Revolutionising Medical Imaging with Computer Vision and Artificial Intelligence

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TABLE OF CONTENTS

CHAPTER 1

INTRODUCTION TO MEDICAL IMAGING AND ARTIFICIAL INTELLIGENCE

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Abstract

This chapter provides a comprehensive overview of the symbiotic relationship between medical imaging and artificial intelligence (AI) in the field of healthcare. It begins by tracing the historical evolution of medical imaging modalities, from the pioneering days of radiography to contemporary magnetic resonance imaging (MRI) and ultrasound techniques. This historical context sets the stage for understanding the transformative impact of AI in healthcare. The chapter delves into the intricacies of image acquisition, emphasizing the critical role of data preprocessing to ensure high-quality medical images. It elucidates the challenges associated with medical image data, including noise and artifacts, and highlights how AI can mitigate these issues. Readers are introduced to the fundamental concepts of AI, making clear the distinction between narrow and general AI, and outlining its growing role in healthcare. The narrative progresses to elucidate AI's multifaceted applications in medical imaging, encompassing disease detection, diagnosis, personalized treatment planning, image interpretation, and workflow optimization. Concluding with a glimpse into the future, the chapter highlights the potential synergy between AI and emerging imaging technologies, such as 3D printing, point-of-care diagnostics, and telemedicine. It underscores the significance of ongoing research and innovation, suggesting that the trajectory of medical imaging and AI is destined for continued growth and transformative change in healthcare practices. In

essence, this chapter serves as a foundational guide for readers seeking to understand the synergy between medical imaging and AI, offering insights into the history, challenges, applications, and ethical dimensions of this dynamic field, and sparking curiosity for the unfolding possibilities in the future of healthcare.

Keywords: Medical Imaging Modalities Magnetic Resonance Imaging, Emerging Imaging Technologies, Positron Emission Tomography, Mammography, X-ray Imaging

1. Introduction

Medical imaging is the ability to provide a non-invasive, detailed visualized image of the subject’s (human body's) internal structures, to help healthcare professionals (Doctors, Nurses, Medical Physicists, and Technologists) make decisions about patient care, treatment procedures, etc **[1, 2]**.

Medical imaging can detect diseases and abnormalities at an early stage, sometimes before symptoms become clearly visible. Computed Tomography (CT) **[3-6]**, Magnetic Resonance Imaging (MRI) **[7]**, Positron Emission Tomography (PET) CT **[8]**, Mammography **[9, 10]**, X-ray Imaging **[11]**, Ultrasound **[12-15]** etc. are some of the examples of medical imaging techniques **[16]**.

Medical imaging is a transformative field that allows healthcare professionals to visualize the internal structures and functions of the human body without invasive procedures. It plays a pivotal role in diagnosis, treatment planning, and monitoring the progression of diseases. By harnessing various imaging modalities, medical imaging provides a non-intrusive means of exploring the intricacies of anatomy and pathology.

The roots of medical imaging can be traced back to the late 19^{th} century with the discovery of X-rays by Wilhelm Roentgen in 1895 **[17]**. Roentgen's accidental revelation paved the way for a revolutionary era in medicine, enabling the visualization of internal structures, such as bones and soft tissues, for the first time. Radiography quickly became a cornerstone in medical diagnostics.

- Medical imaging helps researchers to study disease mechanisms, test new treatments, and train healthcare professionals. Medical students and practitioners use imaging for a better understanding of anatomy and pathology.

- In telemedicine, medical imaging can be shared digitally with experts in remote locations for consultations and second opinions **[18]**.
- In emergency situations, medical imaging can rapidly assess injuries, internal bleeding, and fractures.
- Visual representations of medical imaging can help patients understand their diagnoses. It satisfies the doctor parallelly with the patient and her/his family members.
- In cardiology, imaging techniques like echocardiography and cardiac MRI aid in evaluating heart function and identifying cardiovascular diseases. In oncology, medical imaging plays a crucial role in tumour detection, staging, and treatment response assessment. Neuroimaging techniques, including CT and MRI, provide vital information for diagnosing neurological disorders, such as strokes and brain tumours **[19]**.

2. The Confluence of Medicine and Technology

The convergence of medicine and technology has significantly reshaped the landscape of healthcare, revolutionizing patient care, diagnosis, treatment, and research. This dynamic interplay between medicine and technology has ushered in a new era of precision medicine, personalized healthcare, and improved patient outcomes. The synergy between these two fields is driven by the rapid advancements in medical devices, digital health solutions, telemedicine, and the integration of artificial intelligence (AI) into healthcare systems **[20-22]**.

