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A comparative study of medical imaging modalities

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Abstract

Medical imaging is a technique and process that creates a visual representation of the body and the visual presentation of certain organs and tissue functions for clinical analysis and medical intervention. We consider detecting different physical signals from the patient's body and converting them into medical images. In fact, these signals come from a certain process. Transmission of radiography through the body in X-ray projection and fluoroscopy, mammography, and computed tomography. Ultrasound is reflected in the body to be used for ultrasound. The precession of a spin system in a large magnetic field and its application in magnetic resonance imaging[1]. These radiographic imaging methods in this article are x-ray radiography, mammography, fluoroscopy, computed tomography, magnetic resonance imaging, and ultrasound imaging. Medical imaging technology is creating an internal visual representation of the body. This is a non-invasive method of observation without opening the body by surgery[1, 2]. It is used for the clinical analysis and the diagnosis and auxiliary treatment of different medical conditions. Medical imaging technology has also established normal anatomical and physiological databases, making it possible to identify abnormalities. There are many diagnostic imaging technologies, and they also have risks and benefits. In this article, the application of electromagnetic waves and radio frequency waves in different modalities such as general X-ray photography, fluoroscopy, mammography, computed tomography (CT), magnetic resonance imaging (MRI) and ultrasound will be our investigation. Provide utility and challenge. The opinion of. This article presents a comparative study between the different medical imaging modes and their technologies. The conceptual advantages, risks and applications of this technology will be presented with the details of the modes. As of 2010, up to 5 billion medical studies have been conducted worldwide.

This article presents comparative studies between different medical imaging modalities, and presents the concepts, risks, benefits, and the applications of these technologies in detail. Relevant technologies are: Radiography, Mammography, Fluoroscopy, Computed Tomography, Magnetic Resonance Imaging, and Ultrasound. Comparisons between these techniques in terms of image quality (spatial resolution and contrast), safety (effects of ionizing radiation and heating effects of radiation on the body), and System availability (real time and cost information) was presented. Discussions suggest that none of these techniques can be trusted exclusively in medical applications.

Keywords: medical imaging modalities, visual representation, X-ray

Introduction

Medical imaging is a technique and process that creates a visual representation of the body and the visual presentation of certain organs and tissue functions for clinical analysis and medical intervention. We consider detecting different physical signals from the patient's body and converting them into medical images. In fact, these signals come from a certain process. Transmission of radiography through the body in X-ray projection and fluoroscopy, mammography, and computed tomography. Ultrasound is reflected in the body to be used for ultrasound. The precession of a spin system in a large magnetic field and its application in magnetic resonance imaging [1]. These radiographic imaging methods in this article are x-ray radiography, mammography, fluoroscopy, computed tomography, magnetic resonance imaging, and ultrasound imaging. Medical imaging technology is creating an internal visual representation of the body. This is a non-invasive method of observation without opening the body by surgery [1, 2]. It is used for the clinical analysis and the diagnosis and auxiliary treatment of different medical conditions. Medical imaging technology has also established normal anatomical and physiological databases, making it possible to identify abnormalities. There are many diagnostic imaging technologies, and they also have risks and benefits. In this article, the application of electromagnetic waves and radio frequency waves in different modalities such as general X-ray photography, fluoroscopy, mammography, computed tomography (CT), magnetic resonance imaging (MRI) and ultrasound will be our investigation. Provide utility and challenge. The opinion of. This article presents a comparative study between the different medical imaging modes and their technologies. The conceptual advantages, risks and applications of this technology will be presented with the details of the modes. As of 2010, up to 5 billion medical studies have been conducted worldwide.

