Application And Comparison of Different Medical Imaging Techniques

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Abstract. The health issues have emerged as a vital social problem hitherto, and there are many approaches to test and check the illness. The process of visualization represents the composition and operation of the various human tissues and organs for clinical purposes. In addition, scientific research into the normal and abnormal architecture and physiology of the body is known as medical imaging. Medical imaging methods are used to identify anomalies, cure illnesses, and reveal underlying structures hidden behind the skin and bones. This paper presents a comparison of different techniques in terms of principles, advantages, disadvantages, and applications, ranging from X-ray computed tomography to magnetic resonance imaging. A comparison of these methods will be shown, considering the following factors. One is the system availability, such as the cost and real-time information. The other is the safety, revealing the impact of radiation on the body and ionizing radiation effect. Moreover, it also includes image quality such as contrast and spatial resolution.

Keywords: Medical Imaging; Computed tomography; Magnetic resonance imaging.

1. Introduction

The need to increase human capacities has played a major role in the evolution of civilization. Visual perception is arguably the most significant sense of the world that humans possess [1]. Unfortunately, many natural and manufactured objects are opaque, which significantly limits human vision [2]. Medical imaging provides a method to achieve “an inner vision” and plays a vital role in the diagnosis of diseases. With X-ray, computed tomography (CT), magnetic resonance imaging (MRI), and other imaging techniques, doctors can clearly observe the condition of the organs and tissues in the patient's body, carrying out early diagnosis and localization of the disease [3]. Patients have obviously benefited from the advancements in medical imaging over the past 20 years, living longer and better lives. New technology and applications that are evident in this growth include high-tech services like positron emission tomography (PET), MRI, and multi-section CT [4]. For example, CT can accurately diagnose fractures, cerebral hemorrhage and other conditions, and MRI technology is better for soft tissue injury, tumor, and other diseases. In addition, with the continuous innovation of medical imaging technology, PET-CT and other molecular imaging technology are also gradually applied in clinical diagnosis, providing new means for early detection and diagnosis of diseases. Therefore, the importance of medical imaging in disease diagnosis is noteworthy. Therefore, the application of medical imaging in disease diagnosis has been continuously improved and expanded, providing clinicians with more reliable and efficient diagnostic methods.

The MITs view laboratory testing (blood and specimen tests) as one of the most popular forms of medical testing. The last ten years have seen a revolution in medical imaging thanks to the quick development of more precise, less intrusive, and fast-developing equipment [5]. The Fig. 1 illustrates the core idea of medical imaging techniques. It consists of an energy sensor or source that can enter the human body. As energy moves through the body, signals are created, and depending on the density and atomic number of the various tissues, they are either absorbed or attenuated to varied degrees. These signals are detected by specialized detectors connected to the energy source, and an image is produced by manipulating the signals analytically. Images are obtained by means of the energy contained in human tissue, which results in a categorization determined by the energy administered to the body [6].

Depending on the energy source, several different techniques can be used to obtain information about what is going on inside the patient's body. These technologies are based on signals that pass directly through the patient. These signals interact with the patient's tissue. By detecting signals from the patient's body. The aim of this paper is to compare of different techniques by outlining their principles, advantages, disadvantages, and applications, including X-ray CT and MRI.

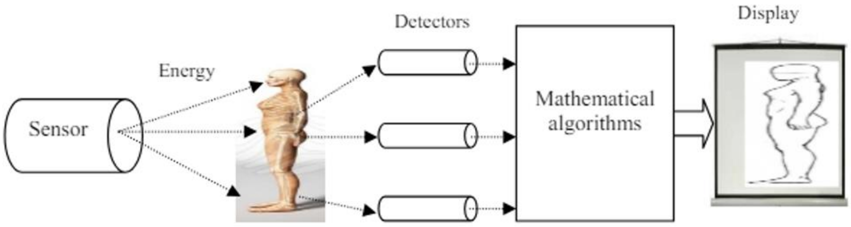

Fig. 1 Concept of a medical imaging system [6].

2. Magnetic Resonance Imaging

MRI is a non-invasive method of mapping the internal structure and certain aspects of function within the body. It appears to have no exposure-related hazards and employs nonionizing electromagnetic radiation. It uses highly calibrated magnetic fields in conjunction with radio frequency radiation to create high-quality cross-sectional pictures of the body in any plane [7].