Historically, medicine and technology have been intertwined since the advent of medical instruments and diagnostic tools. The stethoscope, invented by René Laennec in the early 19th century, marked one of the earliest instances of technology aiding medical practice. Over the years, innovations in imaging, such as X-rays, MRI, and ultrasound, have been instrumental in non-invasively visualizing internal structures, aiding in the diagnosis and treatment of various medical conditions. These developments highlight the historical evolution of medical technology as a critical part of modern medicine.

In recent decades, the rapid digitization of healthcare has accelerated the confluence of medicine and technology. Electronic health records (EHRs) have streamlined the management of patient data, enabling healthcare providers to access comprehensive medical histories, medications, and test results in real-time. Telemedicine has brought healthcare to remote and underserved areas, allowing patients to consult with healthcare professionals via video conferencing, thus increasing accessibility to care.

The introduction of AI has been a transformative force in medicine. Machine learning algorithms are increasingly being used for medical image analysis, aiding radiologists in detecting abnormalities in radiographic and MRI images. AI-driven diagnostic tools are being developed to assist in the early detection of diseases like cancer and provide more accurate treatment recommendations. Moreover, AI-powered predictive models help in forecasting disease outbreaks and optimizing hospital resource allocation **[22]**.

Genomics is another area where technology has propelled medicine forward. Advances in DNA sequencing have made it possible to understand the genetic basis of diseases, paving the way for personalized medicine. Tailoring treatment strategies based on an individual's genetic profile is increasingly becoming a reality, offering more effective and targeted therapies.

Wearable health technologies, like fitness trackers and smartwatches, have empowered individuals to take control of their health by monitoring vital signs, physical activity, and sleep patterns. These devices provide real-time data that can be shared with healthcare providers for a more holistic understanding of a patient's health status.

The confluence of medicine and technology has not been without challenges. Data security and patient privacy concerns, as well as regulatory issues, are paramount in this era of digital health. Striking a balance between harnessing the benefits of technology while safeguarding patient information remains a key challenge.

All imaging techniques provide high-resolution images that enable healthcare professionals to precisely pinpoint the location and injury. This accuracy is invaluable for treatment planning and surgical procedures **[23]**.

- Interventional radiology is the application of medical imaging techniques for guiding doctors to diagnose and treat problems. Real-time imaging guidance to perform procedures like angioplasty, embolization, and biopsies with minimal trauma to the patient.
- At present, multi-modal medical applications play an important role in health care units for, video, audio, and picture analysis. A multi-model medical applicator is software that combines various data

sources, such as medical images, patient records, sensor data, clinical notes, and more, to provide a complete view of a patient's health and easy to aid medical decision-making for medical employees **[23]**.

- With the development of medical technology and the modernization of medical equipment, an enormous amount of medical data has emerged. According to this, medical data can be broadly classified into three main categories **[23]**.
  - ➢ Clinical text data: It includes structured test data such as haemoglobin and urine routine etc **[23]**.
  - ➢ Unstructured text data includes patient complaints and pathology texts recorded by doctors **[23]**.
  - ➢ Image and waveform data: It included imaging data such as ultrasound images, CT images, MRI images, and signal data such as ECG and EEG **[23]**.

3. The Evolution of Medical Imaging

Wilhelm Conrad Roentgen, a German Physicist, discovered X-rays in 1895. X-rays are a type of electromagnetic radiation that can pass through materials and provide images of the internal organs of a human body. This breakthrough completely changed medicine and helped advance medical imaging. The ability to create and regulate X-rays for medical imaging was made possible by British Physicist Sir William Crookes' discovery of the X-ray machine in 1896. Radiography, which creates X-ray images of the human body, began widely used in the early 1900s. This method was applied to discover diseases like tuberculosis, find foreign objects, and diagnose fractures. The first computed axial tomography (CT) scanner began to be utilized in the 1970s for the goal of obtaining fine-grained cross-sectional images of the human body.

Technological Advancements for the Evolution of Medical Imaging

In recent years medical image quality has greatly improved due to advanced technology. AI and machine learning algorithms have a significant role in image analysis.

