ANA 302

GENERAL APPLICATIONS OF IMAGING TECHNIQUES TOWARS CANCER

GROUP 2

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Introduction

Cancer is an abnormal growth of cells. Cancer cells rapidly reproduce despite restriction of space, nutrients shared by other cells, or signals sent from the body to stop reproduction. Cancer cells are often shaped differently from healthy cells, they do not function properly, and they can spread to many areas of the body. Tumors, abnormal growth of tissue, are clusters of cells that are capable of growing and dividing uncontrollably; their growth is not regulated.

Tumors can be benign (noncancerous) or malignant (cancerous). Benign tumors tend to grow slowly and do not spread. Malignant tumors can grow rapidly, invade and destroy nearby normal tissues, and spread throughout the body.

Cancer is malignant because it can be "locally invasive" and "metastatic":

- Locally invasive cancer—The tumor can invade the tissues surrounding it by sending out "fingers" of cancerous cells into the normal tissue.
- Metastatic cancer—The tumor can send cells into other tissues in the body, which may be distant from the original tumor.

Diagnostic procedures for cancer may include imaging, laboratory tests (including tests for tumor markers), tumor biopsy, endoscopic examination, surgery, or genetic testing.

APPLICATION OF IMAGING TECHNIQUES ON PROSTATE CANCER .

Prostate cancer is one of the most common types of cancer in men. Usually prostate cancer grows slowly and is initially confined to the prostate gland, where it may not cause serious harm. However, while some types of prostate cancer grow slowly and may need minimal or even no treatment, other types are aggressive and can spread quickly.

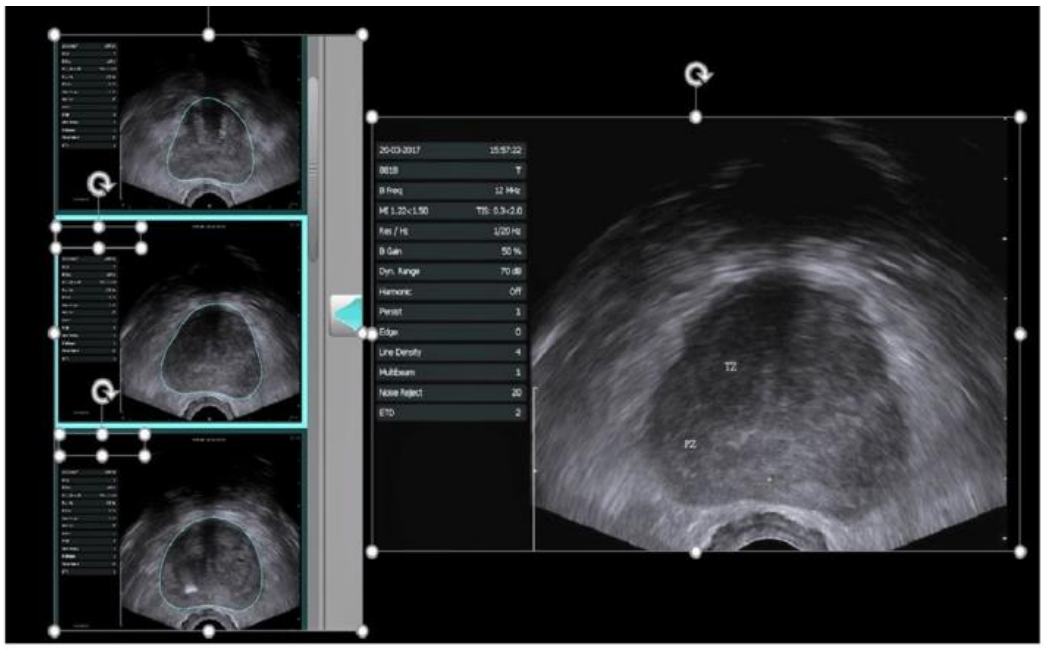
Prostate cancer that's detected early — when it's still confined to the prostate gland — has a better chance of successful treatment.

