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Advancements In Radiology Imaging Technologies: A Comprehensive Review

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ABSTRACT

Introduction: *For clinical and scientific research purposes, Medical imaging provides a complete examination of both normal and diseased anatomy and biological processes by examining the structure and function of various human tissues and organs. Imaging technologies are essential for both issue diagnosis and treatment.*

Aim of work: *To provide a comprehensive assessment of emerging technologies and diagnostic advancements in radiology.*

Methods: *The MEDLINE database's electronic literature was searched using the provided search terms: Advances, radiology, imaging, technology and future. The search was limited to publications between 2019 and 2024 in order to identify relevant material. Relevant search terms were utilized on Google Scholar to locate and explore relevant scholarly articles. The selection of papers was guided by certain inclusion criteria.*

Results: *The publications included in this study were published from 2019 to 2024. The study was organized into several sections with particul[1]ar headers in the discussion section.*

Conclusion: *The practice of capturing pictures of different human tissues and organs in order to examine their normal and abnormal structure and function is known as medical imaging. Medical imaging methods include magnetic resonance imaging, digital mammography, positron emission tomography, single-photon emission computed tomography, computed tomography, and diagnostic sonography. Advanced medical imaging equipment may be used to identify a wide range of medical illnesses, such as heart difficulties, many types of cancer, neurological abnormalities, congenital heart disease, stomach infections, complicated bone fractures, and other major health concerns. These methods guarantee the creation of precise imaging apparatuses with enhanced sensitivity, specificity, and resolution. Future medical*

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diagnostics will concentrate on routinely assessing complex illnesses and providing healthcare remedies as technology systems advance.

Keywords: *Advances, radiology, imaging, technology and future.*

INTRODUCTION

For clinical and scientific purposes, the visual depiction of the composition and operation of various human organs and tissues is known as medical imaging. This allows for a thorough investigation of both normal and aberrant physiology and anatomy. Medical imaging techniques help detect abnormalities and cure diseases by providing a visual representation of the underlying structures hidden underneath the skin and bones (Chandy, 2019). The field of medical imaging is now a part of healthcare science. A vital area of radiology is biological imaging, which makes use of a range of imaging technologies, including digital mammography, medical photography, ultrasound and electrical impedance tomography (EIT), digital mammography, endoscopy, magnetic resonance spectroscopy (MRS), magnetic resonance imaging (MRI), thermography, electrical source imaging (ESI), positron emission tomography (PET), magnetic source imaging (MSI), and single-photon emission computed tomography (SPECT) (Liu et al., 2019).

Imaging technologies are crucial for diagnosing problems and guiding therapy by providing detailed visual representations that help medical professionals understand their patients' conditions (Golubickas et al., 2021). Electrocardiography (ECG), magnetoencephalography (MEG), electroencephalography (EEG), and are techniques used for recording and measuring data. They do not generate visuals but depict data as graphs or maps chronologically, presenting information with restricted precision. These technologies might be seen as a form of miniature medical imaging. By 2010, about 5 billion medical imaging tests were performed worldwide (Cai et al., 2019).

Around half of the ionizing radiation exposure in the United States comes from medical imaging, according to Papadakis et al. (2019). Medical imaging technologies are utilized for the assessment, treatment, and prevention of diseases. The identification of a wide range of clinical abnormalities and illnesses, including neurological disorders, injuries, several cancer types, cardiovascular ailments, and other illnesses, depends heavily on recent advancements in imaging methods. Highly skilled people, especially medical professionals like internists and oncologists, employ medical imaging therapies (Choudry, 2019).

The main application of medical imaging technology is in diagnosis. Determining the ailment and symptoms of a patient is the process of medical diagnosis. Medical diagnosis, which is based on the patient's history, physical examinations, or questionnaires, is essential for therapy. The lack of specificity in the indications and symptoms of a condition makes its identification a tough step in medical science. For instance, erythema, which is redness of the skin, might indicate several disorders. Therefore, many diagnostic tests are necessary to identify the origins of different diseases and develop treatments or preventive measures (Schwartz, 2020).

AIM OF WORK

To provide a comprehensive assessment of emerging technologies and diagnostic advancements in radiology. The scope encompasses current technologies, future prospects, and the implications of these innovations on healthcare delivery.

METHODS

Using various keywords (Advances, radiology, imaging, technology and future), scientific websites (Google Scholar and Pubmed) were searched to retrieve all relevant publications. A set of selection criteria was used to determine which papers were chosen. After reviewing each paper's abstracts and significant titles, we eliminated case reports, duplicate articles, and articles without complete text. The reviews that this study looked at were released between 2019 and 2024.

RESULTS

Studies on the emerging technologies and diagnostic advancements in radiology between 2019 and 2024 were considered in the current investigation. Consequently, the review was published under several topics in the discussion section, including Historical Perspective of Radiological Imaging, Advanced Technologies in Medical Imaging, Computed Tomography (CT), Volumetric Quantitative CT (vQCT), High-Resolution CT (hrCT), Micro-CT (μCT), 3D Ultrasound Computed Tomography (3D USCT), Positron Emission Tomography (PET), Magnetic Resonance Imaging (MRI), Applications of MRI, Single-Photon Emission Computed Tomography (SPECT), Digital Mammography, Medical Ultrasound, Artificial Intelligence in Medical Imaging.