- ➢ **3D Imaging:** Three-dimensional imaging technology produces more widely spread images in different directions **[24]**. 3D image help to visualize arteries, vessels, organs body parts, and abnormal morphology more widely **[24]**.

- **High-Resolution Imaging:** Advances in imaging hardware, such as more advanced detectors used in MRI and CT scanners, have led to higher-resolution images. This makes it easier to visualize fine structures and early abnormality detection.
- **Functional Imaging:** Functional imaging techniques like PET (Positron Emission Tomography) and fMRI (functional Magnetic Resonance Imaging) provide insight image of the physiological and metabolic processes inside the body and help to evaluate diseases at a functional level.
- **Contrast Agents:** According to the requirement contrast agents are used in medical imaging procedures for various imaging modalities to enhance the visibility of specific tissues or abnormalities.
- **Hybrid Imaging:** PET-CT, and SPECT-CT, are examples of binning different imaging modalities. They provide both anatomical and functional details in one information in a single scan, improving diagnostic accuracy.
- **Portable and Point-of-Care Devices:** Portable and point-of-care imaging devices have expanded access to medical imaging in remote or underserved areas, enabling early diagnosis and treatment.

Recent applications of deep learning in medical image analysis involve various computer vision-related tasks such as classification, detection, segmentation, and registration. Among them, classification, detection, and segmentation are fundamental and most widely used tasks **[25]**.

Medical imaging database is a platform for the collection of medical images and related data used for research, diagnosis, and medical education. For the evaluation or comparison of retrieval systems **[26, 27],** PET tests and slides from 41 biopsies were unable to produce any statistically meaningful results **[28]**.

First, typical medical images are obtained using a variety of imaging techniques, including computed tomography (CT), magnetic resonance imaging (MRI), ultrasound (US), and positron emission tomography (PET). Before characteristics are extracted, pictures are homogenized in the second step of preprocessing **[28]**. In terms of pixel spacing, grey-level intensities, histogram bins, etc., homogenization is performed. Segmentation, the third phase, involves calculating the volume of the region of interest (ROI). Clinical requirements are used to define ROIs **[28-30]**.

4. Medical Imaging Modalities

Medical imaging has transformed the practice of medicine by providing non-invasive visualization of internal structures, enabling accurate diagnosis, treatment planning, and monitoring of various medical conditions. The field of medical imaging encompasses a wide range of modalities, each with its unique principles, applications, and advantages **[31]**. Some of the most commonly used medical imaging modalities are briefly described as follows.

Radiography and X-Ray Imaging

Radiography involves the use of X-rays, which are high-energy electromagnetic waves, to create images of the human body. X-rays are passed through the body, and the resulting attenuation patterns are recorded on X-ray-sensitive film or digital detectors.

Radiography is widely used for the imaging of bones, the chest, and the abdomen. It is an essential tool for diagnosing fractures, evaluating lung conditions, and identifying gastrointestinal abnormalities.

Now a days digital radiography has largely replaced traditional film-based radiography, offering immediate image acquisition and reduced radiation exposure. Portable X-ray machines have improved point-of-care imaging in critical settings.

Computed Tomography (CT) Scans

CT scans use a rotating X-ray beam and detectors to create cross-sectional images of the body. Computer algorithms reconstruct these images into detailed, three-dimensional representations **[32]**.

CT scans are instrumental in visualizing soft tissue and bony structures. They are vital for diagnosing injuries, detecting tumours, and guiding interventions.

Dual-energy CT scans provide improved tissue characterization, and low-dose CT protocols reduce radiation exposure. CT angiography is widely used for vascular imaging and coronary artery assessment.

Figure 1: Magnetic Resonance Imaging (MRI) Scanner

Magnetic Resonance Imaging (MRI)

MRI employs strong magnetic fields and radio waves to create detailed images. It relies on the behavior of hydrogen nuclei in the body's water and fat content **[7, 33]**. A typical Magnetic Resonance Imaging (MRI) Scanner is shown in **Figure 1** and its Basic Principle is shown in **Figure 2**.

MRI excels in soft tissue imaging and is essential for diagnosing neurological disorders, musculoskeletal injuries, and various abdominal and pelvic conditions.

Functional MRI (fMRI) reveals brain activity, while diffusion-weighted MRI helps evaluate tissue microstructure. Ultra-high field MRIs offer enhanced spatial resolution.