There are many types of images used to detect and diagnose prostate cancer, the most common imaging techniques are discussed below:

Transrectal Ultrasound (TRUS):

This technique uses a small probe inserted into the rectum to send sound waves into the prostate.

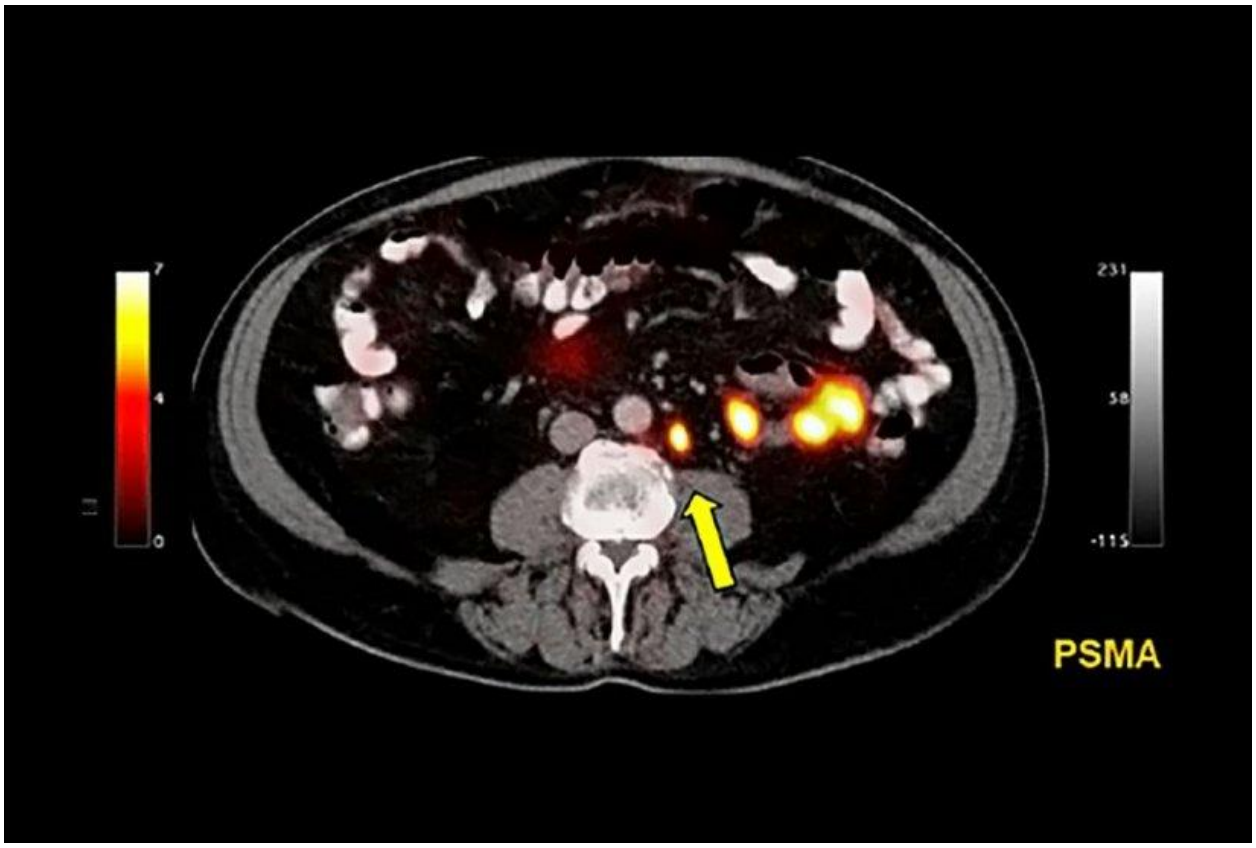
The echo of the sound waves off the prostate is transformed into an image by a computer. TRUS is often used to measure the size of the prostate and as a guide for biopsy and some treatments.



Source: Research Gate

Computed Tomography (CT) scan:

CT scans use x-rays to create a detailed, 3D cross-sectional image of the inside of the body. CT scans may be used to pinpoint the location of a tumor within the prostate, evaluate the extent of cancer, and assess whether the disease is responding to treatment. In some cases, CT technology is used to accurately guide cancer treatment during a procedure.