2.1. Basic Principle

Two particles compose an atom's nucleus. One is the protons which have a positive charge, and the other is neutrons which have a neutral charge. Furthermore, the atom contains electrons. The electrons, which have a negative charge, orbit the nucleus. Elements are often categorized using two attributes. For starters, the atomic number, which represents the quantity of protons in the nucleus, is the fundamental indicator used to differentiate between different atoms. For example, the atomic mass number, which is the total number of protons and neutrons. Atoms with the same atomic number but distinct atomic weights are called isotopes. Nuclear spin is atomic nuclei's third characteristic. These particles are all moving. Protons and neutrons both rotate around their axis [8].

The principle of nuclear magnetic resonance is the signal generated by the hydrogen atom in the magnetic field, which is processed by a computer reconstruction imaging method. The hydrogen atom in the human body is high in content and widely distributed. One can regard it as a small magnet, and the spin axis distribution and arrangement of the small magnet are disorganized. Next, this little magnet will be arranged in the direction of the magnetic field, and then the author applies a radio frequency pulse that affects the magnetic field. Moreover, at the same time they absorb the released energy as a radio frequency signal. After the radio frequency signal is received, the data is reconstructed by the computer and then converted into an image, which is the MRI image people usually see.

The magnetic field of a proton tends to align with an applied magnetic field (B), just as the magnetic field of a gyroscope suspended from a vertical pivot in the earth's gravitational field. When the gyroscope is inclined away from vertical, precession happens. Similarly, the proton's spin gives it angular momentum that causes it to process at a frequency v when it is tipped out of alignment with the Bo field. A group of spins process in synchrony when exposed to a uniform magnetic field, which forms a bulk magnetization represented by a vector that processes at the same frequency [9].

2.2. Advantages and Disadvantages of MRI

The following are MRI's benefits. Soft tissue contrast is the first. The central nervous system, soft tissues, and organs can all be seen in detail with MRI technology. Compared to CT, it provides better contrast resolution, which makes it perfect for identifying anomalies in the muscles, internal organs, brain, and spinal cord. No ionizing radiation is the second. MRI does not use ionizing radiation like

CT does. Rather, it uses radio waves and magnetic fields to generate images, which makes it a safer choice for some patient groups, such youngsters, and pregnant people. Multiplanar imaging comes in third. With axial, sagittal, and coronal imaging possible with MRI, detailed anatomical information can be obtained from a variety of angles.

Additionally, there are certain drawbacks to MRI. Depending on the imaging technique and body area being studied, MRI scans can take anywhere from 15 minutes to over an hour to get, which is longer than CT scans on average. Prolonged scan times can be challenging for patients with claustrophobia or those who struggle to remain still. Secondly, it has metallic implant artifacts. MRI imaging can be significantly affected by metallic implants or objects within the body, leading to artifacts that may obscure or distort image quality. This limitation can restrict the use of MRI in patients with certain types of implants, such as pacemakers or metal prostheses. Thirdly, it has contrast agents. While MRI contrast agents (gadolinium-based) are generally considered safe for most patients, there have been concerns raised about the potential risks of gadolinium retention in the body, particularly in patients with impaired kidney function. This has led to increased scrutiny and more selective use of contrast-enhanced MRI studies.

2.3. Advances and Future Directions and Challenges

The latest developments in MRI technology have centered on improving image quality, reducing scanning times and expanding the capabilities of this imaging modality. One such breakthrough has been the introduction of ultra-high field MRI systems, which provide higher spatial resolution and greater sensitivity to detect fine anatomical detail. In addition, advances in parallel imaging and compressed sensing technology have enabled faster image acquisition, resulting in improved patient comfort and reduced motion artefacts. These technological innovations have paved the way for a wide range of clinical applications of MRI from neuroimaging to musculoskeletal imaging.

Although MRI technology has made significant advances in recent years, there are still several challenges that need to be addressed to further enhance its clinical applications. A key challenge is the development of advanced image reconstruction algorithms to improve image quality and reduce artefacts, especially in challenging imaging scenarios. Future research efforts should also focus on expanding the use of MRI in emerging areas such as interventional MRI, molecular imaging, and therapeutics to better meet the changing needs of patients and healthcare providers.

