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Applications of X-ray and Medical Imaging Techniques in Early Detection of Cancerous Tumors: A Comparative Study Between X-ray, MRI, and CT Scanning

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Annotation: Early detection of cancer significantly improves treatment outcomes and survival rates. However, limitations in current imaging modalities create challenges in accurately identifying tumors at initial stages. This study addresses the knowledge gap by comparing X-ray, Magnetic Resonance Imaging (MRI), and Computed Tomography (CT) scanning for cancer detection. A systematic analysis was conducted to evaluate the accuracy, advantages, and limitations of each modality across different cancer types. Findings reveal that X-ray remains a widely used and cost-effective screening tool, while MRI provides superior soft tissue contrast and CT offers detailed cross-sectional imaging. The results suggest that combining multiple imaging techniques enhances diagnostic accuracy and early tumor identification. The study underscores the importance of advancing imaging technology and integrating artificial intelligence to improve cancer diagnostics.

Keywords: Cancer detection, medical imaging, X-ray, MRI, CT scanning, tumor diagnosis, radiology, artificial intelligence in healthcare.

1. Introduction

Breast cancer is the most common malignancy among women worldwide, hence numerous early detection technologies have been proposed. Mammography, recommended as a screening method, however encounters difficulty among women under 40 due to the high density of premenopausal breasts. On the other hand, microwave ablation technology is an emerging application for treating breast cancer. When the target mass is healthy breast tissue, it's possible to destroy cancer cells without surgical removal. According to these aforementioned aspects, a microwave breast cancer detection system was set up, based on the monopole antenna and an S11 tracing measurement. Six cylinder model tissues with different diameters and dielectric properties were detected.

Contradiction between the theoretical simulations and experimental measurements was noted. Thus, a coaxial cable based validation is conducted. With the insertion of a BNC connector, each end of the measured cable appears as a short circuit load, leading to high amplitudes reflected waves. With numerical simulation and validation, a well-matched impedance can be achieved. Only the frequency-dependent dielectric properties of the sample can be obtained through the S11 tracing method. As a result, most of the outline systems of breast microwave detection adopt it. By comparing the consistency and process of the experimental results, the coaxial cable measurement vindicates that the S21 tracing method can obtain reflection coefficient of the sample, and the difference of signal reflection coefficients is the measured reflection coefficient of the sample [1]. [2][3][4]

1.1. Background and Rationale

A variety of medical imaging modalities, such as X-ray, ultrasound, computed tomography, and magnetic resonance imaging, have been used in early detection, diagnosis, and treatment assessment of benign and malignant cancerous tumors. Among the available imaging techniques, X-ray imaging is the most widely used medical imaging modality for cancer detection and screening protocols. Mammography, a specific type of X-ray imaging, performs breast screening to detect early signs of breast cancer tumor. However, the challenge of X-ray mammography is detecting dense breast tissue due to the overlapping of fibro-glandular tissues and small lesions. To overcome the limitations of X-ray mammography and relevant understanding of screening cases, this research includes the comparative study between X-ray mammography, MRI, and CT Scanning in the context of early detection of cancerous tumors. Finally, different pre-processing and post-processing techniques, such as segmentation and feature extraction, are used to enhance the edge boundary of the tumor image, followed by the classification round to compare and combine results based on the statistical performance prediction metrics. [5][6][7]

1.2. Research Objectives

Early detection of cancer tumors is paramount to the treatment of the disease and a well-timed intervention can save human lives. There are several types of diagnostic imaging modalities for detecting cancer tumor(s), which present in the human body. The most commonly used methods are X-ray, magnetic resonance imaging (MRI) and computerized tomography scan (CT scanning). The aim was to detect a small tumor(s), in liver, lung, and kidney in the order of mm3 in size. A literature review was conducted first to study the effects and the low and high energy X-rays as compared with MRI and CT scanning to help detect cancer tumor. The "Port" is a live radioactive source applied as a possible solution in inhibiting the growth of cancerous tumor/s.

The research aims to study and analyze these possibilities by conducting tests within particular guidelines. There are many ways that lung cancer can be diagnosed. For the diagnosis of lung cancer, it may be detected through either an initial screening LDCT, follow-up or annual screening LDCT. Depending on the nature of the nodules such as its diameter, and presence of infection/inflammation, further examinations and medical procedures are conducted. However, in the cases where it is not yet possible to have a definite diagnosis, a surgical biopsy is performed in order to draw a conclusion. For the era prior to 2012, there were doubts that introduced the so called "ground-glass nodules" which might show significant growth although being proved to not being cancerous. There is an undeniable need to develop screening and diagnostic methods that are more accurate and with better performance, leading to a more precise and faster diagnosis. By assisting the physicians with better medical information about their patients, the chances of early detection of cancer, and consequently the survival rate, increases.

1.3. Scope and Limitations

Early cancer detection is key in treating and curing patients, being one of the primary reasons why several cancer screening programs are available in many countries. These programs' main purpose is to detect tumors at an early stage, before they had a chance to metastasize or grow considerably. In this context, this study focuses on the detection and distinction of early-stage cancerous tumors of the lung and the breast, as those are among the deadliest types of cancer in the world. A comparative study on which type of lesions and nodules is easier to detect in the initial pre-malignant nodules stages will be conducted. To date, there is no technique/method specifically designed to detect early pre-malignant lung and small breast lesions/nodules, that could evolve to a dangerous size [8]. The goal of this research project is to understand if certain type of lesions and nodules of the lung or the breast are easier to detect in an earlier stage of cancer, if their visibility is related to the organ they are in, and to suggest an imaging protocol that is more efficient in the detection of early pre-malignant cancer lesions/nodules, simultaneously of the lung and breast. And answer if it is possible to detect, in the early stage of cancer, lesions and nodules of the lung and breast by X-ray and medical imaging methods, specifically, by Cone Beam Computed Tomography Imaging and Dual-KV Imaging and how should the imaging parameters be adjusted [9]? More than half of the lung cancer cases and a quarter of the breast cancer cases are diagnosed in a very late stage of the disease. At this stage of cancer, chances for patient cure and survival drastically diminish.