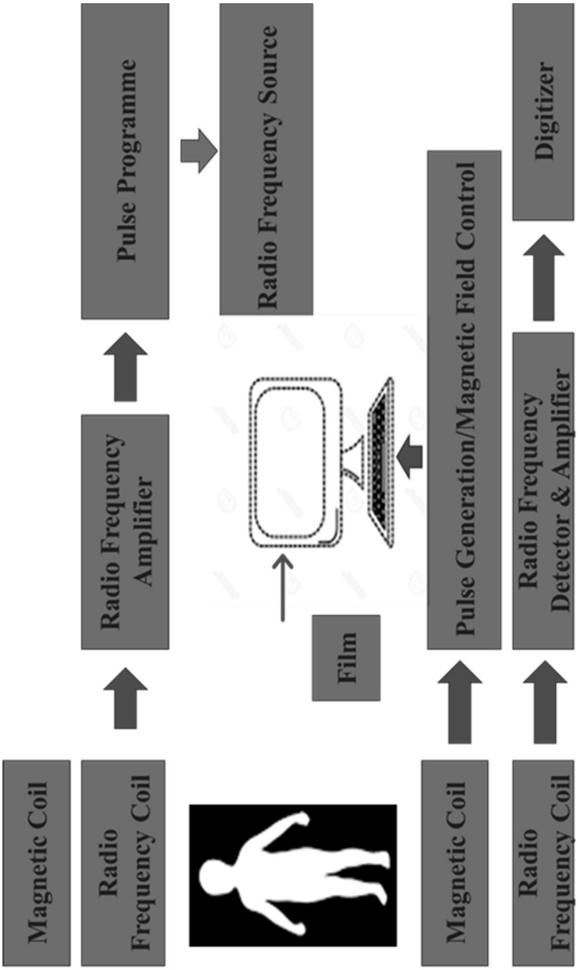

Figure 2: Basic Principle of Magnetic Resonance Imaging (MRI).

Ultrasound

Ultrasound uses high-frequency sound waves that bounce off internal structures to create real-time images. A transducer emits and receives these waves.

Ultrasound is versatile, used in obstetrics for fetal monitoring, in cardiology for echocardiography, and for evaluating abdominal organs, blood vessels, and soft tissues **[35]**.

3D and 4D ultrasound provide volumetric images, while Doppler ultrasound measures blood flow velocity. Portable ultrasound devices have expanded access to imaging in various clinical settings **[35]**.

Nuclear Medicine Imaging

Nuclear medicine involves the administration of radioactive tracers that emit gamma rays. Special detectors capture these rays to create images **[36]**.

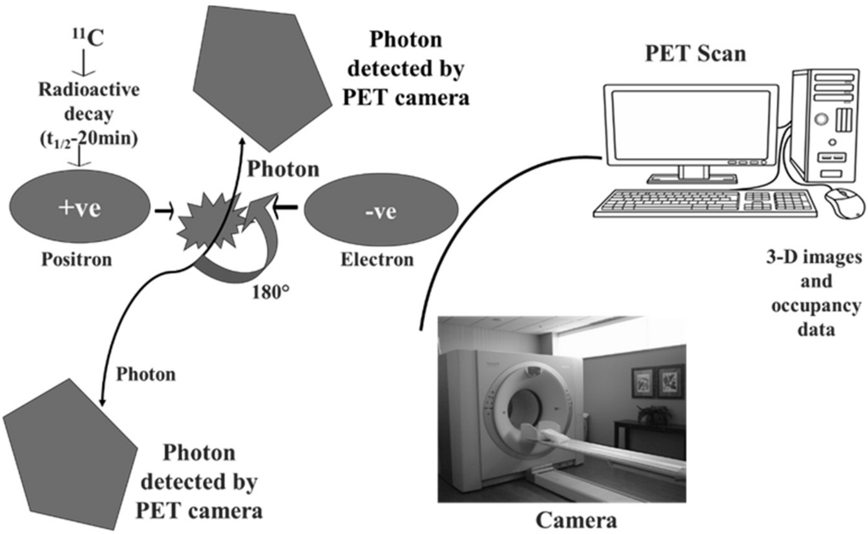

Figure 3: Basic principle of PET scan: (1) a positive electron (positron) is emitted by radioactive decay of radioisotope, for example, carbon-11; (2) this positron hits an electron present in the tissue to be analysed and emits two photons having low energy; (3) scintillation crystals are present in the PET camera to absorb this emitted photon with low energy; (4) the light is produced that is converted into another signal such as electrical signals used by the computer system to produce 3D images.

