Definition of Innovation

Innovation is the process of making changes to something established by introducing something new that adds value to customers and contributes to the knowledge store of the organization

Innovation = Invention + Exploitation

Innovation = Creativity + Exploitation

Drivers of Innovation

Emerging technologies Competitor actions New ideas from customers, strategic partners, and employees Emerging changes in the external environment

Medical imaging is the technique and process of creating visual representations of the interior of a body for clinical analysis and medical intervention, as well as visual representation of the function of some organs or tissues (physiology). Medical imaging seeks to reveal internal structures hidden by the skin and bones, as well as to diagnose and treat disease. Medical imaging also establishes a database of normal anatomy and physiology to make it possible to identify abnormalities.

it is part of biological imaging and incorporates radiology, which uses the imaging technologies of X-ray radiography, magnetic resonance imaging, ultrasound, endoscopy, elastography, tactile imaging, thermography, medical photography, and nuclear medicine functional imaging techniques as positron emission tomography (PET) and single-photon emission computed tomography (SPECT).

Types

Radiography

Magnetic resonance imaging

Nuclear medicine

Ultrasound

Elastography

Photoacoustic imaging

Tomography

Echocardiography

Functional near-infrared spectroscopy

Magnetic Particle Imaging

Radiography

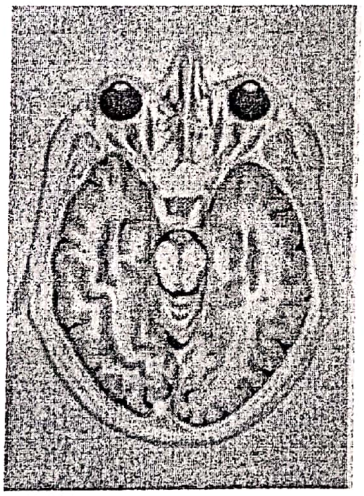
Main article: Radiography

Two forms of radiographic images are in use in medical imaging. Projection radiography and fluoroscopy, with the latter being useful for catheter guidance. These 2D techniques are still in wide use despite the advance of 3D tomography due to the low cost, high resolution, and depending on the application, lower radiation dosages with 2D technique. This imaging modality utilizes a wide beam of x rays for image acquisition and is the first imaging technique available in modern medicine.

- *Fluoroscopy* produces real-time images of internal structures of the body in a similar fashion to radiography, but employs a constant input of x-rays, at a lower dose rate. Contrast media, such as barium, iodine, and air are used to visualize internal organs as they work. Fluoroscopy is also used in image-guided procedures when constant feedback during a procedure is required. An image receptor is required to convert the radiation into an image after it has passed through the area of interest. Early on this was a fluorescing screen, which gave way to an Image Amplifier (IA) which was a large vacuum tube that had the receiving end coated with cesium iodide, and a mirror at the opposite end. Eventually the mirror was replaced with a TV camera.
- *Projectional radiographs*, more commonly known as x-rays, are often used to determine the type and extent of a fracture as well as for detecting pathological changes in the lungs. With the use of radio-opaque contrast media, such as barium, they can also be used to visualize the structure of the stomach and intestines – this can help diagnose ulcers or certain types of colon cancer.

Magnetic resonance imaging

Main article: Magnetic resonance imaging



A brain MRI representation

A magnetic resonance imaging instrument (MRI scanner), or "nuclear magnetic resonance (NMR) imaging" scanner as it was originally known, uses powerful magnets to polarize and excite hydrogen nuclei (i.e., single protons) of water molecules in human tissue, producing a detectable signal which is spatially encoded, resulting in images of the body.[5] The MRI machine emits a radio frequency (RF) pulse at the resonant frequency of the hydrogen atoms on water molecules. Radio frequency antennas ("RF coils") send the pulse to the area of the body to be examined. The RF pulse is absorbed by protons, causing their direction with respect to the primary magnetic field to change. When the RF pulse is turned off, the protons "relax" back to alignment with the primary magnet and emit radio-waves in the process. This radio-frequency emission from the hydrogen-atoms on water is what is detected and reconstructed into an image. The resonant frequency of a spinning magnetic dipole (of which protons are one example) is called the Larmor frequency and is determined by the strength of the main magnetic field and the chemical environment of the nuclei of interest. MRI uses three electromagnetic fields: a very strong (typically 1.5 to 3 teslas) static magnetic field to polarize the hydrogen nuclei, called the primary field; gradient fields that can be modified to vary in space and time (on the order of 1 kHz) for spatial encoding, often simply called gradients; and a spatially homogeneous radio-frequency (RF) field for manipulation of the hydrogen nuclei to produce measurable signals, collected through an RF antenna.

