A STUDY ON MEDICAL IMAGE ACQUISTION USING IONISING RADIATION

Poornachandra S
Lecturer and Research Scholar,
Department of MCA (VTU),
DSCE, Bangalore-78
poorna.sandur18@gmail.com

Dr. Y S Kumaraswamy
Professor and Head,
Department of MCA (VTU),
DSCE, Bangalore-78
Yskldswamy2@yahoo.com

Abstract

This paper highlight on the aspects of medical image acquisition from ionising radiation. Ionising radiation can be divided into two , one is by X-rays and the other is by gamma rays. There are many imaging modalities by X-rays like X-ray radiography,X-ray mammography etc. and the imaging modalities by gamma rays are planar scintigraphy,SPECT and PET modalities.Hence this paper focuses on the acquisition of medical images using X-rays and gamma rays.

Keywords- radioisotopes,Ionising radiation

1. Introduction

Computer era has enabled tomographic and three-dimensional reconstruction of images, illustrating both anatomical features using x-rays and physiological functioning using γ-rays emitted from ingested or injected radioactive tracers, free from overlying structures. Since both x-rays and γ-rays are forms of ionizing radiation, they must be used carefully in order to minimize hazard to the body and its genetic material. Medical imaging systems detect different physical signals arising from a patient and produce images.

An imaging modality is an imaging system which uses a particular technique. Some of these modalities use ionizing radiation, radiation with sufficient energy to ionize atoms and molecules within the body, and others use non-ionizing radiation. Ionizing radiation in medical imaging comprises x-rays and γ-rays, both of which need to be used carefully to avoid causing serious damage to the body and to its genetic material. Non-ionizing radiation, on the other hand, does not have the potential to damage the body directly and the risks associated with its use areconsidered to bevery low. Examples of such radiation are ultrasound, i.e. high-frequency sound, and radio frequency waves.

2. Imaging Orientations of Human Body

Images of the human body can be acquired or displayed in three main orientations. The ***Coronal Plane*** divides the body into front and back. This is the orientation displayed in the common posterior-anterior(PA) chest radiograph , where the X-rays enter from the patient's back(posterior) and are collected by a film placed at his front anterior .fig(1)

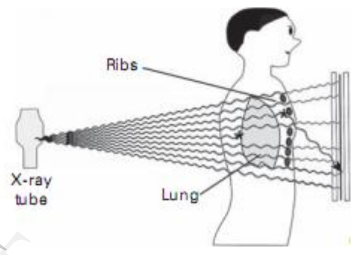
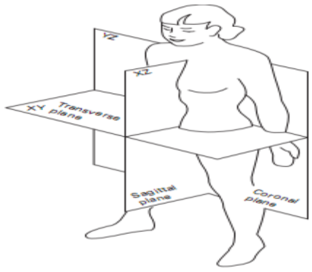


Fig. (1)The Posterior-Anterior Chest Radiograph;the X-ray tube placed at patient's posterior (back) and Film at the Anterior(front) of Patient.

The ***Sagittal plane*** is a side view , dividing the body into right and left ,and the ***Transverse plane*** , sometimes reffered to as the ***axial*** or transaxial plane is a plane perpendicular to the long axis of the body, dividing it into top and bottom planes.(fig (2))



Fig(2). The Three main imaging orientations for the human body: the Coronal , Sagittal and Transverse planes.

3. Images from X-rays

Types of X-ray radiography:

Projection or Planar X-ray radiography:In projection X-ray Radiography, the image is a simple

a) two dimensional projection of a three dimensional object , the part of the patient in the field of view.

b)Film screen radiography : includes chest radiography , abdominal radiography , angiography(study of blood vessels) and mammography.

c) Fluroscopy : in which images are produced in real time using an image intensifier tube to detect the X-rays.

d) Computed Radiography : in which a reusable imaging plate containing storage phosphors replaces the film as the detector.

A typical normal posterior-anterior(PA) chest radiograph in fig .3

Fig 3. Posterior-Anterior chest Radiograph of a normal patient.

X-ray fluroscopy is a continious or dynamic imaging technique, where moving images of the patient can be seen in real time.

Computed Radiography is fast superseding plain (film -screen) radiography . It uses a photostimulable phosphor plate(PSP) or imaging plate to replace the standard intensifiying screen/X-ray film combination in a cassette. The imaging plate comprises a screen coated with a storage phosphor. When the imaging plate is exposed to X-rays, electrons absorbed by the phosphor are excited to higher energy levels and are trapped there, typically for several days, resulting in a hidden image. Reading the hidden image in the imaging plate involves scanning the plate in a raster patternwith a well focused laser beam. The laser light stimulates the release of the trapped electrons,accompained by the release of blue light , which is converted to a voltage by a photomultiplier; the voltage signal is digitized and stored in computer (fig 4). This process avoids the chemical processing required with traditional film , and , after scanning , the imaging plate cane erased by exposure to intense visible light, for subsequent re-use.