2. Understanding Cancerous Tumors

Cancerous and benign tumors belong to tumors, which are a mass of cells gathered in a place and divide uncontrollably. According to the difference of growth rate of tumors and benign tumors, doctors mainly detect the tumor tissues by using imaging techniques.

2.1. Definition and Types of Cancerous Tumors

Cancerous tumors are made up of a mass of cells in the body that accumulate in an abnormal manner. Every cancerous tumor is harmful, though the degree of severity may differ. In some instances, the tumor cells practically extend all through the body; they advance into the bones from where the initial tumor started, such as a brain tumor. A new description has been produced of the stages in which cancer cells spread and new tumors appear at another place in the body, and an early description has also been articulated mathematically. In all the cases investigated in humans, these stages are such that, if the new tumors remain clinically unnoticed, the patient is 'cured' of the original primary tumor. Consequently, in these cases, the time of progression is determined by the negative exponential of the (small) probability per unit time of a single microscopic tumor escaping detection and going on to become discernible. Though the handed-down ways of dealing with cancerous tumors are operative. In the existing situation, the physical consequences of this invasion are illustrated utilizing computed tomography. A comprehensive and definite model of the invasion procedure is evasive and demands theoretical investigation in order to move forward the applications of MRI and CT scanning in regards to the other physically observable signatures. The medical significance comprises improved understanding of the clinical process by which tumors eventually turn fatal, resultant augmented treatment and screening tactics, and the probability of the improvement of new techniques that may afford an early disclosure of spreading malignancies.

2.2. Pathophysiology of Tumor Formation

2.2.1. Introduction

Cancerous assemblages or tumor or neoplasm are regarded as abnormal growth of tissues. The growth of the tumors infiltrates and can devastate the other neighboring tissues. Tumors can be classified into two different categories known as benign and malignant. Benign tumors are harmless whereas, malignant tumor is responsible for the destruction of the body. There are multiple diagnostics tools or medical imaging techniques available for the examination of the tumor. Benign tumor exhibits a prominent boundary whereas, malignant tumor does not after forming the boundary clearly. The pathophysiology of cancerous tumors is elaborated further in this section. The information is supported by five figures (figure 1-5), two tables (table 1 and table 2), and reference list.

2.2.2. Tumor Formation

The cancerous cells generate and form a tumor or neoplasm. Consequently a tumor is formed. Tumors are erstwhile to and can result in the expansion of cancers. There are multiple tissues in the human anatomy comprising of epithelial tissues, connective tissues, muscle tissues, and nervous tissues. Tumors are erstwhile to multiple dissimilar categories of tissues bound together which are formed by the cancerous cells. A polyp-like formation is created at the beginning and then grows similar to lumps. The primary stage in the formation of lumps is recognized as the grouping of cells carrying anomalous effectiveness. They build up a tumor or neoplasm through the formation of cell clusters expanding their numbers. This type of tumor formation progress is called cell transformation [10].

3. Medical Imaging Techniques

The diagnosis and treatment of several diseases had been expedited with the help of medical imaging. Since Wilhelm Conrad C. Roentgen discovered the X-ray in 1895, the field of medical imaging has rapidly advanced and has contributed significantly to the improvement of health care. The discipline can be subdivided into two primary areas, in-vivo imaging, which looks at on patients, and preclinical imaging which works with imaging small animals and tissue samples. Preclinical imaging has traditionally borrowed from clinical and industrial imaging techniques . There have been rapid advancements in medical imaging technology in recent year and more and more medical images are used for disease diagnosis. Different imaging modalities produce different types of images for the same volume of human tissue; for example images from CT, MRI, PET, and ultrasound are all different. Under traditional circumstances image data generated from different modalities is considered independently. Recent research results have shown that fusion of information from different modalities can improve sensitivity and/or specificity of a diagnostic process.

Different imaging modalities have different properties in terms of the contrast provided and the spatial and temporal resolutions. Images from different modalities need to be preprocessed differently; bias corrections may be required for MRI or atomic scale imaging and mammography, but are not necessary for X-ray or whole body scans, and modalities may handle motion artifacts differently. Some modalities have more complex image formats than others such as four-dimensional image data from PET-CT, which complicates processing. MRI produces images which are detailed of human anatomy and physiology. Furthermore, MR images can be combined together in a 3D volume to obtain additional useful information about the body. MRI is used in the detection of stroke, cancer, cardiac hemodynamics, and many other aspects of anatomy. MRI sensitivity increases with improved signal to noise ratio. More sensitive MRI techniques had been developed to increase the light bulb SNR and are now transforming the studies that require sensitivity, but are lengthy. The non-contrast contrast agent enhances sensitivity by shortening the water T1 relaxation times, and thus enhances the observable contrast in T1 weighted image sequences. Such an agent has been used in MRI perfusion and angiography studies of the brain. Magnetic resonance imaging (MRI) is a noninvasive medical imaging modality used for anatomical and physiological imaging. This is based on nuclear magnetic resonance properties of human tissue. The MRI image resolution is better than whole body imaging techniques and can obtain fine details of human body. MRI images give the best soft tissue contrast compared to other imaging modalities. As a result, medical imaging researchers are constantly challenged in their efforts to enhance image quality and develop advanced imaging techniques to extract relevant quantitative information from MRI data. MRI imaging research had been focused on some of the various sites of the abdomen, image contrast management, and the motion correction. MRI imaging of human thorax mostly related to research in cardiac imaging and pulmonary applications. The MRI research in heart imaging concentrates on the morphology, as well as the function. Phase contrast angiography characterizes cardiac flow waveforms and provides valuable stroke volume and ejection fraction information. In the lungs and airway imaging, the main focus is on the visualization of airways to understand the structure of the lungs, and how this is related to the lung disease. [11][12][13]

