MR field strengths range from 0.1 to 4 Tesla (T) with 1.5 T being the most common (1.5 T is about 30,000 times the strength of the earth's magnetic field).
- The Larmor precession frequency of hydrogen is 63.86 MHz in a magnetic field of 1.5 T. Other MR active nuclei precess at different frequencies in the same magnetic field.



Precession. Much as a top rotates around a vertical axis when spinning, the spin axis of a spinning hydrogen nucleus rotates around the direction of the external magnetic field. This movement is called precession, and the rate or frequency of precession is called the precessional, resonance, or Larmor frequency. The Larmor frequency depends on the strength of the external magnetic field and is specific for the nuclear species.

RESONANCE

- Nuclei can be made to undergo transition from one energy state to another by absorbing or releasing energy.
- Energy required for transition from the lower to the higher energy level can be supplied by electromagnetic energy in the RF portion of the electromagnetic spectrum.



Hydrogen nuclei in an external magnetic field. The magnetic dipoles are not aligned exactly with the external magnetic field. Instead, the axes of spinning protons actually oscillate or wobble with a slight tilt from being absolutely parallel with the flux of the external magnet.

Indications

- MRI is the procedure of choice to identify intracranial spread from a head or neck primary tumor, particularly those arising in the nasopharynx, sinonasal cavity, or temporal bone.

- MRI is also helpful for evaluating intracranial complications of infections and inflammatory conditions of the sinonasal, middle ear, and mastoid cavities

- **Orbits**

MRI is, in general, the procedure of choice for orbital imaging because of its lack of ionizing radiation, fine delineation of detail, and excellent demonstration of associated intracranial pathology.

- **Skull Base, Nasopharynx, and Oropharynx**

MRI is the procedure of choice for most pathology of the skull base, nasopharynx and oropharynx.

- **Sinonasal Cavities**

MRI is reserved for evaluating complications of sinus disease, including orbital and intracranial extension, for all suspected neoplasms, and to distinguish tumors and polyps from mucosal thickening and secretions.

Neck

MRI is used to evaluate congenital vascular anomalies, and for imaging the thyroid and parathyroid glands.

Temporal Bone

MRI is the procedure of choice for evaluating sensorineural hearing loss and vertigo in adults, as well as for intracranial spread of infection from the temporal bones and for evaluating the extent of most tumors.

Temporomandibular Joint (TMJ)

MRI is the procedure of choice for evaluating the discs in the TMJ, as well as the bones forming the joints.

ADVANTAGES

- Noninvasive using nonionizing radiation, and
- Making high-quality images of soft tissue resolution in any imaging plane.

DISADVANTAGES

- High cost
- Long scan times
- Various metals in the imaging field either distort the image or may move into the strong magnetic field, injuring the patient.

NUCLEAR IMAGING

- Nuclear medicine is a branch or specialty of medicine and medical imaging that uses radionuclides and relies on the process of radioactive decay in the diagnosis and treatment of disease.

- In nuclear medicine procedures, radionuclides are combined with other chemical compounds or pharmaceuticals to form radiopharmaceuticals.

- These radiopharmaceuticals, once administered to the patient, can localize to specific organs or cellular receptors.

- This property of radiopharmaceuticals allows nuclear medicine the ability to image the extent of a disease process in the body, based on the cellular function and physiology, rather than relying on physical changes in the tissue anatomy.

- In nuclear medicine imaging, radiopharmaceuticals are taken internally, for example intravenously or orally.
- Then, external detectors (gamma cameras) capture and form images from the radiation emitted by the radiopharmaceuticals.

There are several techniques of diagnostic nuclear medicine:

- Scintigraphy is the use of internal radionuclides to create two-dimensional images.
- SPECT is a 3D tomographic technique that uses gamma camera data from many projections and can be reconstructed in different planes.
- Positron emission tomography (PET) uses coincidence detection to image functional processes

- Nuclear medicine tests differ from most other imaging modalities in that diagnostic tests primarily show the physiological function of the system being investigated as opposed to traditional anatomical imaging such as CT or MRI.

Radionuclides - Desirable characteristics

- Primary photon energy levels between 50 and 500 keV
- Physical half life greater than the time required to prepare the material for injection
- Effective half life longer than examination time
- Suitable chemical form and reactivity
- Low toxicity
- Stability or near stability of the product.

