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Advancements and Comparative Study of CT Scan and MRI Imaging Technique in Biomedical Instrumentation

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Abstract

This paper aims to provide an overview of comparative studies between CT and MRI scan techniques and to highlight the latest developments in these fields.

Recent developments in CT scan technology have reduced dangerous radiation to patients, enabled quicker scan speeds, and enhanced image quality.

A comparative study of CT (Computed Tomography) and MRI (Magnetic Resonance Imaging) involves analyzing various aspects of these imaging modalities, including their principles, clinical applications, advantages, and limitations.

Keywords: CT Scan, MRI,

Introduction

Since its development in the 1970s, CT scanning has been the primary instrument used by radiologists in their day-to-day clinical practice. CT scanner demand is expected to increase globally from 2019 to 2022 at a compound annual growth rate (CAGR) of 5.9%, reaching a value of 6429.8 million because to the increased need for minimally invasive operations and better developments in CT technology. Over the past few decades, CT has seen tremendous technological advancements that have improved cancer diagnosis, shortened hospital stays, and aided in surgical preparation. Recent developments in CT scan technology have resulted in lower radiation exposure for patients, faster scan times, and better image quality.

Recent advancements in CT Scan

- **Low-Dose CT Scanning Techniques**

1. Iterative Reconstruction Algorithms: With the substantial reduction of radiation dose made possible, image quality is improved. Techniques such as Adaptive Statistical Iterative Reconstruction (ASIR) and Model-Based Iterative Reconstruction (MBIR) are widely used.
2. Automatic Exposure Control (AEC): This technology adjusts the radiation dose based on the patient's size and the density of the tissues being scanned, optimizing image quality while minimizing exposure.

- **Dual-Energy CT (DECT)**

1. It combines two X-ray energy levels to discriminate and measure components such as calcium, iodine, and uric acid, allowing for more comprehensive tissue characterization.

2. Improved Imaging : DECT improves the detection of diseases such as gout, kidney stones, and pulmonary embolism by increasing contrast and minimizing artifacts.

- **Spectral CT Imaging**

1. Photon-Counting Detectors: These advanced detectors determine the energy of individual photons, resulting in higher image resolution and contrast. This method improves tissue differentiation and enables the detection of tiny lesions.
2. Multi-Spectral Imaging: Offers additional information about tissue composition, which is useful in oncology, cardiology, and other specialties.

- **AI and Machine Learning**

1. Automated Image Analysis: Artificial intelligence systems can automatically segment and analyze CT images, finding abnormalities and supporting radiologists in making faster and more accurate diagnoses.
2. Predictive Analytics: Machine learning models can forecast disease progression and therapy response using CT imaging data, adding to customized medicine.

- **Enhanced CT Angiography (CTA)**

1. Dynamic CTA: Provides a thorough picture of vascular health by capturing various stages of blood flow through the arteries. This is very helpful for planning interventions and identifying vascular disorders.
2. Low-Contrast CTA: Lower doses of contrast agents are used, which lowers risk and improves patient safety for individuals with renal impairment.

- **Cone-Beam CT (CBCT)**

1. Dental and Orthopedic Applications: CBCT produces high-resolution 3D pictures at lower radiation doses than traditional CT, making it excellent for dental implant planning and orthopedic examinations.
2. Guided Procedure: CBCT is utilized to provide real-time image guidance during surgical procedures, improving accuracy and results.

- **Advanced Motion Correction**

1. In order to minimize motion artifacts, respiratory gating synchronizes imaging with the patient's breathing cycle. This technique is especially helpful for thoracic and abdominal imaging.
2. Cardiac Motion Correction: Sophisticated algorithms and ECG-gated methods enhance heart image quality, allowing for more accurate evaluation of coronary arteries and cardiac function.

- **Portable and Point-of-Care CT**

1. Compact Designs: The creation of more compact, portable CT scanners that can be utilized in emergency situations or by the patient's bedside to enable prompt diagnosis and treatment.
2. Field Applications: Because portable CT offers vital imaging capabilities without requiring a large hospital setup, it is especially helpful in isolated locations or during emergencies.

- **Improved Contrast Agents**

1. Microbubble Contrast Agents: Improve vascular and tissue contrast in CT imaging, especially for cancer diagnosis and vascular imaging.
2. Non-Iodinated Contrast Agents: Lowers the risk of allergic reactions and nephrotoxicity, making CT imaging safer for more patients.

- **Image Fusion Technologies**

1. Hybrid Imaging: By combining CT with other imaging modalities such as PET (Positron Emission

Tomography), MRI, or SPECT (Single Photon Emission Computed Tomography), comprehensive diagnostic information is obtained by connecting anatomical and functional data.

2. Software Integration: Advanced algorithms combine images from many modalities to improve diagnostic accuracy and clinical decision-making.

Recent Advances in MRI Technology

The most recent developments in magnetic resonance imaging (MRI) technology have been on the software side, allowing for faster contrast scans, significantly simpler cardiac imaging procedures, and MR scans of the lung. In addition, a few new MRI scanners have joined the market within the last year.