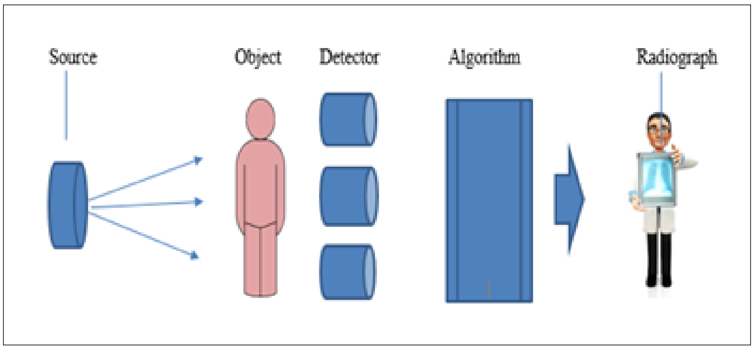


Fig 1: Basic concept of image production

Radiography

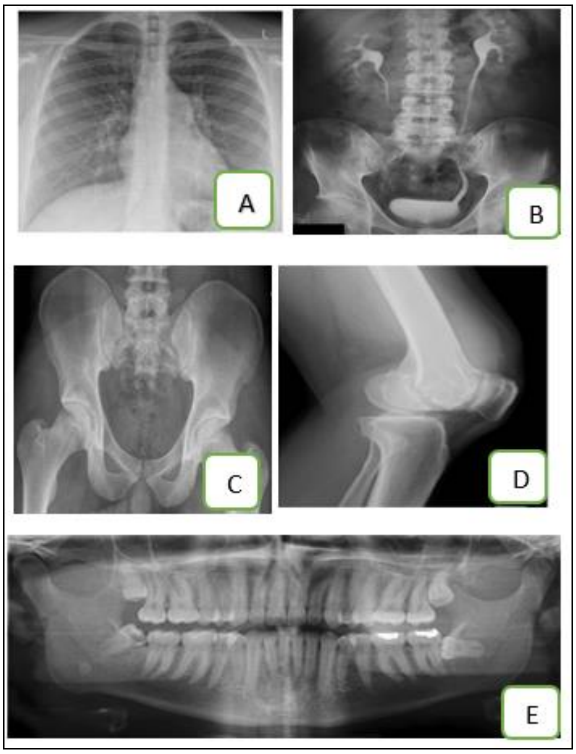
Radiography was the main clinical imaging strategy and made it conceivable when the physicist sir Wilhelm Roentgen found radiographs on November 8, 1895. Roentgen also produced the first radiographic image of human anatomy. Radiology (also called radiology) defined the field of radiology and gave birth to radiologists, doctors who specialize in interpreting medical images. Radiography is done using an X-ray source on one side of the patient and an X-ray detector (usually flat) on the other side. The X-ray tube emits short-duration X-ray pulses (usually less than 1/2 second). Most of the X-rays interact with the patient, and some of the X-rays pass through the patient and reach the patient's detector, where an X-ray image is formed. The uniform distribution of the radiographs entering the patient is modified by the degree to which the radiographs are removed from the beam (i.e., attenuation) by scattering and absorption within the tissue. The attenuation characteristics of tissues such as bone, soft tissue and air in the patient's body are very different, resulting in uneven distribution of radiographs sent by the patient. A radiographic image is an image of such X-beam appropriation, and the finder utilized in radiography might be a visual film (for instance, screen film radiography) or an electronic indicator framework (that is, computerized radiography). The transmission picture alludes to a picture wherein the energy source is on one side of the body, the energy goes through the body, and is identified on the opposite side of the body [2, 3]. Radiography is a strategy for communicating pictures. Imaging alludes to the circumstance where each point in the picture compares to data along a straight line way through the patient. Radiography is likewise an imaging technique. Radiographic pictures can be utilized for a wide scope of clinical signs, including the analysis of breaks, cellular breakdown in the lungs, and cardiovascular infection [3]

Benefits of X-ray radiography

- Non-invasive, quick and painless.
- Support medical and surgical treatment plans.
- Instruct medical personnel to insert catheters or stents into the body to treat tumors or remove blood clots.

Risks of X-ray photography

- Exposure to ionizing radiation, which increases the likelihood of cancer in adulthood.
- Tissue effects, such as cataracts, skin redness, and hair loss, can occur under relatively high levels of radiation exposure.
- Medical applications of X-ray photography
- X-ray photography is used for many types of examinations, e.g. chiropractic, dentistry.
- Fluoroscopy X-rays used to show the movement of organs (such as the stomach, intestines, and colon) in the body can also be used to examine the blood vessels in the heart and brain.