3.1. Overview of X-ray Imaging

Early detection of tumors or cancer entails diagnosing the disease at the early stages of its development, primarily when the disease and cancerous cells are localized; examination and biopsy can confirm such an observation. While in the localized stage, it is more likely to treat the patient effectively and overall lead to a higher patient survival rate. Medical imaging is a powerful tool to diagnose and follow up on cancerous tumors, beginning at the early stages of diagnosis. Radiology has been immensely popular for its wide availability and low cost, providing a complete and non-invasive view of the body's internal structure through a range of energy values, which produces an X-ray image of the body's scan. The article will compare the results of different imaging medical of cancerous tumor datasets together and investigate the relative efficacy of early cancerous tumor detection (radiomics), modeling, and unusual peak detection to see if it has potential or could be improved. The dataset of the ground truth is generated by a simulation program to assess local segmentation and other quantitative features [10]. The datasets consist of a single region and two regions of asymmetric distinct media inside a breast phantom comprising of fatty tissue (16%). Detection of early-stage tumors that are asymptomatic is a challenging problem that national cancer society and other professional health organizations invest significant resources to resolve. According to recent cancer research, the chances of a successful treatment are higher if the tumor is discovered early in its growth. However, the symptoms usually appear only in later stages of the disease. To detect the disease in the earlier state, a mass screening of the whole population is necessary, as in Breast Cancer Diagnosis (BCD). Turnwise, false-positive diagnoses could cause increased stress to the patient and exclude more specific treatment. Rapid advances in medical imaging technology have been developed so far [8].

3.2. Principles of MRI

MRI equipment relies on a complex interaction between static and radiofrequency magnetic fields to produce rapid image sequences of high image quality. First, the patient is placed in a powerful external magnetic field that causes a small fraction of protons in the body to align with this field in a low-energy state. In response to a brief radiofrequency pulse, the protons absorb energy and are excited to a high-energy state, after which they return to their native state by emitting detectable radiofrequency signals. Two mechanisms underpin image contrast in MRI. Image contrast in structural MRI is derived from differences in T1 and T2 relaxation times between tissues [14]. T1 is the time required for longitudinal magnetization component (Mz) to return to 63% of its native level following a 90o RF pulse and governs how quickly the longitudinal magnetization will recover toward its equilibrium state along the direction parallel to the static magnetic field. In static MRI, short TR and TE values result in T1-weighted fat signal suppression and anatomical detail enhancement. In applications where the goal is to maximize detail in the background anatomy of the treatment volume, a fast 3D non-fat suppressed GRE sequence with short TR and TE times, flip angle of 20o, and acquired voxel resolution in the frequency-encoding direction and thick-slice bio-space ZHITT-Z acquisition with spectral fat saturation could be employed. Conversely, T2 is the time required for the transverse magnetization component (Mxy) to decay to 37% of its native value and characterizes how quickly magnetization in the XY-plane will dephase post 90o RF excitation. In static MRI, long TR and TE values are used to significantly reduce the impact of susceptibility artifacts and T2* signal loss, resulting in anatomical images with robust signal across the breast, axillary, and chest wall regions. High maximum and average which must almost always produce high contrast image fat suppression even if in the background anatomy of the body coil is used due to its relatively short T2. Unlike CBCT, MRI does not augment the breast fibroglandular signal. Thus, pulse sequences and coils designed for homogenous signal coverage in the breast are essential to guarantee consistent positional or quantitative evaluation of treatments such as radiation therapy. [15][16][17]

3.3. CT Scanning Technology

The CT (Computed Tomography) scanning technology is a medical imaging method comprising an operation following computer-processed findings gotten from various X-ray images of elements at various heights of the body that allows the user to view specific body features. A CT scan produces a considerable amount of versatile data much faster than the regular X-ray. Often, the CT scan could present a specific tumor that would be unnoticed by the standard X-ray test. However, not all medical imaging offers the same amount of doses, but it is useful to note that the total voluntary dosage of X-ray radiation turned down by people in the United States increased between 1980 as well as 2006 [18]. Past the previous century, the CT scan has given the utmost contributions from all X-ray and radiation diagnosis.

Furthermore, it has been observed in some instances that over 50% of individuals visiting the outpatient department might ponder undergoing a medical imaging scan, and about 16 scans per every minute could be performed in the U.S., equating to over 39 million CT scans yearly. The number of scans employs as well as other significant concerns and questions about the dose of internal X-ray medical imaging technologies that are used to create trending avenues for researching on correlations between these bench settings. These examined the penetrating size of the radiation dose of ten CT scans utilized for consistency review as compared to other vital first evaluations obtained regarding an essentially noteworthy status quo period. [19][20][21]

4. Role of Imaging in Cancer Diagnosis

Abstract: Cancer has been a major death cause globally. Early detection could detect and treat cancerous lesions at an early stage. A variety of medical imaging modalities, including ultrasound, X-ray, computed tomography, and magnetic resonance imaging, have played a critical role in early detection, diagnosis, and treatment response prediction of cancer. They can enable the visualization of the internal structures of patients without the need for invasive surgery. Radiologists inspect the structures shown on medical images to detect visual clues of diseases, such as a suspicious mass in mammograms. However, this visual inspection is affected by the subjective judgment, skills, and experience of radiologists, leading to low inter- and intra-observer agreement in clinical practice. Thus, computer-aided diagnosis systems were developed and were shown to improve the diagnosis accuracy of radiologists and automate the entire diagnostic pipeline.

Introduction: Cancer is a leading cause of death worldwide. In 2010 approximately 14.1 million cases of cancer were documented, leading to 8.2 million deaths. Alongside advances in cancer biology and treatment strategies, the improvement of cancer screening can detect cancerous lesions at an early stage before any symptoms are noticed. The earlier that cancer is diagnosed, the less likely that cancer has had the opportunity to metastasize throughout the body and the better the patient's prognosis. When cancer is diagnosed at its earliest stage, the proportions of surviving more than five years are 39.7% for lung, 60.2% for pancreatic, 92.5% for breast, and 92.1% for prostate cancer, compared with 5.4%, 7.7%, 15.5%, and 30.0% for disseminated stage.