Nuclear medicine is utilized for functional imaging, with applications in oncology, cardiology, and neurology **[36]**. Common procedures include positron emission tomography (PET) [8] and single-photon emission computed tomography (SPECT).

Hybrid systems like PET-CT and SPECT-CT combine anatomical and functional information. Basic principles of PET-CT scan are shown in **Figure 3**. New radiopharmaceuticals and tracers offer improved specificity and sensitivity in disease detection.

Mammography

Mammography is an X-ray-based imaging modality specifically designed for breast tissue. It uses low-dose X-rays to detect breast abnormalities, such as tumours or microcalcifications.

Mammography is primarily used for breast cancer screening and early detection. It is crucial for breast health and women's health programs **[37]**.

Digital mammography and digital breast tomosynthesis (3D mammography) provide enhanced image quality and better lesion detection. Contrast-enhanced mammography is a promising technique for evaluating breast lesions.

Fluoroscopy

Fluoroscopy is an X-ray-based real-time imaging technique. It involves continuous X-ray exposure to monitor the motion of internal structures.

Fluoroscopy is used for various procedures, such as barium swallow studies, cardiac catheterization, and interventional radiology. It provides dynamic imaging of organs and tissues.

Digital fluoroscopy systems offer improved image quality and reduced radiation exposure. Image-guided interventions benefit from real-time fluoroscopic guidance.

Endoscopy

Endoscopy employs a flexible or rigid tube with an attached camera and light source to visualize internal organs and structures.

Endoscopy is utilized for the direct visualization of the gastrointestinal tract, respiratory system, and other cavities. It aids in diagnosis, biopsy, and treatment.

Video endoscopes provide high-definition images, and capsule endoscopy offers non-invasive exploration of the gastrointestinal tract **[39]**. Advances in robotic endoscopy promise enhanced precision and manoeuvrability.

Infrared and Thermal Imaging

Infrared and thermal imaging capture heat radiation from the body to create images based on temperature differences.

Thermal imaging is used in breast health for adjunctive breast cancer screening and in thermography to assess musculoskeletal conditions.

Emerging applications include fever screening and the monitoring of skin temperature in wound care and sports medicine **[40]**.

Optical Coherence Tomography (OCT)

OCT utilizes low-coherence light to create high-resolution cross-sectional images. It is often used in ophthalmology and cardiology.

OCT provides detailed images of the retina and optic nerve in ophthalmology and helps assess coronary artery disease in cardiology.

Swept-source OCT and extended-depth OCT improve imaging capabilities, while handheld and portable OCT devices enhance point-of-care applications **[41]**.

Advancements in medical imaging modalities continue to drive improvements in diagnostic accuracy, treatment planning, and patient care. Key trends in medical imaging include:

Artificial Intelligence (AI) Integration: AI is increasingly used for image analysis, aiding in the detection and diagnosis of diseases. Machine learning algorithms can analyze vast datasets and assist radiologists in identifying abnormalities **[42-48]**.

Personalized and Precision Medicine: Advances in genomics and imaging are fostering personalized treatment plans. Physicians can tailor therapies to an individual's genetic makeup and disease characteristics.

Hybrid Imaging: Combining multiple modalities, such as PET-CT and SPECT-CT, offers comprehensive information by fusing anatomical and functional data, improving diagnosis and treatment monitoring.

Miniaturization and Portability: The development of compact, portable imaging devices is expanding access to medical imaging in remote and resource-limited settings.

Theranostics: Theranostic imaging combines diagnostic and therapeutic capabilities in a single approach. It allows for targeted drug delivery and precise treatment monitoring.

Quantitative Imaging: Quantitative imaging techniques aim to provide objective measurements of tissue properties, allowing for better disease characterization and tracking of treatment responses.