- **Multi-Contrast MRI Images From a Single Acquisition**

The Food and Drug Administration (FDA) approved GE Healthcare's MAGiC (MAGnetic resonance image Compilation) software in September, making it the industry's first multi-contrast MRI technique that delivers eight contrasts in a single acquisition in a fraction of the time of conventional imaging. MAGiC is the outcome of a collaboration with SyntheticMR AB and provides clinicians with more information than traditional scanning. This technology allows users to edit MR images retrospectively, resulting in significant time savings, fewer rescans, and hence cost savings, which can help clinicians make more accurate diagnoses. It employs an acquisition approach that allows it to change image contrast after scanning is complete, which is not feasible with traditional MR.

According to GE, MAGiC increases the clinician's ability to use changes in image contrast to improve diagnosis and reduce rescan orders. Clinicians can generate various picture contrasts in a single MR scan, such as T1, T2, STIR, T1 FLAIR, T2 FLAIR, dual IR, phase sensitive IR, and proton density weighted imaging of the brain. To modify the contrast, users just move the pointer on the interface and adjust the parameters TR, TE, and TI. MAGiC allows for a single scan to perform several functions. MAGiC is available for the GE Optima MR450, Optima MR450w, Discovery MR750, Discovery MR750w, and Signa Pioneer MRI systems.

- **Lung MRI Now Possible**

Since the lungs are filled with air and the hydrogen atoms needed to make MR pictures have a low density, lung MRIs have proven difficult. Because of this, lung imaging has historically been done using computed tomography, or CT. Toshiba debuted their Ultrashort Echo Time (UTE) sequence for specialized lung MRI at RSNA 2015. UTE, which is available on the Vantage Titan 3.0T MR system, enables physicians to observe tissue with high susceptibility regions and very short relaxation durations, where signals often vanish too quickly for precise MR imaging.

- **Software Greatly Reduces MRI Scan Times**

In April, the FDA cleared two new Siemens MRI applications. The Simultaneous Multi-Slice application acquires MR images simultaneously rather than sequentially, which reduces 2-D acquisition times by up to a factor of 8. GOBrain is intended to significantly shorten the time necessary for brain MRIs. Shorter scans are becoming increasingly crucial at a time when brain scans account for around one out of every four MRI examinations and the global number of brain MRI exams is estimated to reach 45 million this year, according to Siemens.

Using SMS, clinicians can shorten the duration of MRI brain scans, which can vary greatly, to timeframes that are consistent with clinical practice (e.g., up to 68 percent for diffusion tensor imaging, or DTI), bringing practical relevance to advanced neurological applications. SMS can be used to treat patients who cannot tolerate lengthier scan times, such as children or the elderly. In cases of brain surgery, SMS may

aid in surgical mapping and increase OR efficiency. The new GOBrain program enables professionally certified brain tests in only five minutes by allowing the acquisition of clinically important image orientations and contrasts with a single button press. Siemens' high-channel density coils and DotGO MRI scanning software serve as the foundation for the technology. GOBrain enhances patient throughput and maybe lower prices per scan. Shorter scan times, which patients tolerate better, can help avoid the need for long and potentially expensive rescans, as well as sedation.
The SMS application is available on Siemens' Magnetom Aera 1.5T, Magnetom Skyra 3T, and Magnetom Prisma and Prisma Fit 3T MRI systems. The GOBrain application is featured on the Magnetom Aera and Magnetom Skyra systems.

- **Simplifying Cardiac MRI**

Because cardiac MRI is complex, requires a lengthy examination, and is expensive, its use has been extremely restricted, accounting for only 1% of all MRIs performed in the US. But at RSNA 2015, GE Healthcare unveiled a new MRI technique that significantly streamlines cardiac MR, with the goal of increasing its use in place of CT scans. The new ViosWorks cardiac MRI software, designed for GE's new Signa MRI scanners, assists in automating the image sequences to perform a full 3-D chest volume scan, which includes blood flow, time, and fully automated quantification in addition to the myocardium's full motion during the cardiac cycle. This results in what GE refers to as a 7-D cardiac MRI exam. Additionally, ViosWorks reduces the imaging time from 70 minutes to roughly 10 minutes.
Gathering a full volume dataset of a moving chest generates a considerable quantity of data, which would ordinarily choke the average picture archiving and communication system (PACS) and post-processing 3-D image workstation. A typical cardiac MRI scan nowadays is around 200 MB, whereas a ViosWorks exam is over 20 GB. So, GE has introduced a new cloud computing service to help process that massive quantity of data fast using remote super-computing capacity.