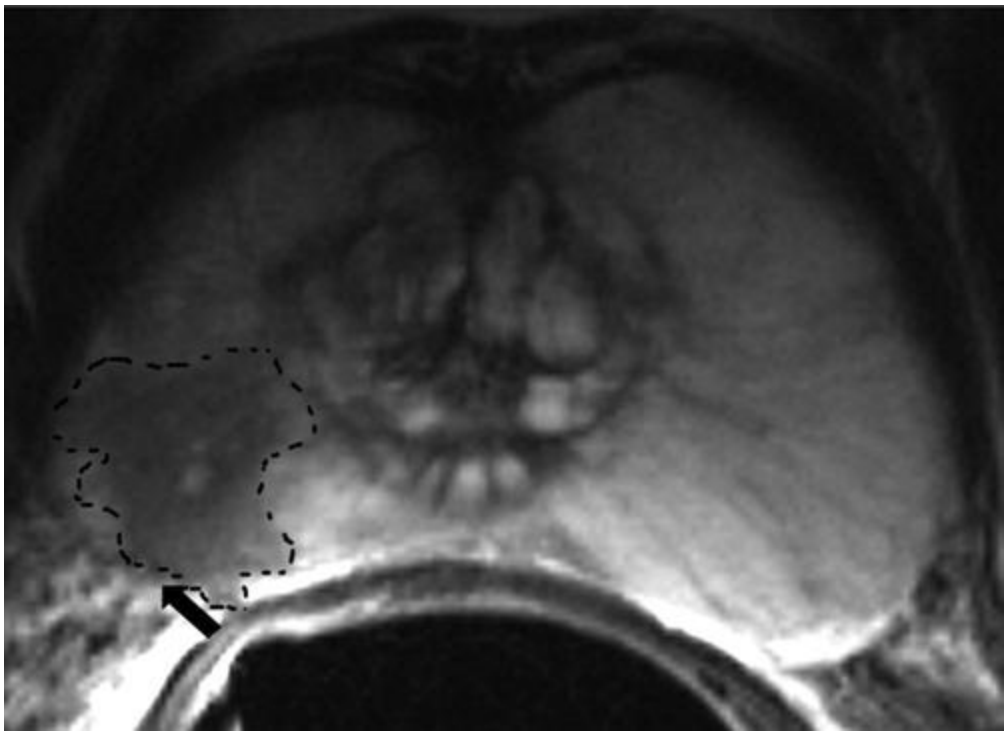


This prostate-specific membrane antigen (PSMA) scan shows a recurrence of prostate cancer. The yellow arrow points to an area with an overexpression of the antigens.

Source: University of California, Los Angeles (UCLA), Health Sciences

Magnetic Resonance Imaging (MRI):

MRI uses a magnetic field and radio waves to create a clear picture of the prostate. MRI can be used to locate diseased tissue within the body and to precisely pinpoint cancerous cells. MRI can also be used to see if cancer has spread outside the prostate to nearby tissues. MRI images help physicians to plan treatments such as surgery or radiation therapy.



Axial T2-weighted turbo spin-echo MR images (repetition time msec/echo time msec, 4260/99; flip angle 120°) of prostate cancer. Source:pubs.rsna.org

Positron Emission Tomography (PET) imaging:

PET imaging uses a small amount of radioactive material, called a radiotracer, and a special camera to see inside the prostate. The specially designed radiotracer is injected into the patient and taken up by prostate cells, the radiotracer emits a small amount of energy which can be picked up by the PET scanner and is used to create a detailed image. This type of imaging can also identify abnormal functions in prostate cells that indicate cancer. PET Scans are usually done in combination with a CT or MRI scan.

APPLICATION OF IMAGING TECHINIQUES ON BREAST CANCER

Introduction

Breast cancer is the most commonly diagnosed cancer and the second leading cause of cancer death among women . The only way today to find out for sure if a breast lump or abnormal tissue is cancer, is by having a biopsy: A suspicious tissue is removed by a surgical excision or needle biopsy and is examined under a microscope by a pathologist who makes the diagnosis. Imaging

techniques of the breast are therefore vital since they will allow early detection of cancer, and localization of the suspicious lesion in the breast for a biopsy procedure.