DISCUSSION

1. Historical Perspective of Radiological Imaging

The earliest medical diagnosis made by humans in history relied on observations made by ancient doctors using their eyes, hearing, and occasionally examining human specimens. Testing of body fluids, including saliva and urine, was a historical practice that dates back before 400 B.C. Doctors in ancient Egypt and Mesopotamia were able to detect conditions pertaining to the heartbeat, blood circulation, spleen, digestive tract, menstruation problems, and more. Regrettably, medical treatment for illnesses was accessible primarily to affluent and noble individuals (Schwartz, 2022).

Hippocrates advocated use the mind and senses for diagnosis around 300 B.C. He was recognized as the "Father of Medicine." Hippocrates advocated for a diagnostic approach that involved checking the patient's urine, noting skin tone, listening to the lungs, and assessing other external features. They also recorded the correlation between disease and inheritance. The hereditary genetic condition hemophilia was originally documented by the Arabic physician Abu al-Qasim al-Zahrawi during the Islamic era. The research examines a family from Andalusia where the male members died due to hemophilia (Schwartz, 2020).

During the middle Ages, physicians utilized many approaches to identify the reasons for the body's imbalanced function. Uroscopy was the predominant diagnostic procedure. The urine of the patient was collected in a specific vessel called "Matula." The urine was examined for color, odor, density, and the existence of precipitates. Physicians analyzed the blood color viscosity and to identify chronic or acute illnesses. Physicians assessed the heart rate, strength, and rhythm of a patient's circulation by palpation. During the middle Ages, physicians often integrated the study of medicine with astrology.

X-rays along with microscopes were essential tools for diagnosis in the 19th century for identifying and treating ailments. In the early 19th century, medical physicians diagnosed illnesses based on symptoms and indicators. In the 1850s, the introduction of diagnostic instruments including ophthalmoscopes, stethoscopes, and laryngoscopes empowered medical physicians to create new procedures and techniques for identifying various disorders (Schwartz, 2020).

Currently, CT scans are often utilized for diagnosing many disorders. Mammography utilizes an X-ray beam to produce detailed pictures of the breast for the detection of breast cancer. X-ray tomography technology was created in the 1940s to locate specific areas within tissue. This method entailed rotating the X-ray tube to concentrate on a particular area of the tissue. Nowadays, advanced imaging methods like computed tomography (CT) and computerized axial tomography (CAT) scanning are replacing tomography. X-ray is a technology that may be used for angiography, which is the process of obtaining pictures of blood arteries. Diagnostics imaging testing and nuclear medicine were initiated in the 1950s. Instead of using X-ray tubes, radioactive materials are used as X-ray sources. Gamma radiation is released by radioactive materials. They are linked to other complexes that are essential to understanding a particular disease as part of the disease analysis process. Bone tumors absorb methylene diphosphonate, which is momentarily linked to technetium 99m. When lung or breast cancer spreads to other body areas, especially the bone, it can be identified using the nuclear bone scan technique (Webb, 2022).

2. Advanced Technologies in Medical Imaging

Various advanced techniques have been produced and may be elucidated based on their working principles, use in medical laboratories, and advancements in imaging methods. Advanced medical imaging techniques include CT, PET, SPECT, MRI, and digital mammography, sonography. The following are included to explain their benefits and uses in diagnosing, managing, and treating various conditions like cardiovascular disease, cancer, neurological disorders, and injuries. Clinicians commonly utilize these strategies to easily determine illness management using imaging.

3. Computed Tomography (CT)

Hounsfield produced the first CT scanner prototype in the early 1960s. CT stands for computed tomography, or X-ray CT. Radiologists, archaeological specialists, biologists, and other specialists utilize CT scans to produce cross-sectional images of scanned objects. Technicians in the medical industry utilize CT scanners to generate pictures for identifying problems and implementing therapeutic interventions. X-rays are generated from various angles with this technique and then analyzed by computers to produce tomographic images. This technique has significantly advanced, producing reconstructed pictures with exceptional resolution. In the pharmaceutical sector, it has been utilized to analyze and enhance the drug production procedure to produce high-quality items (Peyrin & Engelke, 2021).

CT is a useful method for monitoring several types of tumors such bladder, kidney, skeletal, neck, and head cancers, as well as for identifying infections. Additionally, distant metastases in the liver, brain, lungs, and bones can be shown by CT scans. CT has had a significant effect on the lungs and brain. CT scan is superior to other approaches for detecting and documenting changes in tumor size during therapy (Galgano et al., 2020). Bronchus cancer may present with a distended abdomen and swollen lymph nodes. CT scans assist in preoperative evaluations. CT scans are frequently utilized for diagnosing heart conditions such congenital heart disease, myocardial disease, and coronary artery bypass grafts. CT is mainly used by gastroenterologists to take a look at patients' pancreas or liver. CT scans can identify tumors ranging from 1.5 to 2.0 cm in diameter. This method can also be used to monitor biliary blockage induced by lesions (Pierre et al., 2022).