X-Ray radiography Examples
A-Chest Radiograph
B-Intravenous Pyelography (IVP)
C-Radiograph of Pevis
D- Radiograph of knee
E- Dental Radiograph

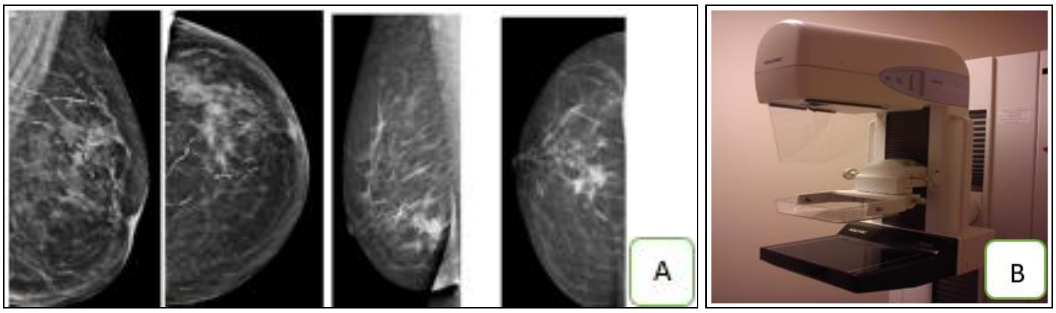
Fig 2

Mammography

A mammogram is an X-ray of the breast, so it is a transmission imaging. Compared with any other radiography applications, mammography uses much lower X-ray energy, so modern mammography uses X-ray machines and detector systems specifically designed for breast imaging. Mammograms are used to detect breast cancer in asymptomatic women (screening mammograms) and to help diagnose women with breast symptoms (such as the presence of lumps) (diagnostic mammograms) [3, 4]. Mammography is a specialized X-ray imaging technique that can be used to detect breast abnormalities, such as lumps and calcifications. The mammogram in the image above shows the presumed mass (arrow), which, in addition to normal blood vessels and anatomical structure, also has the typical appearance of breast cancerous lesions. Special mammography equipment using low X-ray energy, Kedge filter, compression, screen/film detector, anti-scatter grid, and automatic exposure control can generate high-quality, low-dose, and X-ray optimized breast images as details. X-ray mammography is currently the preferred method for screening and early detection of breast cancer because of its high sensitivity, excellent benefit/risk ratio and low cost.

Advantages

- Breast cancer detection every 2 years for 20 years:
- Reduce the risk of dying from breast cancer
- Among 1000 women who have a mammogram every 2 years for 20 years, 7 cases can be avoided Death
- Chemotherapy is needed to reduce the risk of breast cancer
- Screening tests can usually detect cancer in the early stages of cancer development. Then it can be treated without chemotherapy.
- Let women understand the health of their breasts
- If their mammograms and additional exams do not detect cancer, the vast majority of women (almost 98%) will not develop breast cancer.
- Screening for breast cancer every 2 years for 20 years may result in: Restriction
- Screening for breast cancer every 2 years for 20 years does not guarantee:
- All breast cancers will be detected
- 1000 mammograms of the women, 77 are diagnosed with breast cancer every 2 years in 20 years. 21 of them will be diagnosed with cancer, even if the mammogram results are normal. This may happen:
- Cancer is not visible on mammogram



Examples
A- Mammographs
B-Mammographys Machine

Fig 3

Fluoroscopy

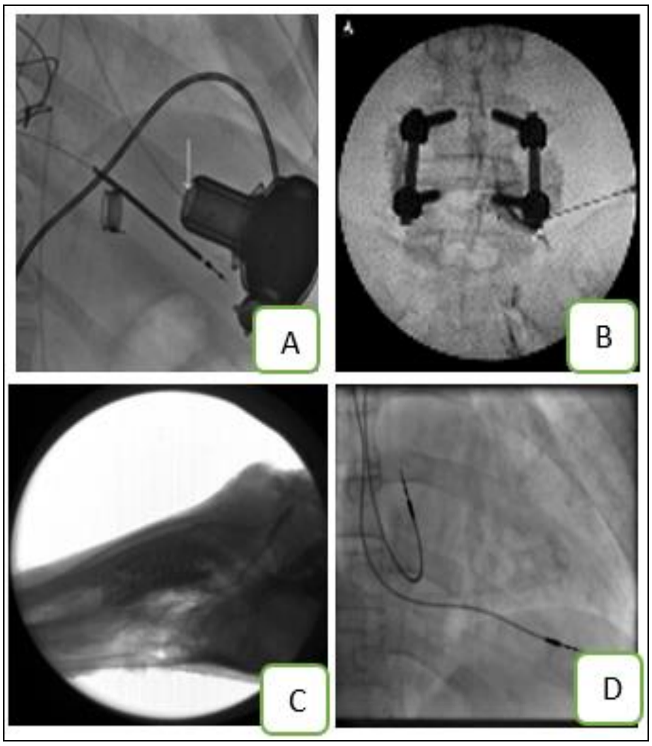
Fluoroscopy alludes to the persistent obtaining of a progression of X-beam images over time, which is basically a continuous X-film of the patient. Viewpoint is a strategy for communicating pictures by projection, basically constant radiography3. The fluoroscopy system utilizes a X-beam finder system fit for producing pictures in a fast time series. Fluoroscopy is utilized for setting catheters in vessels, seeing difference specialists in the gastrointestinal (GI) plot, and for other clinical applications, for example, intrusive treatment methods that require ongoing picture criticism. Fluoroscopy is likewise used to make X-beam movies of physical developments, like the physical developments of the heart or esophagus.