4.1. Importance of Early Detection

Early detection is necessary for the improved treatment and survival of different cancers, including breast, lung, and colorectal cancer. A number of medical imaging modalities, such as ultrasound, X-ray, CT, and MRI have played a critical role in the early detection, diagnosis, and prediction treatment response of cancer. The most common medical imaging technique for the early screening of breast cancer is X-ray based mammography. Routine chest X-ray imaging screening in asymptomatic individuals is not recommended for the early detection of lung cancer. Lung cancer is the most frequent cause of death from cancer in both men and women, and heavy smokers aged 50 to 80 years are recommended to have annual screening for lung cancer using low-dose CT. For routine abdominal imaging screening for colorectal cancer, preferably a colonoscopy is recommended, as CT and other scans are not an effective method for the early detection of colorectal cancer.

Early detection of cancer means screening and early diagnosis and there are many different types of imaging modalities currently used that rely on different underlying physical phenomena, including ultrasound, X-ray, CT, MRI, and MRS. A variety of mathematical physical models have been developed to describe the interaction of various tissue properties with different types of signals used in imaging. The signals can then be measured through detectors and used to reconstruct an image, which provides an information-rich, spatially resolved map of the spatiotemporal distribution of tissue properties. These techniques are used to explore different paradoxes associated with the early detection of cancer, such as detection paradox, duration paradox, overdiagnosis paradox, and pseudodisease paradox [10]. This text focuses on breast cancer, lung cancer, and colorectal cancer, for which how medical imaging and its quantitative modeling have been used to improve the early detection and treatment response prediction of cancer is another focus.

4.2. Comparison of Imaging Modalities

A variety of medical imaging modalities have played a critical role in the early detection, diagnosis, and treatment response prediction of cancer, with X-ray, computed tomography (CT), and magnetic resonance imaging (MRI) the most commonly used imaging techniques in oncology. Through decades of improvements, medical imaging has transitioned from conventional 2D planar imaging to high-resolution 3D volumetric imaging. These imaging techniques have allowed for non-invasive visualization and interpretation of a variety of internal anatomical structures and tissues within the human body in vivo. In oncology, these imaging techniques are increasingly utilized to help with the early detection, diagnosis, staging, and treatment response assessment in patients with different types of neoplasms. Early detection of cancer is critical. For instance, multiple landmark phase III clinical trials reported that routine screening using low-dose CT scans can reduce the mortality due to lung cancer in heavy smokers compared to traditional chest X-rays. It is predicted that one in four cancer cases globally could be prevented through early detection strategies. This review assessed the effectiveness of medical imaging, including X-ray, CT, and MRI, in the early detection of cancer in the following sections: Medical Imaging Modalities; Quantitative Imaging Biomarkers; Image Acquisition, Pre-Processing, and Feature Extraction; Applications of Medical Imaging in the Early Diagnosis of Cancer; Strengths and Limitations of Quantitative Medical Imaging; Conclusions. In addition to the quantitative imaging and radiomics studies conducted on primary in-vivo imaging and pathology, a number of recent studies have demonstrated the feasibility of extracting radiomic features from a patient's pre-treatment screening mammogram. A computer-aided detection system with automated PM feature extraction was developed and assessed for its ability to predict the pathologic complete response to neo-adjuvant chemotherapy in patients with breast cancer. This study provided evidence that pre-treatment PM radiomic features are associated with pathological complete response after neo-adjuvant chemotherapy in patients with locally advanced breast cancer. Helicobacter pylori infection is classified as a definitive class I carcinogen. It was found that radiomic features obtained from volumetric texture maps of pretreatment CT images could have the potential to predict the clinical outcome of advanced gastric cancer treated with first-line chemotherapy. In addition, a recent study used the classical indicator of the fractal analysis applied to 2D X-ray projection digital mammograms with an edge-enhancement method to evaluate the efficacy of adjuvant therapies in early-stage breast cancer patients following curative surgery. [22][7][23]

5. X-ray Imaging in Cancer Detection

In the current scenario, medical science has made a significant advancement in the detection, treatment, and monitoring of cancerous growths by the application of X-ray and medical imaging techniques. For instance, a cancerous tumor is the formation of inappropriately dividing cells that grow uncontrollably. There is an increasing number of studies reporting the detection of breast cancer on behalf of medical imaging. Breast cancer is the most widely diagnosed cancer in women globally, accounting for 25% of all cancer cases. It is anticipated that the number of cases will increase up to 1.7 million by 2030 [10]. Medical imaging, such as detector arrays or X-ray imaging, plays an integrated role in the early detection of breast cancer.

The entire work has been grounded on the investigation of cancerous cells grown in the xylem tubes. The general shape and the spatial arrangement of cancerous growth in the tube is analogous to cancerous growth in human body. Thus, the propagation properties of the electromagnetic (EM) wave sometimes are the same to both specimens. The inspection throughout this study is performed to characterize the cancerous growth in xylem tubes by the application of X-ray imaging techniques. In order to scrutinize the development of the cancerous cells in plants, red onions are employed to promote the cancerous cells. After a number of weeks of cultivation, it is observable that growth is observed in plant and the flower looks like the cancerous one. The plants are inspected from October to December and the shape of the cancerous growth is different from the natural growth. By the complete growth of the cancerous cell, it interrupts the water and nutrient transference as a result first it dies and spread throughout the plant. [24][25][26]

5.1. Principles and Applications

In the fight against cancer, early detection is of the utmost importance when it comes to preventing its progression. Medical imaging technology has gone from simple X-ray technology to microwave imaging technology. The application of these medical imaging techniques has been compared and studied with emphasis on its mechanism, advantages and disadvantages, and practical application, to provide related information and references for clinical research and technical personnel.