One major limitation of CT is the potential inability to detect large masses in the gastrointestinal tract during abdominal scans. It also does not detect some mucosal abnormalities. CT scans are more reliable than other imaging techniques in managing abdominal illnesses such stomach, esophagus, and rectum carcinomas (Samy et al., 2019). CT can visualize the central column of the spine in thoracolumbar fractures with dislocation type of fractures. CT scans can identify lesions and offer non-surgical treatment for some conditions including unstable burst injuries (Samy et al., 2019).

Micro-CT, volumetric quantitative CT (QCT), and high-resolution CT are examples of advanced CT methods for imaging bone. While micro-CT and micro-MR are often used in non-living systems, high-resolution CT and high-resolution MR are frequently used in living creatures. These state-of-the-art methods for bone imaging are used to examine diseases like osteoporosis and bone cancer that impact the bones. When it comes to osteoporosis, enhanced CT bone imaging offers data on bone strength, mineral density (BMD), osteoporosis risk factor, and metrics related to the body's recuperation after medication or bone therapy.

4. Volumetric Quantitative CT (vQCT)

By examining a specific transverse CT scan slice, QCT was first utilized to determine the bone mineral density (BMD) of the trabecular bone in the forearm and lumbar midvertebrae. Sophisticated spiral QCT has a fixed feature that is BMD measuring. By analyzing the cortical bone in the hip and the trabecular bone in the spine, this technique may be used to assess the risk of fractures (Korpinen et al., 2023).

To enhance the 3D structure of the cortex, a spatial resolution of around 0.5 mm isotropic is necessary. However, QCT currently offers a resolution of around 1.5 to 2 mm, which is insufficient for producing precise pictures. This is a disadvantage of QCT. Cortical thickness measurement in the femur is frequently easier than in the spine, particularly in elderly individuals. Studies have shown that women develop more quickly than men do, but they also have smaller vertebrae, less bone mass, and a slower rate of expansion in cross-sectional area. Quantitative computed tomography (QCT) is a CT imaging method used to assess bone density (Cheng et al., 2021).

5. High-Resolution CT (hrCT)

An upgraded CT scanner called high-resolution CT frequently employs a high radiation dosage to produce detailed images of bones, including the forearm bone. It is employed to examine the texture and trabecular and cortical structure (Tse et al., 2021). Several cross-sectional investigations have shown that when it comes to differentiating between fractured and nonfractured vertebral trabecular components, CT imaging performs better than DXA assessments of BMD (Sollmann et al., 2021).

6. Micro-CT (μCT)

Microscopy refers to the use of Micro-CT with spatial resolution ranging from 1 to 100 μm. Micro-CT is a viable alternative to traditional techniques for in vivo measurements in rodents, including mice and rats. Synchrotron radiations were initially used by the micro-CT technique for ultra-high resolution applications. These days, X-ray tube-based micro-CT is mostly found in specialized medical facilities and university research labs. Specialized software such as FEM is used in conjunction with a micro-CT scanner to create 3D bone structures. Engineers are the primary users of finite element modeling (FEM) software. The aim is to assist in analyzing fractured bone structures by comparing them to nonfractured bone structures using 3D information. Structural models are now created using volumetric QCT, and computer systems assign elastic characteristics to components depending on bone density at the element's location (Whittier et al., 2020).

7. 3D Ultrasound Computed Tomography (3D USCT)

The use of three-dimensional ultrasonic computed tomography (3D USCT) in imaging-based breast cancer detection shows significant promise. The USCT system's primary characteristics are attenuation, fast data collection, speed of sound volume, simultaneous recording of repeating reflection, and high picture quality production. The 3D USCT system is a sophisticated instrument utilized for clinical applications. The complete breast volume may be captured in under 4 minutes (Li et al., 2021).

8. Positron Emission Tomography (PET)

A nuclear medicine tool called PET creates bright images of the body's total concentration of radioactively tagged substances. This technique is ideally suited for therapeutic applications and may be used for recognizing biological processes in live organisms (Hooker & Carson, 2019).

Three-dimensional representations of radionuclides that release positrons within the body are produced by a computer system. PET-CT scanners provide three-dimensional images of a patient's body by combining a PET scan with a CT X-ray scan in the same session. Quantitative radiological methods such as PET and NMR provide information on biochemistry, physiology, and the identification of normal or abnormal conditions. In order to produce detailed pictures, nuclear magnetic resonance is only sensitive to the arrangement of molecules containing hydrogen. The device is capable of measuring the overall concentrations of ATP and creatine phosphate in specific brain regions. PET and NMR both effectively fulfilled their unique diagnostic roles. Massachusetts General Hospital built the first PET system back in 1953. Many gadgets were developed, including the PET scanner, tomographic positron emission tomography camera, and other PET apparatus (Abrams-Pompe et al., 2021).

The body's amounts of sugar, fatty acids, amino acids, and receptors may all be measured using a PET scan. A cutting-edge diagnostic tool is utilized to identify conditions including schizophrenia, tumors, atherosclerosis, and aging; however, more advancements in modeling and technology are needed for applications in the future. The danger of ionizing radiation exposure by emission tomography is minimal (Abrams-Pompe et al., 2021).