Radionuclides

- The most commonly used intravenous radionuclides are:
- Technetium-99m (technetium-99m)
- Iodine-123 and 131
- Thallium-201
- Gallium-67
- Fluorine-18 Fluorodeoxyglucose
- Indium-111

The most commonly used gaseous/aerosol radionuclides are:

- Xenon-133
- Krypton-81m·
- Technetium-99m

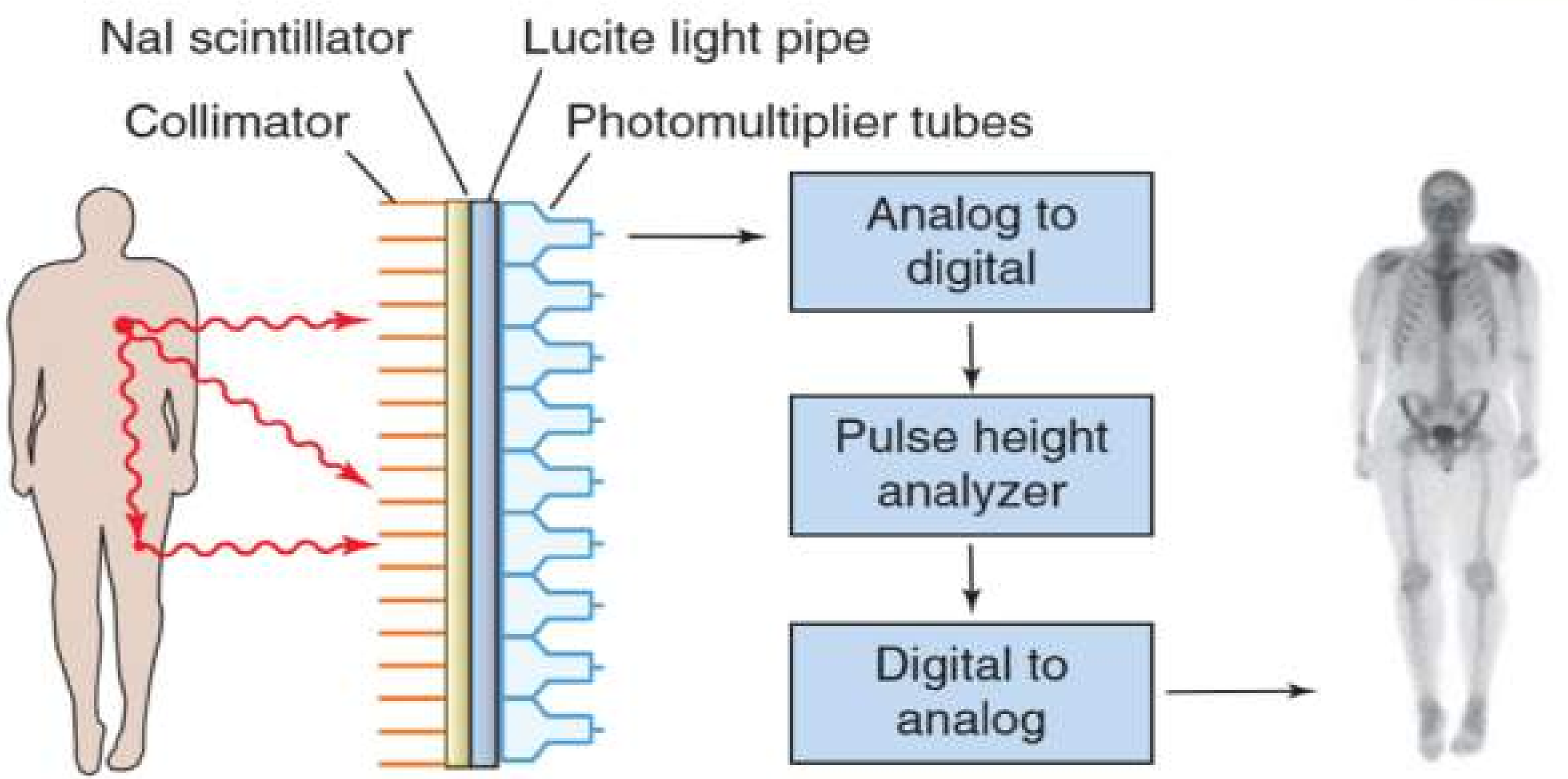
- The most commonly used is technetium 99m (99mTc).
- 99mTc has a half-life of 6 hours and emits primarily 140 keV photons.
- As technetium pertechnetate, 99mTc mimics iodine distribution when injected intravenously and is concentrated by the salivary and thyroid glands and gastric mucosa.
- When it is attached to various carrier molecules, it can be used to examine virtually every organ of the body.
- For example, to image bone, 99mTc is typically bound to methylene diphosphonate (MDP).

Gamma camera

- Also called a **scintillation camera** or **Anger camera**
- It is a device used to image gamma radiation emitting radioisotopes, a technique known as scintigraphy.
- These cameras capture photons and convert them to light and then to a voltage signal.

- The first part of the gamma camera is a collimator. It absorbs γ rays that do not travel parallel to the plates, improving image resolution. The γ rays that pass through the collimator strike a scintillation crystal.
- This crystal, often made of sodium iodide with trace amounts of thallium, fluoresces when it absorbs γ rays.
- These flashes of light are detected by an array of photomultiplier tubes coupled to the crystal with light pipes.
- The photomultiplier tubes capture the flash and amplify the signal.
- The signals from the photomultiplier tubes go through an analog-to-digital converter and then to a pulse height analyzer.