Advantages

- Foreign body location
- Blood flow study
- Injection of anesthetic into the spine or joint
- Orthopedics and urology
- Catheter insertion
- Enema
- Pacemaker implanted.

Risk: The amount of radiation exposure depends on the size of the patient and the duration of the operation. Some possible adverse reactions include:

- Radiation "burns" of skin tissue
- Radiation-induced cancer in old age
- If the patient is pregnant, radiation-induced birth defects.



Examples
A-Stenting
B-Implantation
C-Orthopedic surgical view
D-Angiography

Fig 4

Computed Tomography

Computed tomography started to be utilized in centers in the mid-1970s and was the primary clinical imaging strategy acknowledged by PCs. The CT image is created by pivoting the X-beam tube around the body with the goal that X-beams go through the body at various points. At least one direct identifier clusters confronting the X-beam source to gather transmission projection information. The various information focuses gathered in this manner are combined by a PC into a tomographic image of the patient. The term tomography alludes to a picture (realistic) of a cut (tomo). CT is a transmission innovation that can create image of different squares of tissue in the patient's body. Contrasted and projected pictures, the upside of tomographic image is that they can show the physical construction on the tissue slice (cut) without the upper or lower structure. CT essentially decreased the requirement for exploratory medical procedure, consequently changing clinical practice4. Present day CT scanners can gain 5mm thick tomographic pictures (for example 60 pictures) across a 30cm length of a patient in 10 seconds and uncover the presence of malignant growth, cracked circle, subdural hematoma, aneurysm and a large group of different pathologies.

Advantages of computed tomography

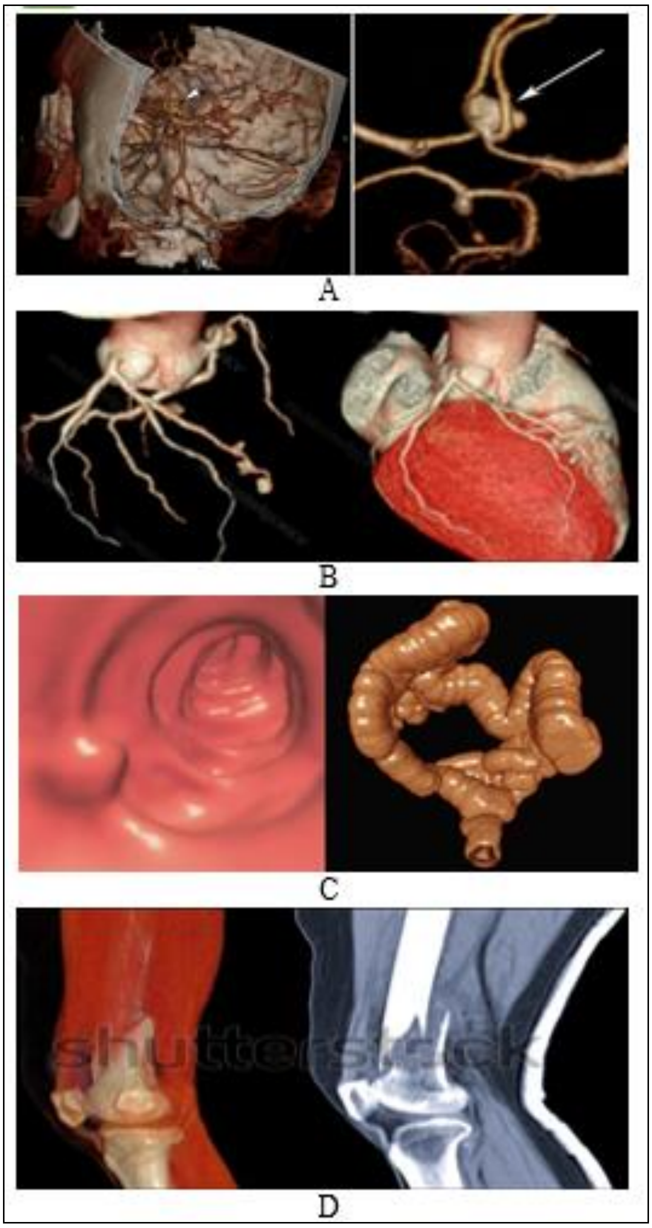
- The procedure is simple and painless.
- The difference lies in the slight difference in physical density.
- Prevent invasive insertion of arterial catheters and guide wires.
- Non-invasive and fast.
- Excellent spatial resolution.
- Global vision of veins.