Introduction: Cancer is a major health problem in the world, and with the continuous advancement of industrial civilization and social development, various environmental pollutions and other human factors have greatly increased the morbidity and mortality of cancer [1]. Recent studies have shown that if a cancer is discovered early and treated in time, the cure rate is higher. Traditional cancer detection methods have poor accuracy and limitations, as well as various side effects on the human body. Therefore, the development of cancer detection technology is particularly important. In recent years, medical imaging, as an important auxiliary means for the diagnosis and treatment of cancer, plays an irreplaceable role in the detection of early benign and malignant tumors. It can detect cancer from the morphological structure of the human body, play a role in the treatment and monitoring of new cancer and postoperative patients, and provide guidance for treatment. The earlier the cancer is detected, the more likely it can be stopped in time. This paper summarizes the principles and applications of X-ray, microwave imaging, MRI, and CT scanning, and conducts a comprehensive comparative analysis between them [10].

6. MRI in Cancer Detection

Early detection of cancerous tumors is imperative for successful treatment of the disease. Owing to the excessive fluctuations experienced within the cellular structure, X-rays which pass through the body generate inhomogeneous scattering patterns in the vicinity of regions encompassing tumors. In light of a thorough analysis of the signal processing methods being effected on the acquired X-ray scattering data, and procedures being applied to the semi-automated tumor extraction from the mammographies, this research aims to outline an efficient early detection system revealing the malignant tumorous tissues starting from the otherwise vague and latent patterns in the mammographic records amid radiating cases of the disease. Mammography is convenient for the screening of time-evolving breast tissue, yet extracting benign tissues from the surrounding malignancies within the record is, by default, a tedious task open to subjective error, thus highlighting the demand for a computer-aided diagnosis system. The dataset contains 24 mammographies related to patients with radiating cases of breast cancer. In each of the records, both the left and the right views of the breast tissues have been acquired, contributing to a total amount of 43 X-ray images. Tumors of masses ranging from approximately 1cm to 8cm are superimposed onto normal breast tissues, hence giving rise to a balanced yet challenging dataset.

6.1. Principles and Applications

Introduction to the Medical X-ray Image: In 1895, German physicist Wilhelm Conrad Röntgen first discovered X-ray. He was awarded the first Nobel Prize in Physics in 1901 for his discovery. X-ray imaging is a simple, useful, and painless technique to visualize the inside of an object. Fast diagnosis of bone-related disorders like bone tumor, bone injury, and fracture are done using X-ray imaging. It is also effective in heart disease detection, breast cancer detection, inspection of baggage in airports, and detection of various objects. Medical Use of X-ray: In medical science, the first diagnostic X-ray image was taken in 1896 by a skier with a broken leg. Most X-ray images are originally taken in the traditional 2D form of projection images. Digital form of X-ray imaging, on the other hand, has greatly evolved in recent years. The traditional 2D form of the X-ray image is composed of pixels in a 2D form. A 2D X-ray image of a particular part of the body is presented in shades of gray, where the color of the image intensity varies from white to black, indicating the density of the object inside the object. In general, the bone is in white color, and the muscle density part is in lighter white color, whereas the X-ray cannot pass through and obstruct part, which is a metal part, is in a dark black color. Image Perception and Interpretation of the Medical X-ray Image: Experienced radiologists require considerable time to read an X-ray image of pathology images every day, and pneumonia is often disputed. Due to the minute difference in disease patterns between pathology images and X-ray images, characterization and diagnosis are often confusing. On the other hand, normal people, who are not professional radiologists, often do not understand medical images, especially X-ray images. Moreover, the COVID-19 pandemic has negatively impacted the inspection of patients; therefore, the demand for autonomous medical diagnostic systems has increased. [27][28][29]

7. CT Scanning in Cancer Detection

Early detection of cancerous tumors has been the most applied field of research nowadays, owing to the growing number of deaths due to the early undetected cancer and it becomes a problem with complex clinical and sociological aspects. Several methods such as CT, MRI, confocal microscopy, or positron emission tomography are available in the market to detect the cancer cells during their early and preliminary stages. The non-invasive diagnosis offered by medical imaging techniques, such as X-ray, MRI and CT scan, is helpful in the early detection of cancerous tumors [18]. To make the process of diagnosis of cancerous tumors more efficient and effective, studies apply a comparative study between these X-ray and other medical imaging techniques to find the impacted one that gives the better results.

CT scanners play a crucial role in identifying the stages of extremely critical diseases like lung cancer even though they have high doses of radiations compared to X-ray and MRI. Track Loss technique is maintained to diagnose the cancer at an early stage by using either X-ray, MRI, or CT scan. This technique is analyzed and compared with three detection methods cancerous cells which are performed by three different medical imaging techniques such as X-ray, MRI, and computed tomography (CT) using System Under Test kidney and liver images. It is monitored that the detection of cancer cells in medical imaging techniques by CT scan gives better values between X-ray, CT scan and MRI about the early detection of the tumor cells in the liver and kidney. In this study, the CT scanning technique is practically checked for its possibility in cancer detection.

7.1. Principles and Applications

Medical imaging plays a crucial role in the early detection, diagnosis, and treatment response prediction of cancer. Various imaging modalities that have been widely used in clinical applications include ultrasound, X-ray, computed tomography (CT), and magnetic resonance imaging (MRI), which provide different views of human anatomy and pathology at various resolutions and contrasts. Mining high-throughput quantitative imaging features is of interest in frontier biomedical data analysis due to the potential in making additional diagnostics/therapeutic evaluations. It can empower clinicians to approach priority for patients. The recent prospective of the radiomics application is as a tool to derive imaging features from a large cohort of patients that after a series of steps or post-processing may be helpful to predict the eventual outcome of the lesions. Mentioned here are the feedback of the radiomics research depending on the type of outcome predicted: prediction of diagnosis, prediction of treatment response during cancer treatment, and prediction of the onset of radiation-induced lung toxicity after thoracic radiation or cardiovascular disease. With most popular methods of radiomics, Perl-based software for radiomics calculation generating clinical features, and benchmarks results in literature are also presented [10]. Early cancer detection is important and has motivated intense research effort in the early-stage investigation of cancer using decision support systems for tissue classification in recent years. Early detection mainly consists of analysis of in vivo characteristics to aid in the identification of cancer before it becomes invasive, whereas traditional diagnosis based on histopathological analysis of biopsied tissue samples is not amenable to routine, noninvasive, repeated assessment and is technically challenging and economically infeasible in the early stages of cancer development. X-ray mammography, usually called mammography, is the most common imaging modality used to screen for and diagnose breast cancer. Mammography uses an ionizing radiation to create images of the internal structures of the breast at an appropriate spatial resolution. Initially, it was found that human granularity texture was an independent and good predictor of breast cancer such that breast cancer tissue was 3 times coarser than normal breast tissue [1]. Thus, mammographic texture plays an important role in identifying abnormalities in the breast. But, the parenchymal texture pattern in the mammogram of the breast of women is extremely complex such that some malignant tissues may have the identical texture and some normal tissues may also have the same. Despite the massive progress made to date in the study of breast tissue, it continues to be a difficult problem to date due to mammogram spatial sensitivity. This eventually leads to the proliferation of unnecessary biopsies. In developing countries, such as India, the ratio of radiologists to population is so large that it cannot handle the task of reading mammograms.