- This device detects the intensity of the signal, and thus the energy of the incident absorbed photons, and uses only photons from the radionuclide when forming the final image.
- Many of the γ rays released from the radionuclide in the patient undergo Compton absorption at some distant site and result in a new scattered photon.
- If these scattered, lower energy photons pass through the collimator of the gamma camera, they may degrade image resolution.
- However, these scattered photons are detected by the pulse height analyzer and are rejected so that they do not contribute to the image.
- Use of a scintillation crystal for acquisition of data for image formation has led to the labeling of this technique as scintigraphy.


NaI scintillator
Lucite light pipe
Collimator
Photomultiplier tubes
Analog to digital
Pulse height analyzer
Digital to analog

Scintigraphy

- **Scintigraphy** ("scint," Latin scintilla, spark) is a form of diagnostic test used in nuclear medicine, wherein radioisotopes (*radiopharmaceuticals*) are taken internally, and the emitted radiation is captured by external detectors (gamma cameras) to form two-dimensional images.

Single photon emission computed tomography

- It is very similar to conventional nuclear medicine planar imaging using a gamma camera.
- However, it is able to provide true 3D information.
- This information is typically presented as cross-sectional slices through the patient, but can be freely reformatted or manipulated as required.

- In the same way that a plain X-ray is a 2-dimensional (2-D) view of a 3-dimensional structure, the image obtained by a gamma camera is a 2-D view of 3-D distribution of a radionuclide.
- SPECT imaging is performed by using a gamma camera to acquire multiple 2-D images (also called projections), from multiple angles.

- A computer is then used to apply a tomographic reconstruction algorithm to the multiple projections, yielding a 3-D dataset.
- This dataset may then be manipulated to show thin slices along any chosen axis of the body, similar to those obtained from other tomographic techniques, such as MRI, CT, and PET.