The risks of computed tomography

- In the case of low soft tissue contrast, the contrast resolution is low.
- Due to some experimental and epidemiological evidence, low-dose radiation exposure is associated with solid organ cancer and leukemia [10].
- It is generally believed that high-dose ionizing radiation increases the likelihood that a person will continue to develop cancer during their lifetime, but the relationship between low-dose radiation (the order used in standard diagnostic tests) and tumorigenesis does not is clear.
- The link between radiation and subsequent tumor formation is based primarily on extrapolated data from studies of survivors of the atomic bomb dropped by Japan in 1945 [11] and a relatively increased risk assessment of tumors in occupationally exposed individuals. Environments. Radiation in the nuclear industry [12].
- Brenner et al. used this extrapolation method, assuming that the small assumed risk is multiplied by a large number of patients, thus it is estimated that 1% and 2% of all cancers in the United States in the future will be secondary. To the effects of ionizing radiation through medical imaging, and a similar study conducted by Berrington de González et al. [13] in 2009 it predicted that 29,000 cancers and 14,500 deaths can be added each year.

Medical Applications of Computed Tomography

- Computed tomography is used primarily for the diagnosis of trauma patients, abnormalities and diseases.
- Examine many parts of the human body, such as the brain, sinuses, facial bones, dentistry, spine, cervical spine, hands, wrists, elbows, shoulders, hips, knees, the ankles, feet, and kidney tracts.
- CT colonography
- High resolution computed tomography (HRCT), recently used in cases of Covid19.
- CT lung biopsy
- CT pulmonary angiography
- Routine CT staging (portal phage), triple phage CT features, CT cholangiography.
- CT urography
- Computed tomography of the heart



Examples
A- CT Brain Angiography
B- Cardiac CT
C-Virtual Colonoscopy
D-3D of CT Knee

Fig 5

Magnetic Resonance Imaging

The strength of the magnetic field used by MRI scanners is approximately 10,000 to 60,000 times the strength of the earth's magnetic field[17]. Most MRIs use the nuclear magnetic resonance properties of protons, the hydrogen nucleus, which is very abundant in biological tissues (about 1018 protons per cubic millimeter of tissue). Protons have a magnetic moment. When placed in a 1.5 tesla (T) magnetic field, protons preferentially absorb energy from radio waves with a resonance frequency of 63 megahertz (MHz). 18. In magnetic resonance imaging, the patient is placed in a magnetic field and the antenna generates radio pulses wave. ("Coil") is located around the patient. The patient's protons absorb radio waves and then re-emit radio wave energy after a period of time, depending on the local magnetic properties of the surrounding tissues. Radio waves emitted by protons in the patient's body are detected by antennas around the patient. By slightly changing the magnetic field strength as a function of the patient's body position (using magnetic field gradients), the proton's resonant frequency will change as a function of position, because the frequency is proportional to the magnetic field strength. Field, magnetic. The MRI system uses the frequency (and phase) of the returned radio waves to determine the location of each patient's signal. The operating mode of an MRI system is commonly referred to as spin echo imaging. Magnetic resonance imaging generates a set of tomographic slices through the patient, where each point of the image depends on the micro-magnetic properties of the corresponding tissue at that point. Because different types of tissues, such as fat, white and gray matter, cerebrospinal fluid, and cancer in the brain, have different local magnetic properties, MRIs are highly sensitive to changes in anatomical structures [18, 19]. So the contrast is very high. MRI scanners can also detect the presence of movement, which is very useful for monitoring blood flow through the arteries (magnetic resonance angiography) [20, 21].