3. Computed Tomography

3.1. Principles of CT Imaging

To create precise cross-sectional images of the body, CT imaging utilizes mathematical reconstruction methods and the principles of X-ray attenuation. A doughnut-shaped gantry with an X-ray tube and detectors is passed through while the patient is positioned on a motorized table for a CT scan. A narrow beam of X-rays is released by the X-ray tube, and as it passes through the body, it is attenuated differently by various tissues. The intensity of the X-rays that are transmitted is measured by the detectors, producing raw data that is processed by a computer to create cross-sectional images.

A planar slice of the body is established using CT, and for X-rays, only directions contained within and parallel to the plane of the slice are allowed to pass through. Because the X-ray beam doesn't probe any part of the body outside of the slice, "depth scrambling" is avoided. The slice, which is frequently a few millimeters thick, appears in the CT image as though it has been physically removed from the body and radiographed using X-rays that are pointed perpendicular to the slice's plane. With a density (linear attenuation coefficient) discrimination of better than 1% and a spatial resolution of roughly 1 mm, the generated pictures depict the human anatomy in section [10].

3.2. Advantages and Disadvantages of CT

There are several advantages of CT. The first is the speed. CT scans can be completed in a matter of minutes, making them a reasonably speedy procedure. Because of this, CT imaging is especially helpful in situations where a prompt diagnosis is crucial, including in cases of trauma or possible internal bleeding. The second is bone imaging. CT imaging is excellent for visualizing bone structures and detecting fractures or bone abnormalities. Its ability to produce high-resolution images of bone anatomy makes it invaluable in orthopedic evaluations and trauma assessment. The third is metal artifact reduction. CT imaging is less susceptible to metal artifacts compared to MRI, making it a preferred modality for imaging patients with metallic implants or foreign bodies. The fourth is cost. CT scans are generally more cost-effective than MRI scans, making them a more accessible option for patients and healthcare providers.

However, disadvantages of CT also exist. On the one hand, it is ionizing radiation. CT scans expose patients to ionizing radiation, which can pose potential health risks, especially with repeated or high-dose exposures. This is a significant concern, particularly in pediatric populations and for individuals requiring frequent imaging studies. On the other hand, it is about soft tissue contrast. While CT imaging provides excellent visualization of bone structures, it is less effective in distinguishing soft tissues of similar densities. This limitation can sometimes result in reduced sensitivity for certain soft tissue abnormalities or lesions.

3.3. Advances and Future Directions and Challenges

CT technology's capabilities and therapeutic relevance have been substantially boosted by recent breakthroughs. In the first, dual-energy CT is discussed. It permits two distinct X-ray energy levels to be acquired simultaneously, improving tissue characterization, and enabling virtual non-contrast imaging. Spectral CT is the second one. It utilizes energy-sensitive detectors to acquire spectral information, facilitating material decomposition and differentiation of various tissue types. The last is about iterative reconstruction algorithms. It employs advanced mathematical techniques and iterative algorithms to reduce image noise and radiation dose, enhancing image quality while minimizing radiation exposure to patients.

4. Conclusion

To summarize, CT and MRI are two widely used diagnostic imaging techniques in modern medicine, each with its own set of advantages and limitations. Both CT and MRI imaging modalities offer unique advantages and are valuable tools in the diagnostic armamentarium of healthcare providers. Collaboration between radiologists, referring physicians, and patients is essential to ensure the appropriate selection of imaging studies tailored to individual patient needs and clinical circumstances. When choosing a suitable imaging modality, in addition to medical considerations, it is important to consider the patient's health status, possible history of allergies, and comfort with the imaging procedure. For some patients with metal implants or pacemakers, MRI may not be the best choice, as its sensitivity to metal can affect image quality. In summary, the decision to use CT or MRI depends on the circumstances, including the patient's condition, clinical needs, and requirements for imaging quality and safety. Collaboration between physicians and radiologists is essential in this process to ensure that the best imaging protocol is developed to provide accurate diagnostic and therapeutic recommendations for the patient.

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