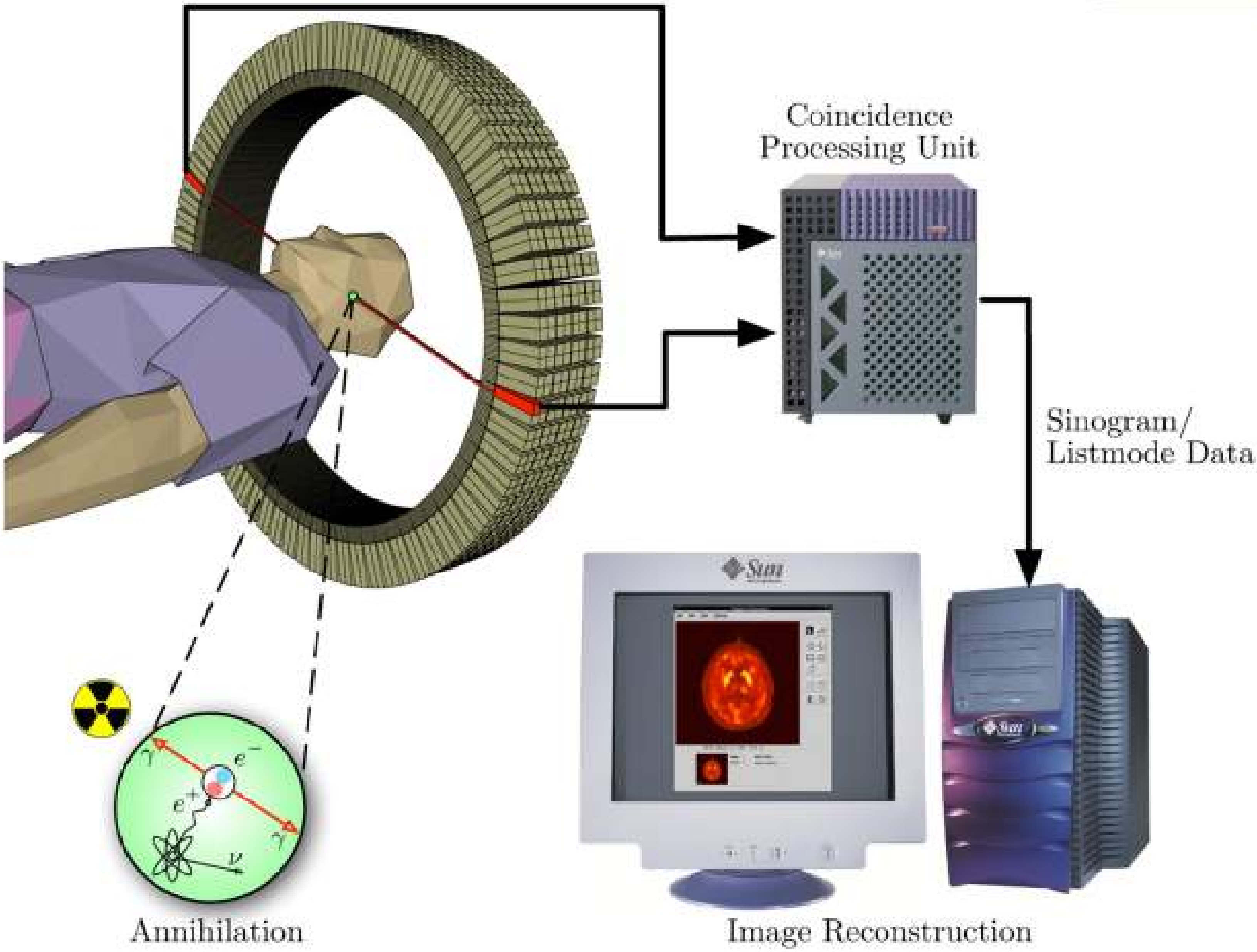
Positron Emission Tomography

- A nuclear medicine imaging technique which produces a three-dimensional image or picture of functional processes in the body.
- The system detects pairs of gamma rays emitted indirectly by a positron-emitting radionuclide (tracer), which is introduced into the body on a biologically active molecule.
- Images of tracer concentration in 3-dimensional or 4-dimensional space (the 4th dimension being time) within the body are then reconstructed by computer analysis.

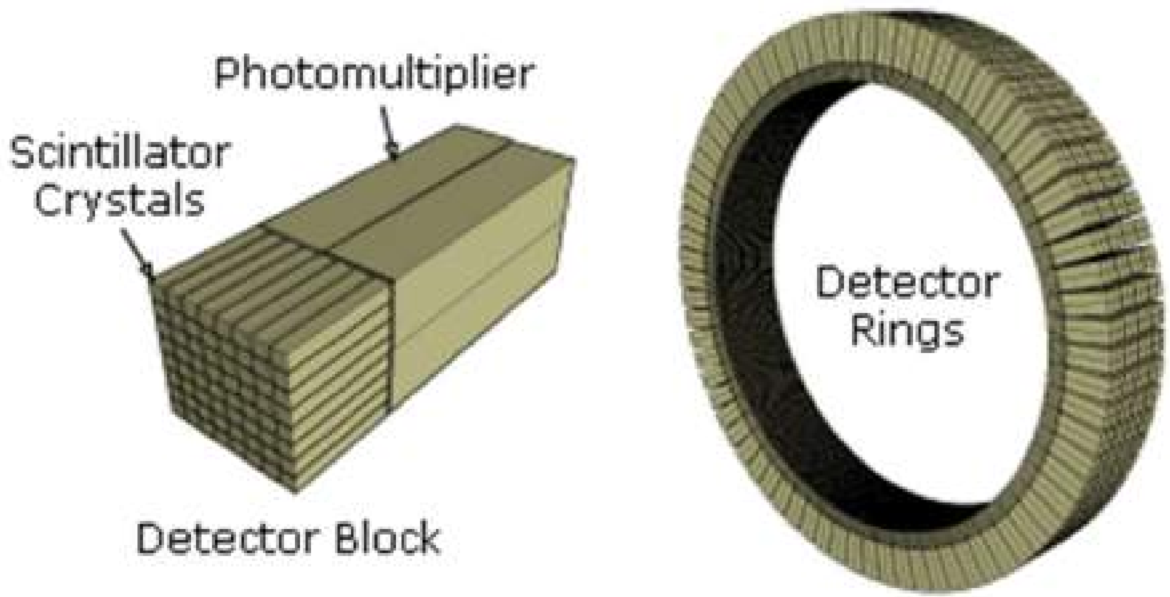
Operation

- To conduct the scan, a short-lived radioactive tracer isotope is injected into the living subject.
- The tracer is chemically incorporated into a biologically active molecule.
- There is a waiting period while the active molecule becomes concentrated in tissues of interest.
- Then the subject is placed in the imaging scanner.

- The molecule most commonly used for this purpose is fluorodeoxyglucose (FDG), a sugar, for which the waiting period is typically an hour.
- During the scan a record of tissue concentration is made as the tracer decays.


Coincidence
Processing Unit
Sinogram/
Listmode Data
Annihilation
Image Reconstruction

Detector block



2D/3D reconstruction

- Early PET scanners had only a single ring of detectors, hence the acquisition of data and subsequent reconstruction was restricted to a single transverse plane.
- More modern scanners now include multiple rings, essentially forming a cylinder of detectors.

Radionuclides

Radionuclides used in PET scanning are typically isotopes with short half lives such as

- carbon-11 (~20 min),
- nitrogen-13 (~10 min),
- oxygen-15 (~2 min), and
- fluorine-18 (~110 min).

- These radionuclides are incorporated either into compounds normally used by the body such as glucose (or glucose analogues), water or ammonia, or into molecules that bind to receptors or other sites of drug action.
- Such labelled compounds are known as radiotracers.
- Presently, however, by far the most commonly used nuclide in clinical PET scanning is fluorine-18 in the form of FDG.