One of the techniques utilised in the management of cancer in all stages is multiple biomedical imaging. Imaging as an important part of cancer clinical protocols can provide a variety of information about morphology, structure, metabolism and functions. Application of imaging technics together with other investigative apparatus including in fluids analysis and vitro tissue would help clinical decision-making. Mixed imaging techniques can provide supplementary information used to improve staging and therapy planning. Imaging aimed to find minimally invasive therapy to make better results and reduce side effects. Probably, the most important factor in reducing mortality of certain cancers is an early diagnosis of cancer via screening based on imaging. The most common cancer in women is breast cancer. It is considered as the second major cause of cancer deaths in females, and therefore it remained as an important medical and socio-economic issue. Medical imaging has always formed part of breast cancer care and has used in all phases of cancer management from detection and staging to therapy monitoring and post-therapeutic follow-up. An essential action to be performed in the preoperative staging of breast cancer based on breast imaging.

The general term of breast imaging refers to

1. breast sonography or Ultrasonography

2. Mammography

3. Magnetic Resonance Imaging (MRI) of the breast /(magnetic resonance mammography)

MAMMOGRAPHIC SCREENING

In mammographic screening, smallimpalpable lesions are identified and assessed. The use of image-guided biopsy optimizes preoperative diagnosis in these women. Confirmed screen-detected cancers are frequently impalpable and may require preoperative marking by the radiologist (wire localization) to enable the surgeon to identify the lesion in the operating theatre.

The established technique for breast imaging, both screening and diagnostic, is film-screen mammography. Using film-screen mammography it is possible to detect about 85% of breast cancers and find these at an early enough stage to reduce mortality by approximately 50%. Mammography is the most commonly used imaging technique today throughout the world. When a patient undergoes a mammography a beam of X-rays traverses the breast and creates a projected image on a film.

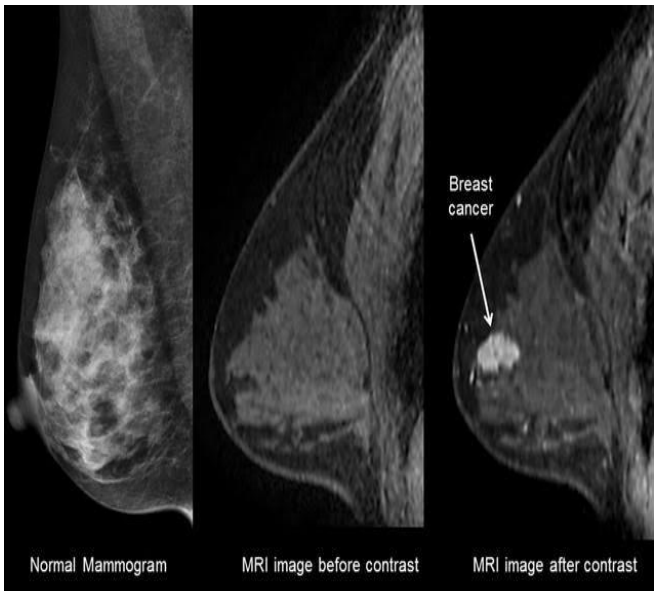
Sentinel node surgery in the axilla is enhanced by the use of scintimammography allowing identification of the first lymph nodes draining the breast hence minimizing subsequent surgical morbidity.

Ref: Google

MAGNETIC RESONANCE IMAGING

a) Breast cancer diagnosis with High Field MRI (1.5T)

Magnetic resonance imaging uses radio waves and magnetic fields to diagnose diseases. Patients are asked to lie on a table during the test, which takes about 30 minutes. They are then



advanced into the MRI machine, which contains a very strong magnetic field. The method consists of injecting a contrast-enhancing dye-like material into the patient's bloodstream and using magnetic resonance imaging to monitor the way in which this material is taken up and cleared out by the tumor tissue.