Like CT, MRI traditionally creates a two-dimensional image of a thin "slice" of the body and is therefore considered a tomographic imaging technique. Modern MRI instruments are capable of producing images in the form of 3D blocks, which may be considered a generalization of the single-slice, tomographic, concept. Unlike CT, MRI does not involve the use of ionizing radiation and is therefore not associated with the same health hazards. For example, because MRI has only been in use since the early 1980s, there are no known long-term effects of exposure to strong static fields (this is the subject of some debate; see 'Safety' in MRI) and therefore there is no limit to the number of scans to which an individual can be subjected, in contrast with X-ray and CT. However, there are well-identified health risks associated with tissue heating from exposure to the RF field and the presence of implanted devices in the body, such as pacemakers. These risks are strictly controlled as part of the design of the instrument and the scanning protocols used.

Because CT and MRI are sensitive to different tissue properties, the appearances of the images obtained with the two techniques differ markedly. In CT, X-rays must be blocked by some form of dense tissue to create an image, so the image quality when looking at soft tissues will be poor. In MRI, while any nucleus with a net nuclear spin can be used, the proton of the hydrogen atom remains the most widely used, especially in the clinical setting, because it is so ubiquitous and returns a large signal. This nucleus, present in water molecules, allows the excellent soft-tissue contrast achievable with MRI.

A number of different pulse sequences can be used for specific MRI diagnostic imaging (multiparametric MRI or mpMRI). It is possible to differentiate tissue characteristics by combining two or more of the following imaging sequences, depending on the information being sought: T1-weighted (T1-MRI), T2-weighted (T2-MRI), diffusion weighted imaging (DWI-MRI), dynamic contrast enhancement (DCE-MRI), and spectroscopy (MRI-S). For example, imaging of prostate tumors is better accomplished using T2-MRI and DWI-MRI than T2-weighted imaging alone.[6] The number of applications of mpMRI for detecting disease in various organs continues to expand, including liver studies, breast tumors, pancreatic tumors, and assessing the effects of vascular disruption agents on cancer tumors.[7][8][9]

Nuclear medicine

Main article: Nuclear medicine

Nuclear medicine encompasses both diagnostic imaging and treatment of disease, and may also be referred to as molecular medicine or molecular imaging and therapeutics.[10] Nuclear medicine uses certain properties of isotopes and the energetic particles emitted from radioactive material to diagnose or treat various pathology. Different from the typical concept of anatomic radiology, nuclear medicine enables assessment of physiology. This function-based approach to medical evaluation has useful applications in most subspecialties, notably oncology, neurology, and cardiology. *Gamma cameras* and *PET scanners* are used in e.g. scintigraphy, SPECT and PET to detect regions of biologic activity that may be associated with a disease. Relatively short-lived isotope, such as ^{99m}Tc is administered to the patient. Isotopes are often preferentially absorbed by biologically active tissue in the body, and can be used to identify tumors or fracture points in bone. Images are acquired after collimated photons are detected by a crystal that gives off a light signal, which is in turn amplified and converted into count data.

- *Scintigraphy* ("scint") is a form of diagnostic test wherein radioisotopes are taken internally, for example intravenously or orally. Then, gamma cameras capture and form two-dimensional[11] images from the radiation emitted by the radiopharmaceuticals.
- *SPECT* is a 3D tomographic technique that uses gamma camera data from many projections and can be reconstructed in different planes. A dual detector head gamma camera combined with a CT scanner, which provides localization of functional SPECT data, is termed a SPECT-CT camera, and has shown utility in advancing the field of molecular imaging. In most other medical imaging modalities, energy is passed through the body and the reaction or result is read by detectors. In SPECT imaging, the patient is injected

with a radioisotope, most commonly Thallium 201TI, Technetium 99mTC, Iodine 123I, and Gallium 67Ga.[12] The radioactive gamma rays are emitted through the body as the natural decaying process of these isotopes takes place. The emissions of the gamma rays are captured by detectors that surround the body. This essentially means that the human is now the source of the radioactivity, rather than the medical imaging devices such as X-ray or CT.