9. Magnetic Resonance Imaging (MRI)

Noninvasively examining the body's structure and physiology in both healthy and pathological conditions is the primary goal of magnetic resonance imaging (MRI). In the latter part of the 1970s, Paul Lauterbur and Peter Mansfield developed the echo-planar imaging (EPI) magnetic resonance imaging technique. An MRI scanner creates pictures of the body's structure and organs using radio waves, electric fields, and magnetic fields. Magnetic flux density, or magnetic field strength, is measured in tesla (T), the SI unit for magnetic flux density. Common MRI findings include CNS tumors, multiple sclerosis, stroke, brain and spine infections, ligament and tendon injuries, muscle atrophy, bone tumors, and blood artery blockages. MRI utilizes nonionizing radiation, often considered more favorable than CT scans. High soft tissue differentiation is provided by MRI, making it possible to distinguish between the brain's white and gray matter regions. Spin-echo, gradient echo, diffusion-weighted imaging (DWI), susceptibility-weighted imaging, perfusion-weighted imaging (PWI), magnetic resonance angiography (MRA), and functional MRI are some of the techniques used in magnetic resonance imaging (MRI). There is no need for the patient to move because of the excellent image quality (Hori et al., 2021). MRI offers a number of benefits, such as noninvasiveness, painlessness, superior spatial resolution, and the use of nonionizing radiation. The majority of the time, MRI is used independently to analyze soft tissues.

10. Applications of MRI

Skeletal metastases can often be examined with whole-body MRI. Because of the large concentration of protons in the tumor matrix, the MRI method allows for the imaging of the tumor. For the purpose of detecting skeletal metastases, it is an imaging method that is more accurate than skeletal scintigraphy, or bone scan. Ankylogous findings in the femur, spine, and pelvis may be made with great success using whole-body MRI. This approach is commonly utilized as the main diagnostic tool for polymyositis, general obesity, and soft tissue problems (Geethanath & Vaughan Jr, 2019).

MRI is distinct from other diagnostic methods due to its lack of ionizing radiation danger. MRI is devoid of adverse effects, unlike PET and CT scans. Examining different body target sections from various viewpoints and views does not diminish the quality of the images. Dynamic contrast-enhanced magnetic resonance imaging (DCE-MRI) is used to identify the tumor microenvironment and guide therapy. The method has gained approval as advantageous and is receiving more and more clinical attention (Tran et al., 2021).

The ability of magnetic resonance imaging (MRI) to yield comprehensive data on the heart's functional architecture, perfusion, metabolism, and blood flow renders it a valuable diagnostic tool for cardiovascular diseases. Cardiovascular MRI detects abnormalities in the pericardium, thoracic aorta, and congenital heart defects, which helps in the diagnosis of heart disorders in patients. MRI scans can be used to distinguish between a myocardial tumor and right ventricular dysplasia based on their distinct imaging characteristics. Cardiovascular magnetic resonance imaging (MRI) is used to measure arterial arteriosclerosis, test myocardial viability, identify ischemia in patients with heart disease, and evaluate cardiac prognosis (Jafari et al., 2023).

Schizophrenia patients have cognitive impairments that lead to aberrant social behavior and trouble comprehending language. Functional MRI has shown to be helpful in the diagnosis of several types of diseases. The patient's brain shows hypoactivity in the frontotemporal cortex. It has also been emphasized how important minor neurological indications and symptoms are. Brain asymmetry images reveal disparities between persons with schizophrenia and a control group, and functional MRI can detect abnormalities in the cerebrum (du Sert et al., 2023).

11. Single-Photon Emission Computed Tomography (SPECT)

SPECT is an advanced imaging method that makes precise three-dimensional (3D) replicas of things using gamma rays. In 1963, Kuhl and Edwards published the first study on computed tomography using single positron emission. According to Kilian and Pyrzyńska (2023), the advancement of single-photon emission tomography was propelled by the incorporation of sophisticated instruments such as rotating gamma cameras and computer-attached systems.

SPECT has emerged as a valuable medical imaging method utilized in both research and clinical settings. The device tracks the three-dimensional data of an item by generating a sequence of tiny slices from tomographic photographs. These crucial CT scans can enhance the ability to detect patients' little and profound fractures (Kowalewska et al., 2022).

SPECT utilizes high-energy gamma rays to analyze numerous two-dimensional (2D) pictures from various perspectives. A computer software reconstructs and records data to generate 3D photographs of a specific area of the body. SPECT is often used in conjunction with other tomographic modalities such as MRI, PET, and CT in clinics and research centers. SPECT and PET use radioactive tracers to monitor gamma ray emissions. The detector in SPECT quickly detects the gamma rays that radioactive tracers release. To create a precise image of the region where radioactive tracers are administered, the computer system evaluates data from the detector. When imaging tiny animals, SPECT imaging is more economical than other imaging modalities. Monitoring heart issues, bone metabolism, and cerebral blood flow is critical (Miyaoka & Lehnert, 2020).