Applications of PET

PET is a valuable technique for some diseases and disorders, because it is possible to target the radio-chemicals used for particular bodily functions.

- Oncology:

PET scanning with the tracer fluorine-18 (F-18) fluorodeoxyglucose (FDG), called FDG-PET, is widely used in clinical oncology.

- FDG-PET can be used for diagnosis, staging, and monitoring treatment of cancers, particularly in Hodgkin's lymphoma, non-Hodgkin lymphoma, and lung cancer.

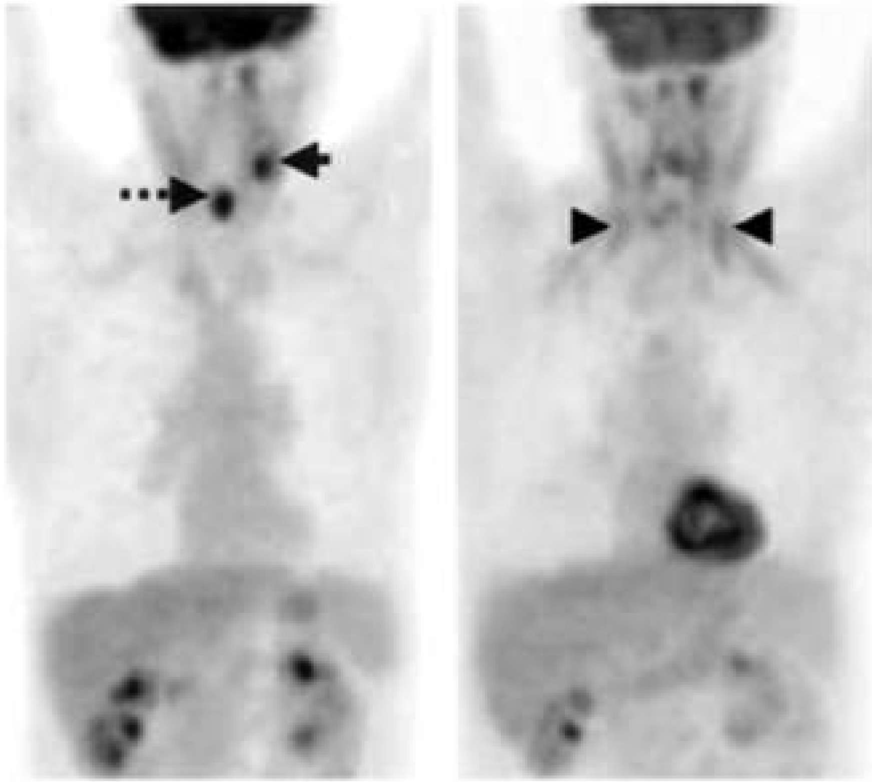
- Many other types of solid tumors will be found to be very highly labeled on a case-by-case basis - a fact which becomes especially useful in searching for tumor metastasis,or for recurrence after a known highly active primary tumor is removed.
- Oncology scans using FDG make up over 90% of all PET scans in current practice.

- Cardiology, atherosclerosis and vascular disease study: In clinical cardiology, FDG-PET can identify so-called "hibernating myocardium".
- Recently, a role has been suggested for FDG-PET imaging of atherosclerosis to detect patients at risk of stroke

FDG PET in Head and neck cancers

- Accurate identification of distant disease in head and neck carcinoma patients is critical to determine the appropriate therapeutic approach and prognosis.

- The diagnostic accuracy of FDG PET for detecting lymph node metastases is superior to those of conventional modalities.
- FDG PET has also been shown to be more beneficial than anatomic imaging in detecting primary tumors in patients with head and neck metastases of unknown origin.
- FDG PET can demonstrate up to 30% of previously undetected primary tumors