- *Positron emission tomography* (PET) uses coincidence detection to image functional processes. Short-lived positron emitting isotope, such as ^{18}F, is incorporated with an organic substance such as glucose, creating F18-fluorodeoxyglucose, which can be used as a marker of metabolic utilization. Images of activity distribution throughout the body can show rapidly growing tissue, like tumor, metastasis, or infection. PET images can be viewed in comparison to computed tomography scans to determine an anatomic correlate. Modern scanners may integrate PET, allowing PET-CT, or PET-MRI to optimize the image reconstruction involved with positron imaging. This is performed on the same equipment without physically moving the patient off of the gantry. The resultant hybrid of functional and anatomic imaging information is a useful tool in non-invasive diagnosis and patient management.

Fiduciary markers are used in a wide range of medical imaging applications. Images of the same subject produced with two different imaging systems may be correlated (called image registration) by placing a fiduciary marker in the area imaged by both systems. In this case, a marker which is visible in the images produced by both imaging modalities must be used. By this method, functional information from SPECT or positron emission tomography can be related to anatomical information provided by magnetic resonance imaging (MRI).[13] Similarly, fiducial points established during MRI can be correlated with brain images generated by magnetoencephalography to localize the source of brain activity.

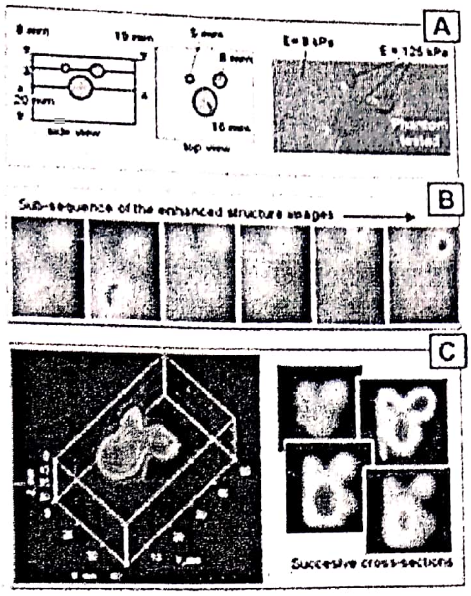
Ultrasound

Ultrasound representation of Urinary bladder (black butterfly-like shape) and hyperplastic prostate

Medical ultrasound uses high frequency broadband sound waves in the megahertz range that are reflected by tissue to varying degrees to produce (up to 3D) images. This is commonly associated with imaging the fetus in pregnant women. Uses of ultrasound are much broader, however. Other important uses include imaging the abdominal organs, heart, breast, muscles, tendons, arteries and veins. While it may provide less anatomical detail than techniques such as CT or MRI, it has several advantages which make it ideal in numerous situations, in particular that it studies the function of moving structures in real-time, emits no ionizing radiation, and contains speckle that can be used in elastography. Ultrasound is also used as a popular research tool for capturing raw data, that can be made available through an ultrasound research interface, for the purpose of tissue characterization and implementation of new image processing techniques. The concepts of ultrasound differ from other medical imaging modalities in the fact that it is operated by the transmission and receipt of sound waves. The high frequency sound waves are sent into the tissue and depending on the composition of the different tissues; the signal will be attenuated and returned at separate intervals. A path of reflected sound waves in a multilayered structure can be defined by an input acoustic impedance (ultrasound sound wave) and the Reflection and transmission coefficients of the relative structures.[12] It is very safe to use and does not appear to cause any adverse effects. It is also relatively inexpensive and quick to perform. Ultrasound scanners can be taken to critically ill patients in intensive care units, avoiding the danger caused while moving the patient to the radiology department. The real-time moving image obtained can be used to guide drainage and biopsy procedures. Doppler capabilities on modern scanners allow the blood flow in arteries and veins to be assessed.

Elastography

Main article: Elastography



3D tactile image (C) is composed from 2D pressure maps (B) recorded in the process of tissue phantom examination (A).