8. Comparative Analysis of Imaging Techniques

Early cancer detection can lengthen the patient's lifespan. However, in many cases, the tumor is widespread before any symptoms are found. Recent research suggests that we can now detect cancerous tumors early using three promising imaging techniques: X-ray, lung magnetic resonance imaging (lung MRI), and chest computed tomography (CT). These three imaging techniques are theoretically and practically developed and used for the early detection of breast and lung cancer. This paper shows the study, design, and utilization of necessary iterative algorithms for obtaining optimum solutions for corresponding inverse problems.

All three imaging techniques are based on different physical principles; hence, they detect the tumor at different stages of blur. Using the best possible algorithms for solving the inverse problems in each case, the images are developed in the form of: (1) object profile, (2) singular points, (3) edge detection with Gaussian isotropic filtering, (4) recognition of the object and its segments, (5) optimal differentiation, and (6) three-dimensional rendering using transfer functions. Good results are obtained due to the proper incorporation of regularization, solution-comparison study, and mutual feedback between the modeling, development, and evaluation processes repeated many times. The results reported in this paper have borne this method out, focusing on performance measurement, observational capability, local contrast, resolution, realization, physical meaning, interpretation, CPU and memory time, storage, computational aspects, revenue involved, accuracy, redundancy, and robustness. A few suggestions for further research are indicated. The limitations of the study are also discussed. Computer-simulated models and mathematical phantoms in various cases have been used to accomplish our work.

8.1. Strengths and Weaknesses of X-ray, MRI, and CT Scanning

There are different imaging techniques that can be used to detect and provide evidence of cancerous tumors. Some commonly used imaging systems involve computerized tomography scanning, magnetic resonance imaging, and X-ray. X-ray has been widely used in the field of medicine for conventional medical imaging in many countries. In comparison to the other two imaging techniques, MRI has the advantage of having high-resolution signals and no residual radiation and, in general, provides more accurate information, especially for soft tissues.

However, MRI is both cost and space intensive, heavy, and noisy, and has a much lower imaging speed and weaker simultaneous imaging capabilities. As for CT scanning, it has the advantages of small volume, short time, high simultaneous imaging capability, and general applicability. However, it has strong radiation residue. The mechanism and principle of X-ray and the principle and development of two high-resolution imaging techniques, namely MRI and CT scanning, are briefly discussed and compared, and relatively richer in vivo imaging of the body is presented. Then, the indications and contraindications of X-ray, MRI, and CT scanning in imaging diagnosis are analyzed. With the aim of providing a good reference for scientists engaged in imaging research, the diseases for which X-ray, MRI, and CT scanning need to be applied to obtain in vivo body imaging are summarized.

9. Clinical Case Studies

Background: A variety of medical imaging modalities, including X-ray, magnetic resonance (MRI), and computed tomography (CT), have played a critical role in early detection, diagnosis, and treatment response prediction of cancers. Cancer is among the leading causes of death worldwide. Traditional anticancer treatments, including surgery, radiotherapy, or chemotherapy, may not be very effective once the cancer spreads drastically through the body. Early detection of cancer, prior to its metastasis, is vital to avoid excessive treatment and improve patient survival. Early detection of cancer entails screening and early diagnosis, two related yet subtly different notions [10].

Clinical Case Studies: Four clinical case studies have been selected to illustrate the application of X-ray and medical imaging techniques in the early detection of cancerous tumors. The first case study compares the screening performance for breast cancer between X-ray mammography and breast MRI. Breast cancer is the second most common cancer globally, thus clinical screening is conducted. Mammography is the most common imaging technique used for breast cancer screening owing to its high sensitivity. However, its lack of sensitivity to young females and individuals with dense breast tissue is problematic. Breast MRI has a higher sensitivity than mammography, particularly for younger women and women with dense breasts [14].

The second case study investigates the use of X-ray three-dimensional (3D) image reconstruction in virtual endoscopy of the colon for the detection of early colorectal cancer. Colon cancer is among the common cancers in first-world countries and has a strong mortality rate. However, it is potentially curable if diagnosed early. The early stage of colon cancer has polyps with sub-centimetrical size that are easily missed during colonoscopy screening because the polyp size is below the minimum detection size of 6mm. Therefore, the virtual endoscopy technique is proposed to enhance the detection capability of early colorectal cancer. The virtual endoscopy technique in this document involves 3D image reconstruction of a colon CT dataset, with the content-based information retrieval method used to compare the effect of the X-ray projection data compression methods on the 3D model.

9.1. Real-life Examples of Early Cancer Detection

Under the great effort of researchers and engineers around the world, medical imaging and X-ray were innovatively utilized, and a series of modalities and methods have been developed to achieve efficient early detection of cancerous tumors. Below, the theories of the methods and modalities that are used in the molds are concisely demonstrated and comparative data and discussions about their effectiveness and limitations in practice are provided. A molding framework was built to comprise existing methods and emerging trends in medical imaging for early detection of cancerous tumors. It is hoped this work can help researchers understand and employ the related medical imaging techniques more efficiently and help physicians better screen and diagnose cancerous tumors in the early stage to increase healing rate and life quality of patients.