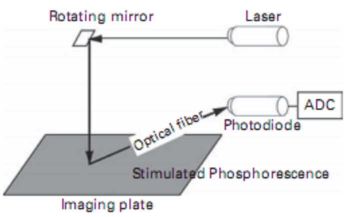


Fig. 4 Reading of an image plate in Computed Radiography

X-ray mammography is one of the most challenging areas in medical imaging . It is used to distinguish subtle differences in tissue type. Clusters of microcalcifications , tiny calcium deposits , are diagnostic of early stage breast cancer .Ill-defined masses with strans of tissue(spiculations) radiating out from them , and producing a stellate appearance , are a diagnostic feature of malignancy. Reading mammograms can be a tedious and time consuming task : computer assisted diagnosis software is able to highlight suspicious areas in digital mammorgams automatically for checking by a human expert. Fig. 5 shows the dense opacity and andspiculations indicative of a malignant lesion.

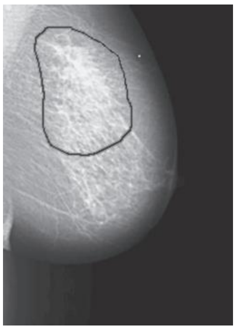


Fig .5 Dense Opacity and spiculations (outlined area) show presence of malignant

Computed Tomography:

Conventional radiographic procedures, which were described so far, produce planar images , that are projections of three dimensional objects onto two dimensional planes .This results in a considerable loss of information .

Tomographic imaging of which X-ray computed tomography (CT) is an example, is a technique that was developed for producing transverse images , by scanning a slice of tissue from multiple directions using a narrow fan-shaped beam.The data from each direction comprise a one dimensional projection of the object, and a transverse image can be retrospectively reconstructed from multiple projections. (fig. 6)

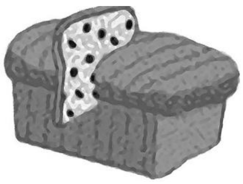


Fig. 6 The body as a loaf of sliced bread; a transverse image is a slice of bread viewed end on

In a CT scanner the patient is placed within the aperture of the rotating frame or gantry (fig 7(a). The X-ray tube mounted on the gantry revlolves around the patient ,a tightly collimated fan-beam of X-rays enters the patient, and an arc of detectors on the opposite side , and rotating synchronously with the X-ray tube, records the intensity of emerging radiation (Fig 7 (b)). The X-ray tube is alwayson , and readingg from the detectors are taken about a thousand times during the rotation.

Fig 7(a) Outside view of third-generation CT scanner showing the patient table and gantry aperture.

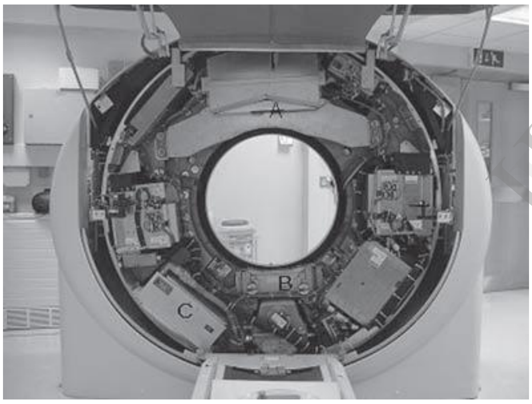


Fig 7(b) When the cover is removed, the x-ray tube and the arc of detectors can be seen. The gantry holding the x-ray tube and detector rotate around the patient as the data are gathered

4. Images from Gamma Rays

Nuclear Medicine(NM) imaging uses the gamma rays emitted from radioactive isotopes attached to pharmaceutical tracers that are specific to certain physiological, metabollic and pathological activities These radio-labelled pharmaceutical tracers are injected into the body where they are circulated and/or metabolized . The gamma rays which they emit during radioactive decay pass out of the body and are collected by detectors (gamma cameras) placed around the patient; these measure the distribution of the tracer withing the body,and produce images which show the functional or metabollic activity in the relevant organs. The ideal radioisotope should release only monochromatic , i.e. Single energy , gammarays and not alphaand beta particles. Gamma ray photons with energy in the range of about 70-500 keV are ideal since they are able to penetrate out of the body and be detected.