Elastography is a relatively new imaging modality that maps the elastic properties of soft tissue. This modality emerged in the last two decades. Elastography is useful in medical diagnoses, as elasticity can discern healthy from unhealthy tissue for specific organs/growths. For example, cancerous tumours will often be harder than the surrounding tissue, and diseased livers are stiffer than healthy ones.[14][15][16][17] There are several elastographic techniques based on the use of ultrasound, magnetic resonance imaging and tactile imaging. The wide clinical use of ultrasound elastography is a result of the implementation of technology in clinical ultrasound machines. Main branches of ultrasound elastography include Quasistatic Elastography/Strain Imaging, Shear Wave Elasticity Imaging (SWEI), Acoustic Radiation Force Impulse imaging (ARFI), Supersonic Shear Imaging (SSI), and Transient Elastography.[15] In the last decade a steady increase of activities in the field of elastography is observed demonstrating successful application of the technology in various areas of medical diagnostics and treatment monitoring.

Photoacoustic imaging[edit]

Main article: Photoacoustic imaging in biomedicine

Photoacoustic imaging is a recently developed hybrid biomedical imaging modality based on the photoacoustic effect. It combines the advantages of optical absorption contrast with an ultrasonic spatial resolution for deep imaging in (optical) diffusive or quasi-diffusive regime. Recent studies have shown that photoacoustic imaging can be used in vivo for tumor angiogenesis monitoring, blood oxygenation mapping, functional brain imaging, and skin melanoma detection, etc.

Tomography

Basic principle of tomography: superposition free tomographic cross sections S_1 and S_2 compared with the (not tomographic) projected image P

Tomography is the imaging by sections or sectioning. The main such methods in medical imaging are:

- X-ray computed tomography (CT), or Computed Axial Tomography (CAT) scan, is a helical tomography technique (latest generation), which traditionally produces a 2D image of the structures in a thin section of the body. In CT, a beam of X-rays spins around an object being examined and is picked up by sensitive radiation detectors after having penetrated the object from multiple angles. A computer then analyses the information received from the scanner's detectors and constructs a detailed image of the object and its contents using the mathematical principles laid out in the Radon transform. It has a greater ionizing radiation dose burden than projection radiography; repeated scans must be limited to avoid health effects. CT is based on the same principles as X-Ray projections but in this case, the patient is enclosed in a surrounding ring of detectors assigned with 500–1000 scintillation detectors[12] (fourth-generation X-Ray CT scanner geometry). Previously in older generation scanners, the X-Ray beam was paired by a translating source and detector. Computed tomography has almost completely replaced focal plane tomography in X-ray tomography imaging.

- Positron emission tomography (PET) also used in conjunction with computed tomography, PET-CT, and magnetic resonance imaging PET-MRI.
- Magnetic resonance imaging (MRI) commonly produces tomographic images of cross-sections of the body. (See separate MRI section in this article.)

Echocardiography

Main article: Echocardiography

When ultrasound is used to image the heart it is referred to as an echocardiogram. Echocardiography allows detailed structures of the heart, including chamber size, heart function, the valves of the heart, as well as the pericardium (the sac around the heart) to be seen. Echocardiography uses 2D, 3D, and Doppler imaging to create pictures of the heart and visualize the blood flowing through each of the four heart valves. Echocardiography is widely used in an array of patients ranging from those experiencing symptoms, such as shortness of breath or chest pain, to those undergoing cancer treatments. Transthoracic ultrasound has been proven to be safe for patients of all ages, from infants to the elderly, without risk of harmful side effects or radiation, differentiating it from other imaging modalities. Echocardiography is one of the most commonly used imaging modalities in the world due to its portability and use in a variety of applications. In emergency situations, echocardiography is quick, easily accessible, and able to be performed at the bedside, making it the modality of choice for many physicians.

Functional near-infrared spectroscopy[

Main article: Functional near-infrared spectroscopy

FNIR Is a relatively new non-invasive imaging technique. NIRS (near infrared spectroscopy) is used for the purpose of functional neuroimaging and has been widely accepted as a brain imaging technique.[18]

Magnetic Particle Imaging[

Main article: Magnetic particle imaging

Using superparamagnetic iron oxide nanoparticles, magnetic particle imaging (MPI) is a developing diagnostic imaging technique used for tracking superparamagnetic iron oxide nanoparticles. The primary advantage is the high sensitivity and specificity, along with the lack of signal decrease with tissue depth. MPI has been used in medical research to image cardiovascular performance, neuroperfusion, and cell tracking