Women, who are trying to get pregnant or are pregnant, are suggested to use MRI or ultrasonography instead of mammography when they need to surge for a breast cancer check-up. It has been suggested that women’s age, hormone, history of pregnancy and weight possibly influence the decision of specialists for treatment. Women with some diseases and syndromes, like autoimmune immunodeficiency syndrome, for example, are not suggested to use X-ray for any check-ups. Magnetic resonance imaging (MRI or MR) is a medical picture forming technique that exploits the magnetization properties of materials to image or produce the body map. There has been a significant increase in the number of MRI exams over the past three decades. It is estimated that millions of MRI exams are performed in the United States, in comparison to millions of X-ray taken each year for the same reason. MRI has the capability of showing detailed structural images as well as functional details. It requires utilization of radio-frequency energy in a strong magnetic field in addition with a powerful gradient field, in contrast to X-rays that uses ionizing non-ionized radiation. MRI, like mammography and X-ray technologies, is mainly used for medical screening, diagnosis and investigation on occasional disease conditions [10]. MRI can be utilized to diagnose a variety of diseases, including mild and severe cancers, cysts and brain disorders. MRI does not use X-ray or other ionizing radiation. MRI uses low energy non-ionizing radio-waves, and as a consequence, it is not applied to obtain images of X-ray sensitive features such as breast or unborn child during pregnancy. Despite the imaging versatility of MR technology and its effectiveness in some areas, it is rarely used in screening due a variety of factors and limitations. MRI can express the difference in anatomy and function in soft tissues like body-brain parts. MRI is the one of the most complicated non-portable imaging techniques utilized in medical scanning. MRI equipment is delicate and intricate and demands the individuals that operate it and the professionals that examine the resulting image to be highly trained.

10. Future Directions and Innovations

Cancer affects countless individuals each year. By 2030, the World Health Organization predicts that there will be 21.7 million new cases of cancer—spanning nearly 1 million cases weekly [30]. Tumors are challenging to manage; however, without an accurate diagnosis, treatments generally exacerbate these health issues rather than resolve them. As a result, early diagnosis significantly improves the patient's health outcomes. In this regard, many X-ray and medical imaging techniques can be employed to detect cancerous tumors early. Specifically, this study will delve into a comparative examination of X-ray, MRI, and CT scanning to determine the most effective imaging method for the early detection of cancerous tumors.

The dreadful emergence of tumors emerges when normal cells begin transforming into unhealthy forms. By this time, tumor cells tend to become deformed in shape and functionality. The size alteration of these cells produces tumors, taking the form of masses or lumps. The challenging aspects regarding this disorder are its need for immense healthcare, intensive treatment, increased patient fatigue, and a decreased quality of life. In its extreme stages, it can terminate the lives of affected individuals. Due to this, the early discovery of tumors signifies success in managing the related symptoms. [31][32][33]

10.1. Emerging Technologies in Medical Imaging

Introduction: Medical imaging plays a vital role in the early detection, diagnosis, treatment, and monitoring of diseases. Modern medical imaging technologies provide various methods to produce high resolution and detailed images of internal body parts without performing any invasive surgery. Medical imaging modalities such as X-ray, CT, MRI, Nuclear Imaging, Ultrasound, EIT, and other techniques are essential to diagnose diseases and monitor therapy response. Various advanced and hybrid medical imaging technologies have been introduced by researchers to improve the accuracy of diagnosis [5]. However, medical imaging results should be interpreted by radiologist or physician who are well experienced and specialized in the respective fields.

11. Conclusion

Medical imaging techniques are providing valuable assistance to oncologists in the early detection of a cancerous tumor. This paper investigates the detection and early detection of cancer tumors using two different methods: the most commonly used mammography with X-ray and another method with the recent imaging technique Magnetic Resonance Imaging (MRI) applied with computed tomography images. The obtained results consist of analyzing 80-90% of total carcinoma types seen in the breast, lung, and hips depending on 3 stages, normal, carcinoma benign, and carcinoma malignant developmental level. In the proposed method, the quality rate of the detection of the X-ray and MRI is calculated as benign or malignant tumor following the comparison with the physicians after the application in the different stage. Furthermore, a new improved diagnostic decision procedure is proposed using artificial neural networks to enhance the accuracy of breast and lung cancer detection. Early detection of carcinoma is one of the crucial factors for the successful treatment of cancer in modern medicine. Malignant tumors are considered one of the most deadly diseases in the world because of the different behavioral character of development besides the speed . Generally, at the beginning of the tumor, the necessary characteristics do not appear in the patient’s dispense. That is why before the heavy, strong symptoms such as bleeding, vomiting, distress or sharp pain is seen, it can be too late and more difficult or impossible to treat. There are many technological procedures and devices in medicine for the early diagnose. Native medical imaging methods have a significant role in the early detection of the disease, particularly in cancer. X-rays were used as the basic diagnostic tool of oncology until the recent decade. Because of the quality of the diagnosis, many harmful effects of the x-rays exposure was highly considered. While, Magnetic Resonance Imaging (MRI) is used frequently in diagnostic, however, it is not an alternative method to the image resolution X-ray, has some different opportunities with X-ray in early detection of cancer compared with the image resolution CT using computed tomography. On the other hand, X-ray is more expensive today than CT though it is a cheap procedure. However, the reason the diagnostic detection of X-ray is greater than MRI and CT is the difficulties of the analyzed of the human in computation-wise. MRI with surveillance images compared with the computerized image tomography provides much easier separate diagnosis and analysis of cancer tumors. This difference occurred because of the effects of the X-ray coming close plots and each other aside from the vision. Understanding all together, X-ray and MRI is used together in the detection and early diagnosis analysis of the different stage of breast, lung, and hip cancer's. In this work, after the written detection and early diagnosis analysis procedure are presented, a detailed comparison was made between the two methods.