SPECT was developed especially for brain imaging using neurochemicals. It makes detailed analyses of neuropsychiatric disorders using a powerful imaging technology. It's a crucial developmental method with a lot of potential for tracing the pathophysiology of a number of complex brain conditions (Kalyoncu & Gonul, 2021). In the realm of nuclear medicine, hybrid SPECT and CT technology is currently extensively accessible and in use. When bone infections, inflammation, bone cancers, bone regeneration, trauma, and other illnesses affect complex joints including the hand/wrist, shoulder, knee, hip, and foot, SPECT/CT is a useful tool for detecting aberrant bone metabolism. Typically, CT scans are used for specificity and SPECT scans for high sensitivity in combination to get a comprehensive diagnosis. SPECT/CT also provides essential information for therapeutic planning. For example, it tells us whether to use SPECT/CT by itself or to have a joint arthroplasty. Joint arthrography of the knee was found to have superior outcomes in comparison to SPECT/CT alone (Koppula et al., 2021).

12. Digital Mammography

Mammography is a method employed for screening and diagnosing the human breast. Mammography tests for and diagnoses breast cancer early by using low-energy X-rays at 30 kVp. Mammograms utilize ionizing radiation to generate pictures for the evaluation of abnormal situations. Ultrasound is commonly used to provide further details regarding masses identified during mammography. The use of mammography is supported by positron emission mammography (PEM), discography, and MRI. Because older women have larger breast densities than younger women, mammography is more accurate in this age group. Currently, digital mammography has superseded traditional mammography (Einav et al., 2020).

3D mammography is a sophisticated method used to create comprehensive 3D pictures of breast tissues for in-depth investigation of breast cancer. Better results are obtained when regular mammography and 3D mammography are combined. 3D mammography is a worry because to its cost-effectiveness and significant radiation exposure (Heindel et al., 2022).

Digital mammography is a specialized technique used to examine breast tissues for the investigation of breast tumors. Digital mammography differs from film mammography by utilizing a specialized detector to transform transmitted X-ray radiation into a picture signal through a computer system rather than film. Digital mammography is a fast and sophisticated imaging technique with the capability to diagnose and screen for breast cancer effectively. New diffusion technologies have the potential to change the healthcare system through several processes. Various outcomes are associated with breast healthcare when comparing digital-screen and film mammography. Digital mammography might alter how diagnostic services are provided by guaranteeing mammograms with positive screening results (Hussain et al., 2022).

Digital mammography detects breast cancer more accurately than film mammography among young, premenopausal women. Generally speaking, a digital system costs 1.5–4 times as much as a film system. The use of computers for diagnosis in digital mammography yields better quality and quickly accessible images for transmission, retrieval, and storage. Advanced digital mammography utilizes a low average radiation dosage without compromising diagnostic accuracy (Hong et al., 2020).

Digital mammography produces clearer images of healthy breast tissue compared to film mammography. Researchers examined 42,760 women's breast X-rays using digital as well as film mammography. These methods are trustworthy for identifying cancer. Women under 50 with thick breast tissue had a 28% higher risk of breast cancer, according to digital mammography. Digital mammography employs a certain type of detector to receive transmitted X-rays, which are then processed by a computer system to create a picture. It is thought that screening for breast cancer using digital mammography is less economical than screening with conventional mammography (Ghorbani et al., 2023).

13. Medical Ultrasound (US)

Brain scans were formerly performed using US imaging technology as a diagnostic tool. One common imaging method used in diagnostic labs and clinics is ultrasound. It is devoid of radiation exposure danger, somewhat more cost-effective, and more portable in comparison to imaging methods such as MRI and CT. This method is utilized across several disciplines. Organs and bodily structure may be diagnosed using ultrasonography by using high-frequency sound waves. High frequency operation characterizes the ultrasonic system. Experts use it for evaluating the kidneys, heart, liver, blood vessels, and other internal organs. The transducer is the main part of ultrasonography. Electrical impulses can be converted into sound waves via an ultrasonic transducer, and vice versa. Using a specialized probe, sound waves are sent into tissues to create an ultrasonic picture, often known as a sonogram. To varying degrees, various tissues reflect these noises. The operator identifies and displays images of reflected sound waves, referred to as echoes. Ultrasound is utilized for several purposes in the medical field. A dependable and effective technique for evaluating normal pregnancies, multiple pregnancies, placenta previa, and other pregnancy-related illnesses is ultrasound scanning (Caradeux et al., 2024).

Transvaginal ultrasound (TVS) is an ultrasound imaging method that changes how we approach the care and diagnosis of pregnancy. The TVS provides a thorough understanding of early pregnancy complications. It examines the position and viability of the pregnancy. During pregnancy, ultrasound scans can detect the fetal heart activity, providing the first indication of the viability of the pregnancy. Irregular fetal heart rate rhythm suggests a future miscarriage. Between six and eight weeks, a lower fetal heart rate raises the possibility of fetal health issues. The fetal heart pulse is detectable by transvaginal sonography (TVS). Consistent utilization of transvaginal ultrasonography (TVS) can improve the management of early pregnancy loss. Increased knowledge among pregnant women and developments in early prenatal care can successfully prevent miscarriage. Transvaginal sonography is a very useful method for detecting miscarriage early on. The method uses color to identify blood flow and trophoblastic tissues in the intervillous gap. According to Ficara et al. (2020), Doppler imaging is useful in assessing the level of expectant management.