The ability to identify a mass in the breast requires that the mass has a different appearance (or a different contrast) from normal tissue. With MRI, the contrast between soft tissues in the breast is 10 to 100 times greater than that obtained with x-rays (several studies have indicated that MRI can detect cancers that are not seen on mammography). The main disadvantage of breast MRI is its cost, which is about 5 times that of X-ray mammography. t tool for problem solving, in evaluating patients with a high risk of breast cancer due to family history etc, where mammography may be inadequate and also in certain scenarios such as those patients with lobular cancers, as it is more able to accurately size the lesion and inform surgical planning.

b) MR guided biopsy with open systems (mid-field)

Open configuration MR imaging systems consists of a low-field (0.5T) superconducting magnet of an open configuration that allows access to the interventional field. The system was built with the major goal of guiding therapies: imaging may be performed during the procedure, in nearly real-time. This means that the radiologist can select the image plane during the procedure, before and during needle advancement. Those systems are still in the experimental stage, are very expensive, and very few are actually in use throughout the world

ULTRASONOGRAPHY

a) High frequency Sonography

Sonography has the ability to demonstrate margins and internal texture, often more fully than mammography. Most importantly, this makes it possible to diagnose simple cysts within the breast. In many patients sonography also makes it possible to increase or decrease suspicion that a lesion is malignant and to more accurately map the extent of tumor within the breast than is possible with mammography.

b) Vascular imaging: Doppler, power Doppler, color Doppler

Carcinomas of the breast show remarkable changes of vascularity, which are essential for their enhanced metabolism. Doppler imaging allows investigating normal and pathological vascularisation in the breast. The technique is non-invasive, fast and easy. color is used to encode blood velocity or volume.

c) Contrast Imaging

Ultrasound contrast imaging is a recent technique in which a “contrast agent” consisting in gas microbubbles is injected intravenously. The microbubbles act as echo-enhancers which cause the received signal to be longer and greater in the cancers than in the benign lesions. The cancers also display characteristic vascular morphologic features, with more additional vessels visualized in relation to the lesion. Contrast imaging can be effectively used with vascular imaging. The signal-to-noise ratio is markedly improved, and diagnostic confidence is increased. Ultrasound imaging using microbubble contrast agents will definitely open up new opportunities.

d) Sonoelasticity

It is the use of ultrasonography to visualize in real time the hardness or stiffness of tissues and organs by depicting the tissue’s motion in response to an applied vibration source. As a result, hard or dense tumors that are undetectable by conventional ultrasonography often can be visualized in sonoelasticity imaging by virtue of their altered vibration response.

e) Guided biopsy

Using real-time imaging like a motion picture, the ultrasound-guided system allows for definitive diagnosis of breast tissue. This technique can be used along with mammography.

Ultrasonography showing breast cancer

RADIONUCLIDE IMAGING

a) PET Imaging (Positron Emission Tomography)
With PET, patients are injected with a glucose that has been labeled with a radioactive tracer. Cells that are undergoing more metabolic activity, such as sites of infection and cancer, will take up more glucose. Positron radioactivity emitted by the radiolabeled glucose is recorded by a PET camera, processed and reconstructed by computer so that the areas of greatest metabolic activity light up on a computergenerated image, which is much like a conventional CT scan. Due to its high cost and the limited availability of the traced isotope, widespread use of PET scanning is unlikely. PET imaging also allows doctors to predict within about a week of starting hormone therapy if women will likely respond (doctors would normally wait several months for signs of tumor shrinkage). In some countries a PET scan is required to determine whether a cancer has spread before a patient undergoes surgery.

b) Sestamibi imaging: The most frequently reported tracer applied to breast imaging has been Tc-99m-sestamibi. They are radioactive isotopes, often attached to biologically active molecules, and are usually injected into patients. These radiopharmaceuticals are designed to target the specific part of the body to by studied. A gamma camera is used to transform the radiopharmaceutical emissions into useful diagnostic images that illustrate both function and anatomy. Sestamibi scanning of the breast has only been shown to be effective in relatively large breast cancers, and its role in the diagnostic armamentarium of breast imagers remains unestablished.