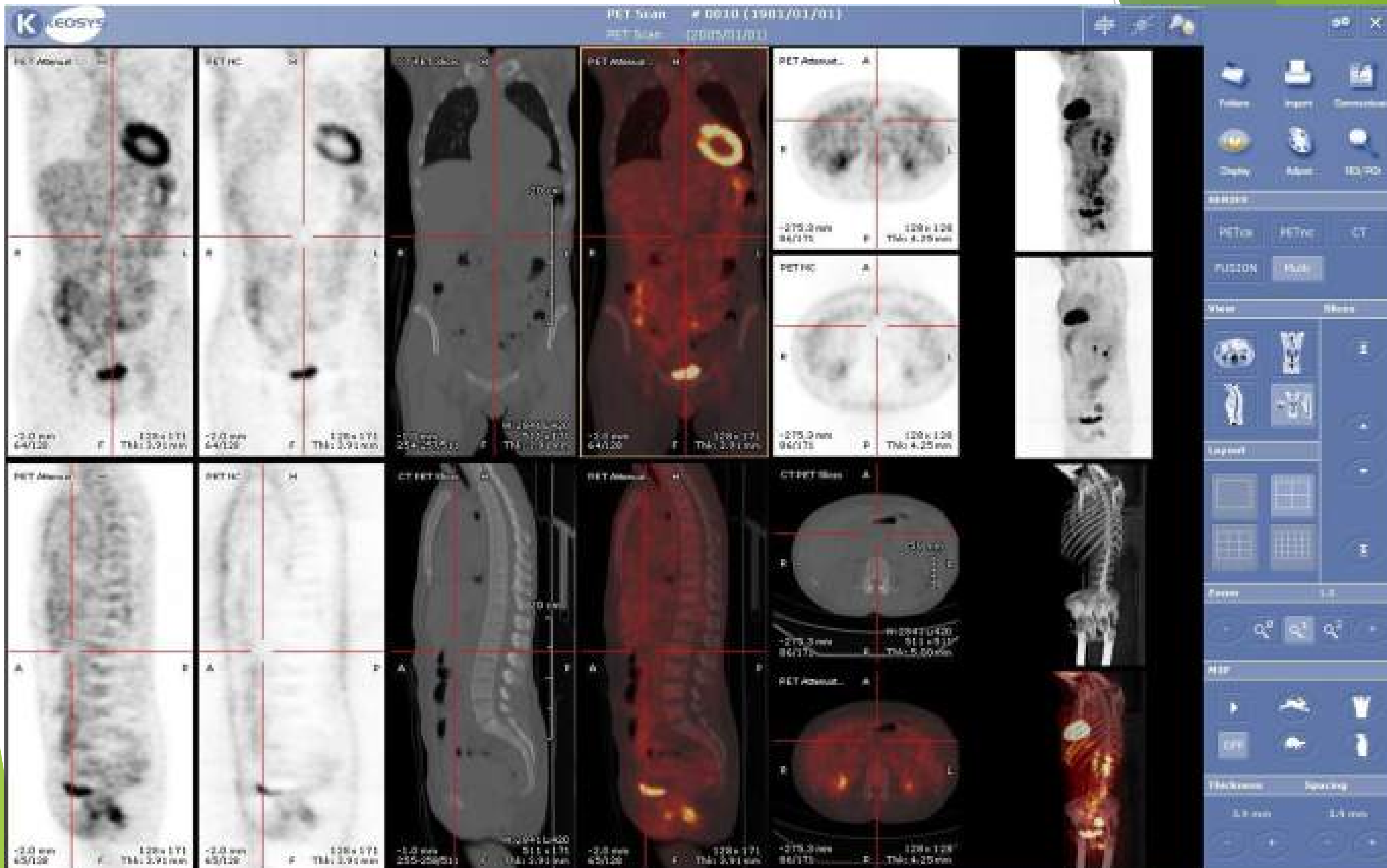
a. b.