Functional ultrasound (fUS) is the best option for brain imaging because it is able to detect transient changes in blood volume in the brain more clearly than other imaging modalities. fUS technology uses high frame rate plane-wave illumination to measure the blood volume in tiny arteries. The brain's active region can be identified by functional ultrasonography (Deffieux et al., 2021). As a noninvasive, outpatient imaging method for examining neuromuscular issues in children, ultrasound offers a number of advantages. Ultrasonography is used to assess muscle contraction, fiber length, and thickness. Muscle visualization is achieved with the use of real-time ultrasonography. Ultrasound can detect various muscle disorders in neuromuscular patients by observing specific patterns of muscle echo. For example, patients with muscular dystrophy exhibit a bright spotted pattern of increased muscle echo, while those with spinal muscular atrophy show a moderate increase in echo (Lin et al., 2021).

Advanced 3D ultrasound algorithms assist early care physicians in comprehending intricate patient situations. Specialized health facilities use high-speed networks to enhance patient care services. Due to 2D ultrasound's limitations, 3D ultrasound is often used.Utilizing clinical 3D US enhances the diagnosis of illnesses and provides a 3D picture to assist with invasive therapy. Enhancements in both 3D imaging software and hardware will result in the regular utilization of this technology (Bureau et al., 2023).

High-resolution ultrasound, commonly referred to as ultrasonic biomicroscopy (UBM), is used for clinical imaging of the human eye. When compared to conventional ocular ultrasound techniques, UBM produces high-resolution images by using frequencies of 35 MHz or higher. Ocular injuries and complex hypotony are detectable by UBM. The instrument may identify hyphema, zonular defects, cataracts, lens subluxation, iridodialysis, and displacement of the eye's lens. Hyphema is the presence of blood in the front chamber of the eye caused by an injury (Abramowicz et al., 2022).

14. Artificial Intelligence in Medical Imaging

Machine learning and deep learning are two of artificial intelligence's (AI) subfields. These domains address problems pertaining to medical imaging applications, such as retrieval, annotation, lesion segmentation, image-guided treatment, medical image analysis, and computer-aided diagnosis. An artificial intelligence system evaluates picture quality, interprets images, analyzes biomarkers, and generates reports. Oncologic imaging is influenced by artificial intelligence. A frequent and dangerous type of cancer detected by thoracic imaging is lung cancer. AI can assist with the identification and classification of these nodules as malignant or benign (van Leeuwen et al., 2021). Pattern recognition is at the heart of machine learning. Conventional AI systems were built on predefined engineering feature algorithms with precise parameters derived from expert knowledge. The features were created with the intention of assessing certain radiographic characteristics, such intratumoral texture and a tumor's three-dimensional structure. Then, a selection strategy is used to extract only the most crucial features. In order to find possible imaging-based biomarkers, the data is put into statistical machine learning algorithms (Sharma et al., 2020). Deep learning algorithms analyze and navigate the data space to enhance their problem-solving abilities. Convolutional neural networks (CNNs) are the primary deep learning architectural models used in contemporary medical imaging applications, despite the existence of several other deep learning designs for diverse purposes (Oren et al., 2020).

CONCLUSION

The visual representation of the human body's tissues and organs through medical imaging allows for the observation of both normal and abnormal architecture and function. Computed tomography, X-rays, magnetic resonance imaging, positron emission tomography, digital mammography, single-photon emission computed tomography, and diagnostic sonography are among the many medical imaging modalities used. Advanced medical imaging techniques are used to diagnose cardiac ailments, several forms of cancer, gastrointestinal disorders, neurological issues, complex bone fractures, congenital heart disease, and other serious medical conditions. Each imaging technique has its own set of pros and cons. There are precautions taken to reduce the dangers of radiation exposure from imaging methods. These techniques guarantee the creation of precise imaging instruments with enhanced sensitivity, resolution, and specificity. Future technological developments will make it possible for the medical diagnostic industry to regularly evaluate complicated disorders and provide healthcare solutions.

REFERENCES:

Abramowicz, J. S., Adhikari, S., Dickman, E., Estroff, J. A., Harris, G. R., Nomura, J., ... & Barr, R. G. (2022). Ocular Ultrasound: Review of Bioeffects and Safety, Including Fetal and Point‐of‐Care Perspective. Journal of Ultrasound in Medicine, 41(7), 1609-1622.

Abrams-Pompe, R. S., Fanti, S., Schoots, I. G., Moore, C. M., Turkbey, B., Vickers, A. J., ... & Eastham, J. A. (2021). The role of magnetic resonance imaging and positron emission tomography/computed tomography in the primary staging of newly diagnosed prostate cancer: A systematic review of the literature. European urology oncology, 4(3), 370-395.

Bureau, F., Robin, J., Le Ber, A., Lambert, W., Fink, M., & Aubry, A. (2023). Three-dimensional ultrasound matrix imaging. Nature Communications, 14(1), 6793.