OPTICAL DIFFUSION IMAGING
Imaging with light in the Near Infrared (NIR) has gained increasing interest the last few years due to the very attractive potential of probing tissue oxygenation and metabolism, non-invasively, employing relatively low cost instrumentation and using non-ionizing radiation. Tissue has a low absorbing window in the NIR that allows light penetration of several

centimeters employing laser power. The information obtained depends on the attenuation characteristics of breast tissues at visible and near-infrared wavelengths and can be used to determine tissue malignancy

Lung cancer simply put occurs when abnormal cells grow out of control in the lung. These cells can create tumours with neighbouring cells and can affect any part of the respiratory system as well as spread to other parts of the body. When the cell starts proliferating, it's just a single act of rebellion.

Imaging Techniques that can be used to diagnose lung cancer include:

1. **Conventional chest radiography**
   Chest radiography is the most commonly performed diagnostic imaging test for the diagnosis of many pulmonary diseases throughout the world. Simplicity, low cost, low radiation, large amounts of information and wide availability are many advantages of this technique . The most satisfactory routine radiographic views are the postero–anterior (PA) and lateral projections with the patient standing up. Lordotic projections, with the X-ray beam in a cephaled angle of 15°, can be used for an improved visibility of the lung apices, superior mediastinum and thoracic inlet . Oblique studies are sometimes useful in locating a pleural or chest wall disease process.Many advances in conventional thoracic imaging are made, thanks to several technical innovations in the fields of digital detection and post-processing. The most remarkable is the rapid conversion from film-based to digital radiographic (DR) systems . Advantages of DR systems are the high image quality and the potential for dose reduction together with a favourable cost–benefit ratio and an increased efficiency . Post-processing techniques in digital radiography are temporal subtraction and dual-energy subtraction. To increase the accuracy of detection of lung nodules, nowadays, temporal subtraction can be used. Temporal subtraction is based on a subtraction of two postero-anterior chest radiographs taken at two different points in time [1]. These images can show subtle parenchymal changes that can be overlooked due to overlying and distracting anatomical structures. Dual-energy subtraction uses the different absorption characteristics of calcified and non-calcified structures as a function of exposure voltage. These images, obtained with high- and low-energy X-rays have been shown to also improve the detection of pulmonary nodules and may improve lung cancer screening using conventional X-rays .

   Chest radiography was the first imaging technique for lung cancer screening. Large randomised trials were performed in the USA and in Europe to investigate the role of chest radiography in lung cancer screening. These studies found a higher incidence of resectable diseases in the screened population, but none of them showed a lung cancer mortality reduction. Since these disappointing results, lung cancer screening with chest radiography has been abandoned.

Chest radiography can be used for characterisation of lung lesions as benign or malignant. The speed of growth of a lesion over time indicates the cell replication rate within the lesion and gives information about its benign or malignant character. Tumour doubling time is an independent and significant prognostic factor for lung cancer patients.