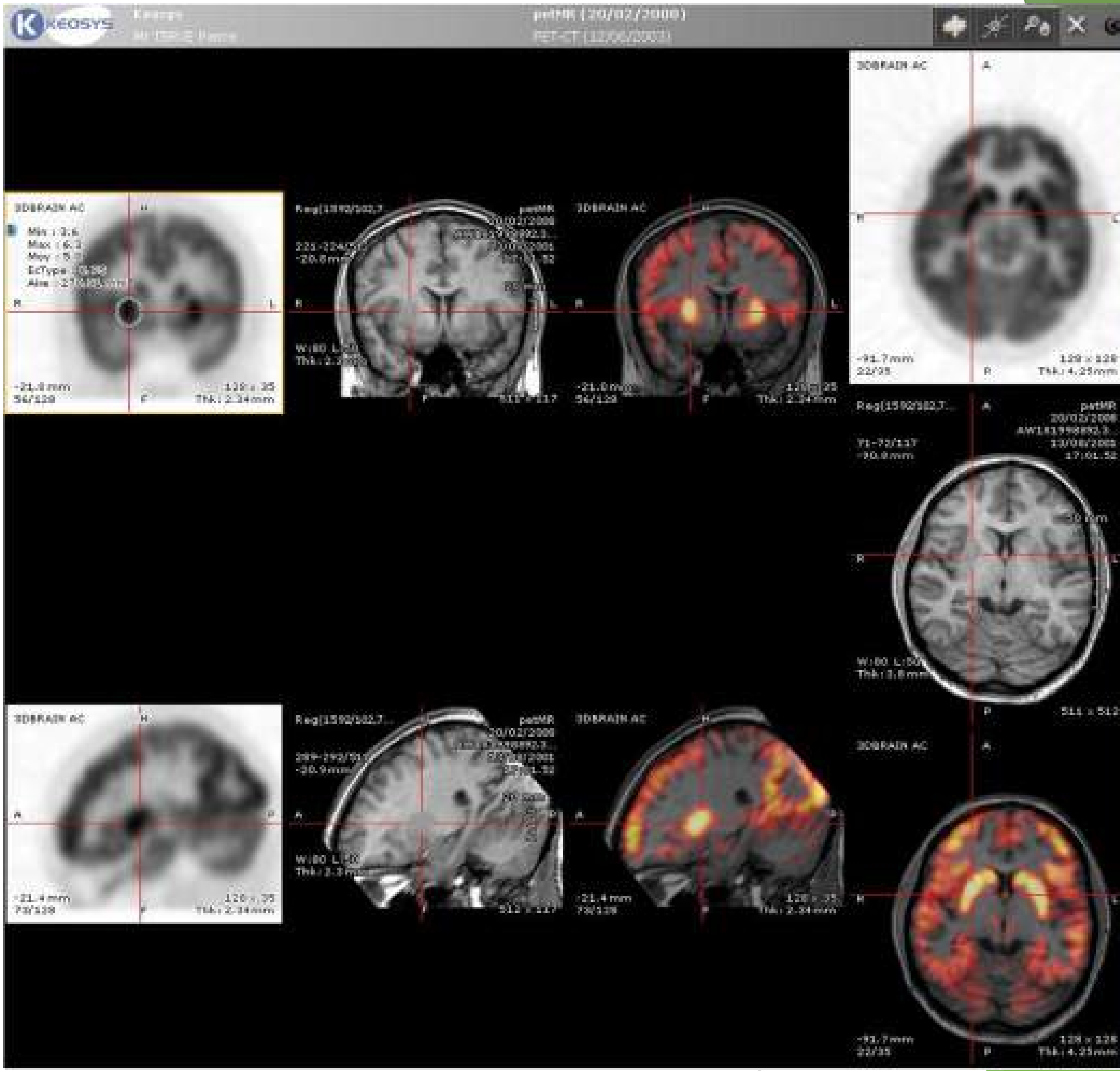
Figure 24. Supraglottic cancer in a 66-year-old man with a metastasis in a left cervical lymph node (same patient as in Fig 22). FDG PET was performed before treatment and 7 months after treatment. **(a)** Initial coronal FDG PET image shows uptake in a supraglottic cancer (arrow with dotted tail) and a left cervical lymph node (solid arrow). **(b)** Posttherapy FDG PET image shows resolution of focal hypermetabolism in the supraglottic cancer and left cervical lymph node. The mild diffuse and linear activity represents postoperative changes and muscle spasms in the sternocleidomastoid muscles (arrowheads).

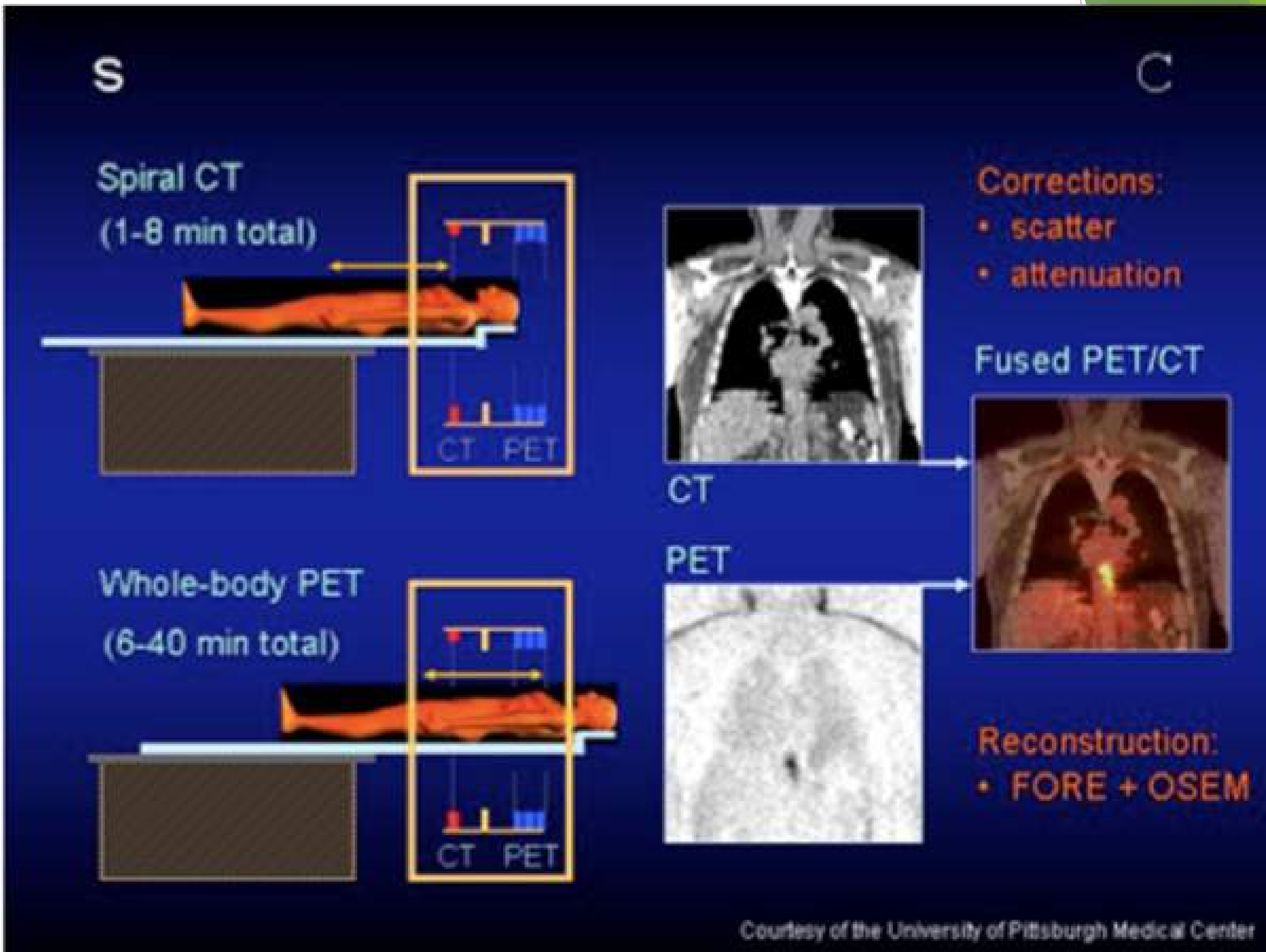
PET CT (Hybrid imaging)