Cai, C., Chen, L., Zhang, X., & Gao, Z. (2019). End-to-end optimized ROI image compression. IEEE Transactions on Image Processing, 29, 3442-3457.

Caradeux, J., Martínez-Portilla, R. J., Martínez-Egea, J., Ávila, F., & Figueras, F. (2024). Routine third-trimester ultrasound assessment for fetal growth restriction. American Journal of Obstetrics & Gynecology MFM, 101294.

Chandy, D. A. (2019). A review on iot based medical imaging technology for healthcare applications. Journal of Innovative Image Processing, 1(1), 51-60.

Cheng, P., Yang, Y., Yu, H., & He, Y. (2021). Automatic vertebrae localization and segmentation in CT with a two-stage Dense-U-Net. Scientific Reports, 11(1), 22156.

Deffieux, T., Demené, C., & Tanter, M. (2021). Functional ultrasound imaging: A new imaging modality for neuroscience. Neuroscience, 474, 110-121.

du Sert, O. P., Unrau, J., Gauthier, C. J., Chakravarty, M., Malla, A., Lepage, M., & Raucher-Chene, D. (2023). Cerebral blood flow in schizophrenia: A systematic review and meta-analysis of MRI-based studies. Progress in Neuro-Psychopharmacology and Biological Psychiatry, 121, 110669.

Einav, L., Finkelstein, A., Oostrom, T., Ostriker, A., & Williams, H. (2020). Screening and selection: The case of mammograms. American Economic Review, 110(12), 3836-3870.

Ficara, A., Syngelaki, A., Hammami, A., Akolekar, R., & Nicolaides, K. H. (2020). Value of routine ultrasound examination at 35–37 weeks' gestation in diagnosis of fetal abnormalities. Ultrasound in Obstetrics & Gynecology, 55(1), 75-80.

Galgano, S. J., Porter, K. K., Burgan, C., & Rais-Bahrami, S. (2020). The role of imaging in bladder cancer diagnosis and staging. Diagnostics, 10(9), 703.

Geethanath, S., & Vaughan Jr, J. T. (2019). Accessible magnetic resonance imaging: a review. Journal of Magnetic Resonance Imaging, 49(7), e65-e77.

Ghorbani, S., Rezapour, A., Eisavi, M., Barahman, M., & Faradonbeh, S. B. (2023). Cost-benefit analysis of breast cancer screening with digital mammography: A systematic review. Medical Journal of the Islamic Republic of Iran, 37.

Golubickas, D., Lukosevicius, S., Tamakauskas, V., Dobrovolskiene, L., Baseviciene, I., Grib, L., ... & Veikutis, V. (2021). Image quality in computed tomography coronary angiography and radiation dose reduction. Informatica, 32(4), 741-757.

Heindel, W., Weigel, S., Gerß, J., Hense, H. W., Sommer, A., Krischke, M., & Kerschke, L. (2022). Digital breast tomosynthesis plus synthesised mammography versus digital screening mammography for the detection of invasive breast cancer (TOSYMA): a multicentre, open-label, randomised, controlled, superiority trial. The Lancet Oncology, 23(5), 601-611.

Hong, S., Song, S. Y., Park, B., Suh, M., Choi, K. S., Jung, S. E., ... & Jun, J. K. (2020). Effect of digital mammography for breast cancer screening: a comparative study of more than 8 million Korean women. Radiology, 294(2), 247-255.

Hooker, J. M., & Carson, R. E. (2019). Human positron emission tomography neuroimaging. Annual review of biomedical engineering, 21, 551-581.

Hori, M., Hagiwara, A., Goto, M., Wada, A., & Aoki, S. (2021). Low-field magnetic resonance imaging: its history and renaissance. Investigative Radiology, 56(11), 669.

Hoshino, N., Murakami, K., Hida, K., Sakamoto, T., & Sakai, Y. (2019). Diagnostic accuracy of magnetic resonance imaging and computed tomography for lateral lymph node metastasis in rectal cancer: a systematic review and meta-analysis. International Journal of Clinical Oncology, 24, 46-52.

Hussain, S., Mubeen, I., Ullah, N., Shah, S. S. U. D., Khan, B. A., Zahoor, M., ... & Sultan, M. A. (2022). Modern diagnostic imaging technique applications and risk factors in the medical field: A review. BioMed Research International, 2022.

Jafari, M., Shoeibi, A., Khodatars, M., Ghassemi, N., Moridian, P., Alizadehsani, R., ... & Acharya, U. R. (2023). Automated diagnosis of cardiovascular diseases from cardiac magnetic resonance imaging using deep learning models: A review. Computers in Biology and Medicine, 106998.

Kalyoncu, A., & Gonul, A. S. (2021). The Emerging Role of SPECT Functional Neuroimaging in Schizophrenia and Depression. Frontiers in Psychiatry, 12, 716600.

Kilian, K., & Pyrzyńska, K. (2023). Scandium Radioisotopes—Toward New Targets and Imaging Modalities. Molecules, 28(22), 7668.