MRI Benefits

- Non-ionizing radiation
- Better soft tissue resolution
- Painless and non-invasive
- High spatial resolution
- Manipulator independent
- Easy to blind and can use advanced technology to measure flow and velocity
- MRI does not requires contrast agent Can perform
- Open MRI and
- Silent MRI have recently appeared on the market

MRI Risks

- Long scanning time and post-processing
- Expensive surgery
- No real-time images
- Some patients feel claustrophobic during the operation
- Children who cannot stand still may need sedation
- These include strong magnetic fields, radio frequency energy, time/ Variations, magnetic gradient fields, cryogenic liquids, restricted imaging equipment, and noisy operations.
- Patients with implants, prostheses, aneurysm clips, pacemakers, heart valves, etc.

MRI Applications

- Brain and spinal cord abnormalities
- Cysts, tumors and other abnormalities in different parts of the body
- Heart MRI
- Breast cancer screening for women at high risk of cancer
- Joint abnormalities and lesions, such as back and knee
- Magnetic resonance Spectrum
- Diagnosis of diseases of the liver and other abdominal organs
- MRI angiography
- Assessment of pelvic pain in women with infertility, fibroids, and endometriosis
- Virtual colonoscopy with MRI

Examples
A- MR Spectroscopy
B- MR Angiography
C- Cardiac MRI
D- MRI Brain
E- MRI C-Spine
F- MRI Abdomen
G- MRI Hip
H- MRI Cholangiography

Fig 6

Ultrasound Imaging

When a paperweight falls on the floor, the affect causes pressure waves (called sound) to travel through the air, so that they can be heard from a distance. Mechanical energy in the form of high frequency ("ultra") sound can be used to generate images [22] of the patient's anatomy. The ultrasound transducer is in direct physical contact with the tissue being photographed, producing short-term sound pulses. Sound waves enter the tissues and are reflected by the internal structure of the body, producing echoes. The reflected sound wave then reaches the transducer, which records the returning sound beam. This mode of operation of ultrasound equipment is called pulse echo imaging. The sound beam is scanned within a certain angle range (fan-shaped), and the echo of each line is recorded and used to calculate the ultrasound image in the form of fan-shaped (fan-shaped scan). Ultrasound is strongly reflected at interfaces, such as the surface and internal structure of abdominal organs. Since ultrasound is less harmful to a growing fetus than ionizing radiation, ultrasound imaging is preferred for obstetric patients. The interface between the tissue and the air has a strong echo, so very little sound can enter the air-filled cavity from the tissue. Therefore, ultrasound is not very useful in the chest because the air in the lungs has a wall that the sound beam cannot penetrate. Similarly, the interface between tissue and bone has a strong echo, so, for example, brain imaging is impractical in most cases[23]. The ultrasound image is a grayscale image of the tissue boundary echoes of high-frequency sound waves (usually 2 to 20 MHz) pulses encoded in a two-dimensional tomographic image. A phase ray sensor operating at 3.5 MHz produces this normal value[24].

Benefits of Ultrasound

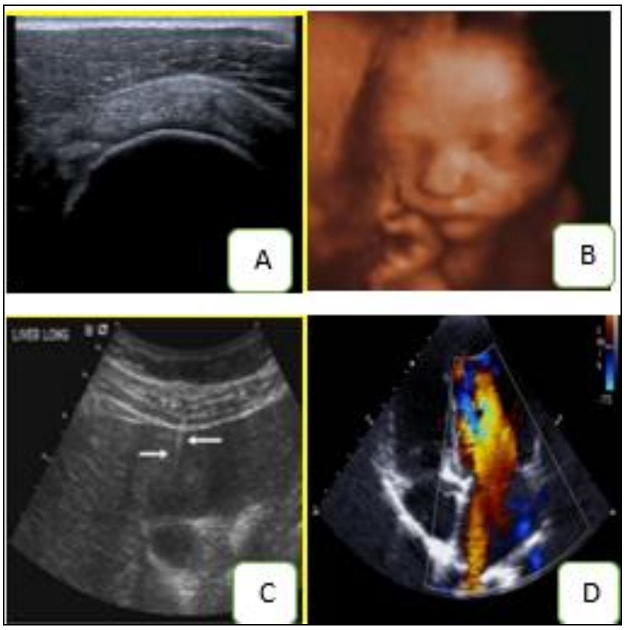
- It is a painless and non-invasive procedure
- No ionizing radiation
- Real-time imaging technology
- High resolution images
- Used to detect abnormalities in and out of light
- Provides information on flow velocity
- Breathing imaginable control stage[24, 25]