- PET scans are increasingly read alongside CT or magnetic resonance imaging (MRI) scans, the combination ("co-registration") giving both anatomic and metabolic information (i.e., what the structure is, and what it is doing biochemically).

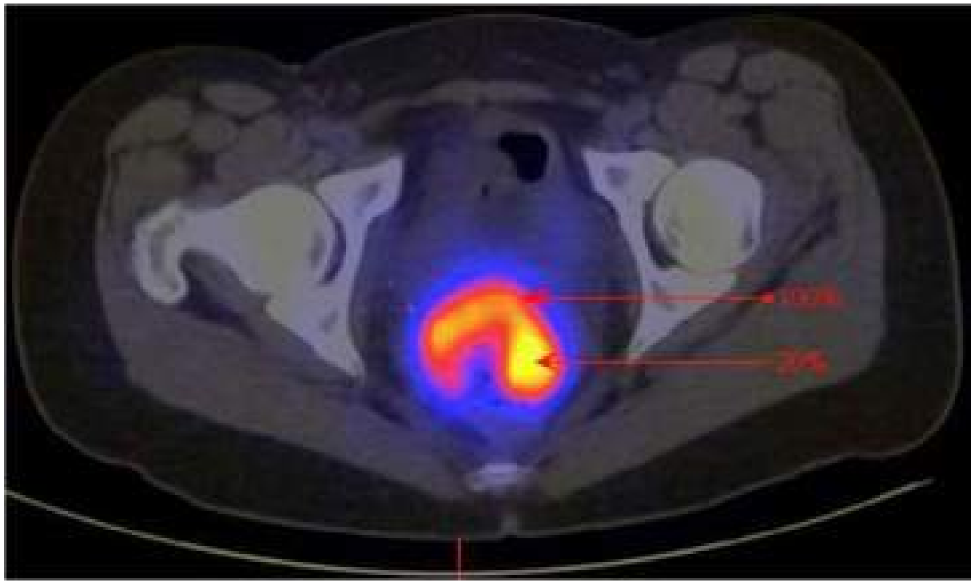
- Because PET imaging is most useful in combination with anatomical imaging, such as CT, modern PET scanners are now available with integrated high-end multi-detector-row CT scanners.
- Because the two scans can be performed in immediate sequence during the same session, with the patient not changing position between the two types of scans, the two sets of images are more-precisely registered, so that areas of abnormality on the PET imaging can be more perfectly correlated with anatomy on the CT images.


PET Scan
PET NC
CT
FUSION


KEOSYS
petMR (20/02/2000)
3DBRAIN AC
Reg(1592/102.7
W:80 L:50


S
C
Spiral CT
(1-8 min total)
CT PET
Whole-body PET
(6-40 min total)
CT PET
CT
PET
Corrections:
• scatter
• attenuation
Fused PET/CT
Reconstruction:
• FORE + OSEM
Courtesy of the University of Pittsburgh Medical Center

Characteristics of a malignant node



Periphery will show greater uptake as compared to centre

- Preiphery: Red
- Centre: yellow

Indications for bone scanning

- Detection and follow up of metastatic disease.
- Differentiate between osteomyelitis and cellulitis
- Determination of bone viability: infarction, avascular necrosis.
- Evaluation of fractures difficult to assess on radiographs.
- Evaluation of prosthetic joints for infection and loosening.
- Determination of biopsy site.
- Evaluation of bone pain in patients with normal radiographs
- Evaluation of growth differences

Thank You