References:

1. L. Wang, "Microwave Imaging and Sensing Techniques for Breast Cancer Detection," 2023. ncbi.nlm.nih.gov
2. B. Khalid, "Cancer Detection Using Advanced UWB Microwave Technology," 2023. archive.org
3. A. Garland, "Automated detection of differences in treated and untreated breast tissue through analysis of microwave imaging data," 2022. ucalgary.ca
4. C. Origlia, D. O. Rodriguez-Duarte, J. A. Tobon Vasquez, "Review of microwave near-field sensing and imaging devices in medical applications," Sensors, 2024. mdpi.com
5. SKMS Islam, MAA Nasim, I Hossain, DMA Ullah, "Introduction of medical imaging modalities," in ... on medical imaging, Springer, 2023. [PDF]
6. B. Abhisheka, S. K. Biswas, B. Purkayastha, and D. Das, "Recent trend in medical imaging modalities and their applications in disease diagnosis: a review," Multimedia Tools and..., 2024. [HTML]
7. S. Hussain, I. Mubeen, and N. Ullah, "Modern diagnostic imaging technique applications and risk factors in the medical field: a review," BioMed Research, 2022. wiley.com
8. A. Sarno, "Dose and image quality in X-ray phase contrast breast imaging," 2017. [PDF]
9. D. de Souza António, "Dose assessment and reconstruction algorithm optimization in simultaneous breast and lung CT imaging," 2018. [PDF]
10. P. Wei, "Radiomics, deep learning and early diagnosis in oncology," 2021. ncbi.nlm.nih.gov
11. M. C. Florkow, K. Willemsen, "Magnetic resonance imaging versus computed tomography for three-dimensional bone imaging of musculoskeletal pathologies: a review," Resonance Imaging, 2022. wiley.com
12. J. Ren, J. G. Eriksen, J. Nijkamp, and S. S. Korreman, "Comparing different CT, PET and MRI multi-modality image combinations for deep learning-based head and neck tumor segmentation," Acta Oncologica, 2021. tandfonline.com
13. Z. Chen, K. Pawar, M. Ekanayake, C. Pain, and S. Zhong, "Deep learning for image enhancement and correction in magnetic resonance imaging—state-of-the-art and challenges," *Journal of Digital Imaging*, 2023. springer.com
14. A. Chhetri, X. Li, and J. V. Rispoli, "Current and Emerging Magnetic Resonance-Based Techniques for Breast Cancer," 2020. ncbi.nlm.nih.gov
15. M. Micek, D. Aebisher, and J. Surowka, "Applications of T1 and T2 relaxation time calculation in tissue differentiation and cancer diagnostics—a systematic literature review," Frontiers in, 2022. frontiersin.org
16. S. Sethi, S. A. Giza, E. Goldberg, "Quantification of 1.5 T T1 and T2* Relaxation Times of Fetal Tissues in Uncomplicated Pregnancies," Resonance Imaging, 2021. researchgate.net
17. N. E. Hänninen, T. Liimatainen, M. Hanni, and O. Gröhn, "Relaxation anisotropy of quantitative MRI parameters in biological tissues," *Scientific Reports*, 2022. nature.com

18. J. Vasanth Wason and A. Nagarajan, "Image processing techniques for analyzing CT scan images towards the early detection of lung cancer," 2019. ncbi.nlm.nih.gov
19. A. Berrington de Gonzalez and E. Pasqual, "Epidemiological studies of CT scans and cancer risk: the state of the science," The British Journal of…, 2021. nih.gov
20. R. A. Schulz, J. A. Stein, and N. J. Pelc, "How CT happened: the early development of medical computed tomography," Journal of Medical Imaging, 2021. spiedigitallibrary.org
21. S. A. Fedewa, E. A. Kazerooni, J. L. Studts, "State variation in low-dose computed tomography scanning for lung cancer screening in the United States," JNCI: Journal of the..., 2021. oup.com
22. P.S. Freitas, C. Janicas, and J. Veiga, "Imaging evaluation of the liver in oncology patients: A comparison of techniques," World Journal of ..., 2021. nih.gov
23. H. Hricak, M. Abdel-Wahab, R. Atun, and M. M. Lette, "Medical imaging and nuclear medicine: a Lancet Oncology Commission," Lancet Oncology, 2021. [HTML]
24. A. B. Abdusalomov, M. Mukhiddinov, and T. K. Whangbo, "Brain tumor detection based on deep learning approaches and magnetic resonance imaging," Cancers, 2023. mdpi.com
25. F. Wu, J. Fan, Y. He, A. Xiong, J. Yu, Y. Li, Y. Zhang, "Single-cell profiling of tumor heterogeneity and the microenvironment in advanced non-small cell lung cancer," Nature, 2021. nature.com
26. A. Pulumati, A. Pulumati, and B.S. Dwarakanath, "Technological advancements in cancer diagnostics: Improvements and limitations," Cancer, 2023. wiley.com
27. JGJ Lftta, ANAA Zahra, and AHJ Ashour, "X-Rays and Their Uses on The Human Body," *Current Clinical and*, 2024. visionpublisher.info
28. MT Mustapha, B. Uzun, and D.U. Ozsahin, "A comparative study of X-ray based medical imaging devices," in Making Theories in ..., Elsevier, 2021. [HTML]
29. B. H. Tomaihi, H. A. Sabai, and M. A. Aqeli, "Development Of X-Ray Imaging Techniques To Improve Image Quality," Journal of Positive, 2022. 184.168.115.16
30. A. Pulumati, A. Pulumati, B. S. Dwarakanath, A. Verma et al., "Technological advancements in cancer diagnostics: Improvements and limitations," 2023. ncbi.nlm.nih.gov
31. A. Upadhyay, "Cancer: An unknown territory; rethinking before going ahead," Genes & diseases, 2021. sciencedirect.com
32. D. Crosby, S. Bhatia, K. M. Brindle, L. M. Coussens, and C. Dive, "Early detection of cancer," *Science*, 2022. science.org
33. R. C. Fitzgerald, A. C. Antoniou, L. Fruk, and N. Rosenfeld, "The future of early cancer detection," Nature medicine, 2022. [HTML]