2. COMPUTERISED TOMOGRAPHY SCAN

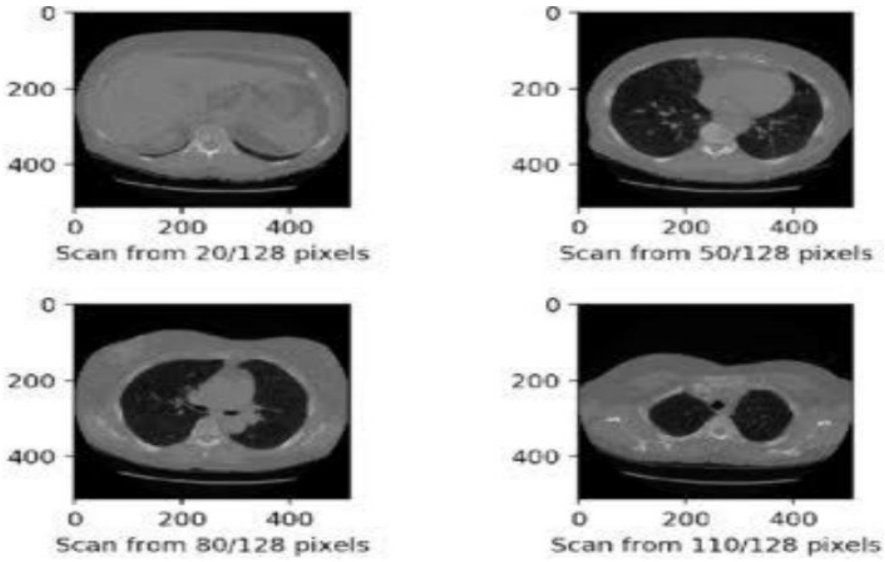
The CT scan as it is infamously called reveals the anatomy of the lungs and surrounding tissues which can be used to diagnose and monitor tumour growth. A CT scan takes a cross sectional detailed image of the lung. It detects small lesions and helps to distinguish it from benign lesions. CT scans have been tested and proven to able to detect lung cancer at a relatively early stage. Usually, symptoms of lung cancer do not appear until the disease is at an already advanced stage. People can be rather unlucky and develop lung cancer due to other reasons but it doesn't go unsaid that smokers are the main target of lung cancer and the saying "smokers are liable to die young" have never been more true.

ADVANTAGES

1. Most systems in the body can be scanned in a CT scan
2. It is relatively quicker than the MRI imaging technique
3. It provides a better detail

LIMITATIONS

1. Artefacts are common
   Involved in the use of high doses of radiation
2. Requires breath holding which some patients can't manage
3. Not useful for people who quit smoking about 15years ago.



POSITRON EMISSION IMAGING TECHNIQUE

For lung PET scan, you're injected intravenously with a small amount of glucose that contains a radioactive tracer substance about an hour before the scan. Most often, an isotope of the element fluorine is used. The needle may sting temporarily, but otherwise the procedure is painless.

Once in the bloodstream, the tracer substance accumulates in your organs and tissues and begins to give off energy in the form of gamma rays. The PET scanner detects these rays and creates detailed images from them. The images can help your doctor examine the structure and functioning of the specific organ or area being examined. During the exam, you need to be lying down on a narrow table. This table slides inside a tunnel-shaped scanner. You're able to talk to technicians while the scan takes place, but it's important to lie still while the scan runs. Too much movement could result in blurry images.The scan takes about 20 to 30 minutes.

STAGING

A lung PET scan is also used to stage lung cancer. Tissues with a higher metabolic rate (higher energy usage), such as lung cancer tumors, absorb more of the tracer substance than other tissues. These areas stand out on the PET scan. Your doctor can use the three-dimensional images to detect growing cancer tumors.

Solid cancer tumors are assigned a stage between 0 and 4. Staging refers to how advanced a particular cancer is. For instance, stage 4 cancer is more advanced, has spread farther, and is usually more difficult to treat than stage 0 or 1 cancer.

Staging is also used to predict outlook. For example, a person who receives therapy when diagnosed at stage 0 or 1 lung cancer is more likely to live longer than someone with stage 4 cancer.

Advantages

Increased patient comfort

A PET/CT scan is noninvasive, painless and takes about 30 minutes. Along with providing better imaging data, it notably increases patient comfort and convenience by reducing the number of scanning sessions a patient must undergo. The procedure is covered by private insurance and Medicare.

Better data, better treatment plans

Clinical research has shown that in comparison to a PET scan alone, PET/CT technology provides new information that can alter a patient's treatment plan to better target the cancer in approximately one-third of the cases.

The Pros and Cons of PET/CT Scans

A PET/CT scan combines two different types of imaging scans during a single procedure with one machine. This technologically advanced screening combines two distinctive technologies to reveal critical information about the function and form of cells and organs inside the body.

Positron emission tomography(PET)is a nuclear imaging technique that uses radioactive tracers that are ingested or injected and then absorbed by body tissue. A scan will show areas of greater absorption (where more chemical activity is occurring in the body), which may indicate disease. PET scans can provide details about how well blood or oxygen travels throughout the body, how well sugar is processed, and more. A PET scan may reveal cancerous tissue not revealed by a CAT scan.