5. Three Basic Imaging Modalities in Nuclear Medicine

There are three basic imaging modalities in nuclear medicine. Projection studies called ***planar scintigraphy***are analogous to projection radiography. A single gamma camera, or a dual headed gamma camera to take anterior and posterior images simultaneously, is used to detect the emitted gamma-rays .

Tomographic medical imaging i.e. ***Single Photon Emission Computed Tomography (SPECT)*** uses a rotating gamma camera to obtain projection from multiple angles, which are used to reconstruct cross-sectional images.

The Positron emission tomography (PET) detects pairs of 511 keV gamma photons, which are emitted when positrons are annihilated.

In Planar Scintigraphy , gamma rays are emitted in all directions and pass through the body much like X-rays.In order to locate the source of the gamma rays a collimator is place between the patient and the detector (fig. 8) . The detector i.e the gamma camera, comprises a single , large scintillation crystal to convert the gamma rays into light photons , the scintillation crystal like sodium iodide , doped with thallium is used .The light photons are detected by a hexagonal array of photomultiplier tubes(PMT's) , which convert the light into an electrical signal and amplify it. For every 7-10 light photons incident on the photocathode of the photomultiplier tube, a single electron is released by the photoelectric effect. It is accelerated and produces 3-4 secondary electrons by collision with electrodes ,the process is repeated and after 10-14successsive stages , the electrons read the output anode .This current is amplified to provide a voltage pulse with a peak voltage and further the voltage signal is digitized and stored in the computer for further image processing.

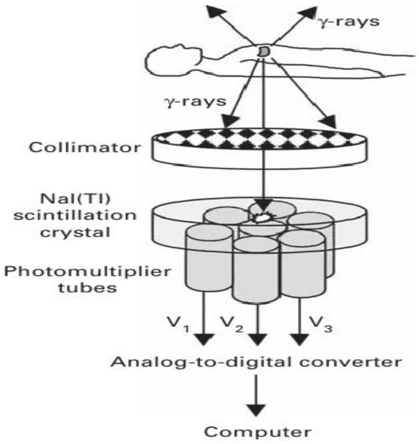


Fig. 8 Schematic diagram for obtaining a planar nuclear medicine image, using a gamma camera

6. SPECT Imaging

Single-photon emission computed tomography is a nuclear medicine tomographic imaging technique using gamma rays . It is similar to nuclear medicine planar imaging using a gamma camera.SPECT provides true 3D information. This information is typically presented as cross-sectional slices through the patient, but can be freely manipulated as required.

In signle-photon emission computed tomography, SPECT , a rotating gamma camera , with one , two or three detector heads , rotates around and as closely as possible to the patient because spatial resolution decreases with the distance from the collimator .And also, sensitivity increases and acquistion time decreases with more detector heads.

The different acquired projections are used to reconstruct cross-sectional or three dimensional images by filtered back projection. The reconstruction computation is more complicated than X-ray computed tomography because the detected signals depend upon both the spatialdistribution of the radioisotopes and the attenuation properties of voxels .

7. PET Imaging

Positron Emission Tomography is the recent nuclear medicine imaging technique , it measures physiological function rather thangross anatomy .A positron emitting radioisotope with a short half life such as nitrogen-13 , carbon-11 and fluorine-18 is incorporated into a metabolically active molecule such as glucose or ammonia , and then injected into a metabolically active molecule and injected into the patient . Such compounds are known as ***radiotracers.*** When a positron is positively charged electron , is emitted within a patient, it travels up to several millimeters while losing its kinetic energy .When the slowly moving positron encounters an electron , they spontaneously disappear and their rest masses are converted into two 511 keV annihilation (gamma ray) photons, which propogate away from the annihilation site in opposite directions . The patient is surrounded by multiple rings of gamma photon detectors.

PET Images have higher signal-to-noise ratio and better spatial resolution than planar scintigraphy and SPECT images.

8. Conclusion

This paper mainly focussed on imaging modalities based on ionising radiation like X-ray mammography, X-ray planarScintigraphy, X-ray CT and these imaging modalities are based on X-rays and the other imaging modalities like PET, SPECT are based on gamma rays.

The other set of imaging modalities are based on Non-ionising radiation like Ultrasound imaging, Magnetic Resonance imaging (MRI) etc. The two imaging modalities i.e. the ionising radiation and non-ionising radiation imaging modalities can be combined i.e PET-MRI combination can be used to detect cancerous tissues . Thus , a further survey study on Non-ionising radiation and Hybrid imaging modalities can be done.

9. References

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