Koppula, B. R., Morton, K. A., Al-Dulaimi, R., Fine, G. C., Damme, N. M., & Brown, R. K. (2021). SPECT/CT in the evaluation of suspected skeletal pathology. Tomography, 7(4), 581-605.

Korpinen, N., Oura, P., & Junno, J. A. (2023). Sex-and site-specific, age-related changes in bone density: a Terry collection study.

Kowalewska, B., Drozdz, W., & Kowalewski, L. (2022). Positron emission tomography (PET) and single-photon emission computed tomography (SPECT) in autism research: Literature review. Irish Journal of Psychological Medicine, 39(3), 272-286.

Li, F., Villa, U., Park, S., & Anastasio, M. A. (2021). 3-D stochastic numerical breast phantoms for enabling virtual imaging trials of ultrasound computed tomography. IEEE transactions on ultrasonics, ferroelectrics, and frequency control, 69(1), 135-146.

Lin, S., Zhu, B., Zheng, Y., Huang, G., Zeng, Q., & Wang, C. (2021). Effect of real-time ultrasound imaging for biofeedback on trunk muscle contraction in healthy subjects: a preliminary study. BMC musculoskeletal disorders, 22(1), 1-8.

Liu, X., Faes, L., Kale, A. U., Wagner, S. K., Fu, D. J., Bruynseels, A., ... & Denniston, A. K. (2019). A comparison of deep learning performance against health-care professionals in detecting diseases from medical imaging: a systematic review and meta-analysis. The lancet digital health, 1(6), e271-e297.

Miyaoka, R. S., & Lehnert, A. L. (2020). Small animal PET: a review of what we have done and where we are going. Physics in Medicine & Biology, 65(24), 24TR04.

Oren, O., Gersh, B. J., & Bhatt, D. L. (2020). Artificial intelligence in medical imaging: switching from radiographic pathological data to clinically meaningful endpoints. The Lancet Digital Health, 2(9), e486-e488.

Papadakis, M. A., McPhee, S. J., & Rabow, M. C. (2019). Medical Diagnosis & Treatment. Mc Graw Hill: San Francisco, CA, USA.

Peyrin, F., & Engelke, K. (2021). CT imaging: Basics and new trends. In Handbook of Particle Detection and Imaging (pp. 1173-1215). Cham: Springer International Publishing.

Pierre, T., Selhane, F., Zareski, E., Garcia, C., Fizazi, K., Loriot, Y., ... & Balleyguier, C. (2022). The Role of CT in the Staging and Follow-Up of Testicular Tumors: Baseline, Recurrence and Pitfalls. Cancers, 14(16), 3965.

Reif, B., Ashbrook, S. E., Emsley, L., & Hong, M. (2021). Solid-state NMR spectroscopy. Nature Reviews Methods Primers, 1(1), 2.

Samy, A. M., Tantawy, H. I., Gobran, H. A., & Alsowey, A. M. (2019). ROLE OF MULTIDETECTOR COMPUTED TOMOGRAPHY IN BILIARY OBSTRUCTION. Zagazig University Medical Journal, 25(2), 207-215.

Sharma, P., Suehling, M., Flohr, T., & Comaniciu, D. (2020). Artificial intelligence in diagnostic imaging: status quo, challenges, and future opportunities. Journal of thoracic imaging, 35, S11-S16.

Sollmann, N., Rayudu, N. M., Lim, J. J. S., Dieckmeyer, M., Burian, E., Löffler, M. T., ... & Subburaj, K. (2021). Multi-detector computed tomography (MDCT) imaging: association of bone texture parameters with finite element analysis (FEA)-based failure load of single vertebrae and functional spinal units. Quantitative Imaging in Medicine and Surgery, 11(7), 2955.

Swartz MH. Textbook of physical diagnosis E-book: history and examination. Elsevier Health Sciences; 2020 Feb 3.

Tran, A., Koh, T. S., Prawira, A., Ho, R. Z. W., Le, T. B. U., Vu, T. C., ... & Huynh, H. (2021). Dynamic contrast-enhanced magnetic resonance imaging as imaging biomarker for vascular normalization effect of Infigratinib in high-FGFR-expressing hepatocellular carcinoma xenografts. Molecular Imaging and Biology, 23, 70-83.

Tse, J. J., Smith, A. C., Kuczynski, M. T., Kaketsis, D. A., & Manske, S. L. (2021). Advancements in osteoporosis imaging, screening, and study of disease etiology. Current osteoporosis reports, 19, 532-541.

van Leeuwen, K. G., Schalekamp, S., Rutten, M. J., van Ginneken, B., & de Rooij, M. (2021). Artificial intelligence in radiology: 100 commercially available products and their scientific evidence. European radiology, 31, 3797-3804.
Webb, A. (2022). Introduction to biomedical imaging. John Wiley & Sons.
Whittier, D. E., Boyd, S. K., Burghardt, A. J., Paccou, J., Ghasem-Zadeh, A., Chapurlat, R., ... & Bouxsein, M. L. (2020). Guidelines for the assessment of bone density and microarchitecture in vivo using high-resolution peripheral quantitative computed tomography. Osteoporosis International, 31, 1607-1627.