Computed tomography (CT)utilizes X-rays taken from different angles and then processed by a computer to create a 3D, cross-sectional image of the body. CT scans produce more accurate and

precise images than X-rays. These scans can reveal the size, shape and location of a tumor, as well as the blood vessels feeding it.

The combined PET/CT scan provides information from a single imaging session about the cells, structures, and functioning of body tissues and organs, providing a more robust diagnosis than either scan can produce independently.

There are more advantages to having a PET/CT scan than there are disadvantages. What follows are some of the pros and cons of having this combined imaging procedure.

Advantages of PET/CT Scans

Double the Diagnostic Clarity.Clearly, the fact that a PET scan and CT scan show different things, that when combined patients reap twice the diagnostic benefits. Alone, a PET scan will show areas of increased activity within the body – while a CT scan alone produces detailed images of tissues and organs inside the body. Together, the scans allow your doctor to see exactly where the issues are, and what may be contributing to it. It can help differentiate between a cancerous and noncancerous mass in the body.

It is a relatively painless procedure that measures both anatomy and metabolic function within the patient's body as images are captured in a single scan.

The actual scan only takes about a half an hour to complete.

Easy, Nondisruptive.Aside from the initial injection of the radioactive material, the exam is noninvasive and requires no recovery or downtime afterward. Patients may immediately assume normal activities after a PET/CT scan.

Disadvantages of PET/CT Scans

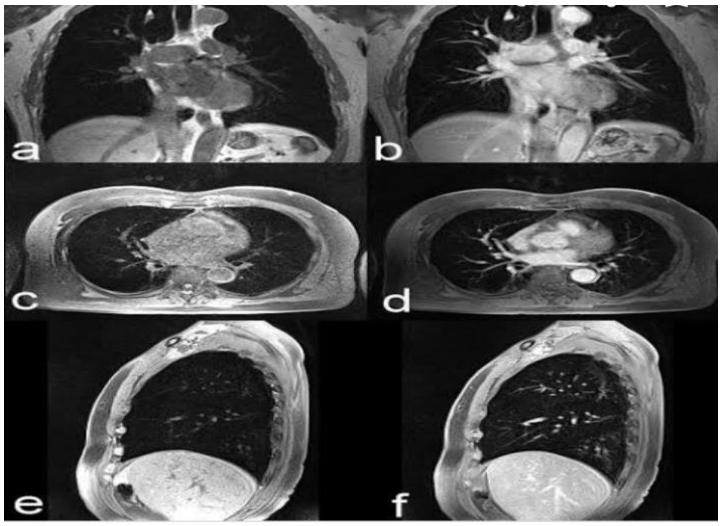
Pregnant women should not undergo PET/CT scans because the radioactive tracers used may be dangerous to the baby. While the amount of radiation received is negligible and isn't any more dangerous to patients than the exposure they'd receive from a low dose X-ray, pregnant women should avoid any exposure to radiation while pregnant or breastfeeding.

Diabetics may undergo a PET/CT scan, but with certain precautions. Because the radioactive material is combined with glucose and then injected into the patient, this can be a concern for some diabetic patients. Before having a PET/CT scan, a diabetic patient's blood sugar level will

be evaluated, and a glucose serum blood test might be administered. This can significantly increase the time required to complete the testing.

3. MAGNETIC RESONANCE IMAGING

Magnetic resonance imaging (MRI) scan. An MRI also produces images that allow doctors to see the location of a lung tumor and/or lung cancer metastases and measure the tumor's size. An MRI uses magnetic fields, not x-rays, to produce detailed images of the body. A special dye called a contrast medium is given before the scan to create a clearer picture. This dye can be injected into a patient's vein or given as a pill or liquid to swallow. MRI scanning does not work well to take pictures of parts of the body that are moving, like your lungs, which move with each breath you take. For that reason, MRI is rarely used to look at the lungs. However, it may be helpful to find lung cancer that has spread to the brain or bones.



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