Risks of Ultrasound

- Tissue heating
- Acoustic cavitation
- Gaseous effects hazards
- Potential for pressure injury
- No specific guidance
- Operator-related procedures
- Slow
- Blind testing is challenging
- Cannot perform a global view of the veins.
- Affected by hydration status.

Medical Application of ultrasound

- This image is a 2D representation of a slice entering the body A 3D image can be generated by acquiring a series of adjacent 2D images
- Generally a dedicated probe is used that mechanically scans traditional 2D image transducers
- However , due to mechanical scanning speed Slow and difficult to make 3D images of moving tissues Recently, 2D phase array transducers have been developed that can scan 3D beams
- These can image faster and can even be used for make 3D images of living tissues. The Beating Heart
- Recent advances have been made in 4D fetal ultrasound.
- Check the development of the fetus during pregnancy
- Image most of the structures of the head and neck, including the thyroid and parathyroid glands, lymph nodes and salivary glands
- Image solid organs in the abdomen, for example; pancreas, aorta, inferior vena cava, liver, gallbladder, bile duct, kidney and spleen
- Instruct injection needles when placing local anesthetics near nerves
- Echocardiogram
- to diagnose cardiac, ventricular and valve function
- Biopsy ultrasound-guided
- Musculoskeletal ultrasound



Examples:-
A-Musculoskeletal
B-3D Fetus
C-Ultrasound guided liver biopsy
D-Color Doppler

Fig 7

Comparison Between The Medical Imaging Techniques

Medical applications can be compared in three concepts; the first concept is image quality, which can be expressed in terms of spatial resolution and better contrast. The spatial resolution of refers to the spatial extent of small objects in the image. Noise refers to the accuracy with which the signal is received. Contrast refers to the difference between the area of interest in the light and Dark image at points and the surrounding background. The second concept is the usable system, which can be represented by the system cost and the availability of real-time information. The third concept is safety, which can be expressed by the effect of ionizing radiation on the patient and the effect of heating on the body.

Table 1: A Comparison between the medical imaging modalities

Imaging Modalities	Image Quality	System Availability	Safety
X-ray Radiography	1mm special resolution and soft and fluid contrast good	It's don't give real time information and Cost is medium	Heating effect low but have ionizing radiation
Mammography	1mm Special resolution and soft tissue contrast good	It's don't give real time information and Cost is medium	Heating effect low but have ionizing radiation
Fluoroscopy	1 mm special resolution and soft and hard contrast good	It's don't give real time information and Cost is medium	Heating effect low but have ionizing radiation
Computed Tomography	0.5 mm special resolution soft and hard tissue very good contrast, soft tissue contrast good	It's don't give real time information and Cost is high	Heating effect low but have ionizing radiation
Magnetic Resonance Imaging	0.5 mm special resolution and soft tissue contrast very good and hard tissue contrast good	It's don't give real time information and Cost is high	Heating effect medium and have non ionizing radiation
Ultrasound Imaging	1mm special resolution and fluid and soft tissue contrast good	Low cost and provide real time information	Heating effect low and rare but don't have ionizing radiation

Conclusion
This article presents comparative studies between different medical imaging modalities, and presents the concepts, risks, benefits, and the applications of these technologies in detail. Relevant technologies are: Radiography, Mammography, Fluoroscopy, Computed Tomography, Magnetic Resonance Imaging, and Ultrasound. Comparisons between these techniques in terms of image quality (spatial resolution and contrast), safety (effects of ionizing radiation and heating effects of radiation on the body), and System availability (real time and cost information) was presented. Discussions suggest that none of these techniques can be trusted exclusively in medical applications

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Ethical Approval
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