- **Silent MRI Scanning**

GE Healthcare has expanded its SilenScan MRI noise reduction technology to the Signa Pioneer 3T system, which now includes an upgraded SilentScan package to significantly reduce noise during MRI scans. SilentScan has been introduced for musculoskeletal (MSK) and spine imaging, as well as a comprehensive neuro exam that incorporates diffusion weighted imaging (DWI). SilentScan uses two independent ways to eliminate acoustic noise: treating the source, the gradient-magnet interaction, and mechanical vibration. SilentScan is available for GE's Discovery MR750w, Optima MR450w, Signa PET/MR, Signa Pioneer, and Signa Explorer.

Comparative Study of CT scan and MRI Imaging Technique

Analyzing the concepts, clinical uses, benefits, and drawbacks of CT (Computed Tomography) and MRI (Magnetic Resonance Imaging) entails comparing and contrasting these two imaging modalities. Here's a summary:

Sr. No.		**CT Scan**	**MRI**
1.	Technology	Uses X-rays to create cross-sectional images of the body	Uses strong magnetic fields and radiofrequency pulses to produce detailed images.
2.	Mechanism	A rotating X-ray tube and detectors measure the attenuation of X-rays as	Aligns hydrogen nuclei in the body, then perturbs this alignment with

Sr. No.		CT Scan	MRI
		they pass through the body, generating detailed images based on varying densities of tissues	radiofrequency pulses. The emitted signals from relaxing hydrogen atoms are detected and used to create images
3.	Image Formation	Produces images based on the differential absorption of X-rays by various tissues.	Produces images based on the magnetic properties of hydrogen atoms in different tissues.
4.	Common Uses	For imaging bone fractures, detecting cancers, guiding biopsies, evaluating lung and chest problems, and assessing abdominal pain.	Ideal for soft tissue evaluation, including brain, spinal cord, muscles, and joints. It's extensively used for neurological, musculoskeletal, and cardiovascular imaging
5.	Specific medical usage	Emergency Situations due to its speed and effectiveness in diagnosing acute conditions like trauma, stroke, and internal bleeding	Capable of providing functional information, such as fMRI (functional MRI) for brain activity and MRA (Magnetic Resonance Angiography) for blood vessels.
6.	Speed	Faster imaging process, making it suitable for emergencies	Takes longer to perform than CT scans, which can be a drawback in emergencies.
7.	Cost and Availability	More widely available and often less expensive than MRI.	More expensive and less available than CT in some areas.
8.	Soft Tissue Contrast	Less effective than MRI in differentiating between soft tissues	Provides excellent contrast for soft tissues, making it superior for detecting abnormalities in the brain, spinal cord, and joints
9.	Diagnostic Accuracy in Neurology	CT is often used for initial assessment in acute stroke due to its speed.	MRI is preferred for detailed imaging of the brain and spinal cord, such as in detecting multiple sclerosis, brain tumors, and spinal cord injuries.
10.	Diagnostic Accuracy in Oncology	whereas CT is often used for initial detection, staging, and monitoring of cancers, especially in the lungs and abdomen	MRI provides superior soft tissue contrast for detecting and characterizing tumors,

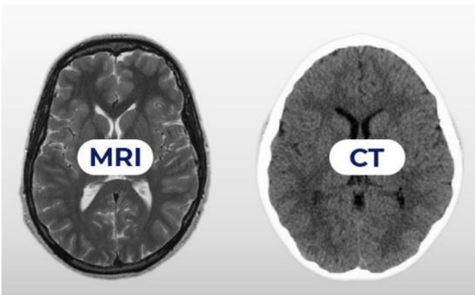

Figure 1: Comparison of two images

Conclusion:
Choosing the most appropriate scan produces the greatest data for a quick diagnosis. Depending on your symptoms, one scan may be more beneficial than another.

Abbreviations and Acronyms
ASIR : Adaptive Statistical Iterative Reconstruction
MBIR : Model-Based Iterative Reconstruction
CT : Computer Tomography
MRI : Magnetic Resonance Imaging
DWI : Diffusion Weighted Imaging
DECT : Dual-Energy Computer Tomography

References
3. American College of Radiology (ACR)**: Provides guidelines, research articles, and continuing education opportunities
4. Radiological Society of North America (RSNA)**: Offers journals, conference proceedings, and educational resources
5. European Society of Radiology (ESR)**: Hosts the European Congress of Radiology (ECR) and publishes related research
6. "Radiopaedia": An educational site with articles on CT technology and case studies
7. "IEEE Xplore": A digital library for research articles and conference papers in engineering and technology, including medical imaging.
8. 'Google Scholar: A search engine for scholarly articles across various disciplines, including medical imaging.
9. Aunt Minnie**: A news and community site for radiologists, featuring articles on the latest in medical imaging.

Example of List of Reference Books.
1. 'R.S.Khandpur', 'Handbook of Biomedical Instrumentation' 3rd Edition, 2014, McGraw Hill Education (India) Private Limited, ISBN: 9789339205430
2. 'Leslie Chromwell, 'Fred Weibell', Erich A. Pfeiffer', Biomedical Instrumentation and Measurements.2nd Edition, 1 January 1990, Prentice Hall India Learning Private Limited, ISBN: 8120306538.