5. Image Acquisition and Preprocessing in Medical Imaging

Medical imaging plays a pivotal role in modern healthcare, providing valuable insights into the human body's internal structures and functions. The effectiveness of medical imaging relies not only on the sophisticated technologies of various imaging modalities but also on the crucial steps of image acquisition and preprocessing **[49-55]**. The fundamental processes of obtaining medical images and the subsequent preprocessing steps that ensure the production of high-quality, diagnostically relevant images are described as follows:

Image Acquisition: The Foundation of Medical Imaging

Modalities and Techniques

The diversity of medical imaging modalities demands an understanding of the principles behind each technology. X-ray-based modalities, such as radiography and computed tomography (CT), utilize ionizing radiation to generate images, whereas magnetic resonance imaging (MRI) leverages magnetic fields and radiofrequency pulses to create detailed soft tissue images. Ultrasound relies on sound waves for imaging, while nuclear medicine involves the use of radioactive tracers.

Image Resolution and Contrast

Image resolution, the ability to distinguish fine details, is a critical aspect of image acquisition. Spatial resolution in modalities like CT and MRI is influenced by factors such as slice thickness and pixel size. Contrast resolution, the ability to differentiate between adjacent structures, is equally important. Techniques like dual-energy CT enhance contrast resolution by providing information about tissue composition.

Signal-to-noise ratio (SNR) and Artifacts

Achieving an optimal signal-to-noise ratio is essential for image quality. A higher SNR improves the visibility of anatomical structures and enhances diagnostic accuracy. Various factors, including imaging parameters and equipment quality, influence SNR. Additionally, minimizing artifacts—unwanted distortions or discrepancies in the image-ensures accurate representation. Common artifacts include motion artifacts, metal artifacts, and aliasing artifacts.

Three-Dimensional Imaging

Advancements in medical imaging have led to an increasing emphasis on three-dimensional (3D) imaging. Modalities like CT and MRI can acquire volumetric datasets, allowing for multiplanar reconstructions and 3D visualizations. This capability enhances the clinician's ability to assess complex anatomical structures and plan interventions with greater precision.

Interventional Imaging

In interventional procedures, real-time imaging is crucial for guidance. Fluoroscopy, a dynamic X-ray imaging technique, provides continuous visualization during procedures like angiography and catheter-based interventions. In these settings, acquiring high-quality images with minimal radiation exposure is paramount.

Radiation Dose Considerations

Given the ionizing nature of X-rays, managing radiation dose exposure is a significant concern in medical imaging. Various strategies, including dose optimization techniques, iterative reconstruction algorithms, and the use of low-dose protocols, aim to minimize patient exposure while maintaining diagnostically useful images.

Image Preprocessing: Enhancing Diagnostic Accuracy

Noise Reduction

Noise, unwanted variations in pixel intensity, can compromise image quality and affect diagnostic interpretation. Image denoising techniques, such as filtering algorithms, are employed during preprocessing to reduce noise while preserving diagnostically relevant information. Adaptive filtering methods, which adjust to local variations in image intensity, are particularly effective.

Contrast Enhancement

Enhancing image contrast is essential for improving visibility and highlighting specific anatomical structures. Contrast adjustment techniques, such as histogram equalization and contrast stretching, redistribute pixel intensities to cover the full dynamic range. This ensures that subtle details are not lost in regions of low contrast.

Image Registration

In cases where multiple imaging modalities or time points are involved, image registration aligns the images spatially. This is crucial for combining information from different sources, such as in the fusion of anatomical and functional images. Registration algorithms, including rigid and deformable methods, ensure accurate alignment.

Artifact Correction

Artifacts introduced during image acquisition, such as motion artifacts or metal streaks in CT scans, can compromise diagnostic accuracy. Preprocessing techniques, such as motion correction algorithms and metal artifact reduction methods, are applied to mitigate these issues and enhance image quality.

Image Segmentation

Segmentation involves partitioning an image into meaningful regions, such as organs or lesions. Automated segmentation algorithms assist in delineating structures of interest, facilitating quantitative analysis, and aiding in treatment planning. Manual or semi-automated segmentation may also be performed in certain cases for precision.

Image Fusion

The integration of information from multiple imaging modalities, known as image fusion, provides a comprehensive view of the patient's anatomy and pathology. Fusion techniques, such as PET-CT or SPECT-CT, combine functional and anatomical data, offering valuable insights for diagnosis and treatment planning.

Correction for Non-uniformities

Non-uniformities in image intensity, commonly seen in MRI images due to variations in the magnetic field, can be corrected during preprocessing. Techniques like bias field correction ensure that the image intensity accurately reflects the underlying tissue properties.

Computer-Aided Diagnosis (CAD)

CAD systems, incorporating machine learning algorithms, are increasingly employed in image preprocessing. These systems can automatically detect abnormalities, assisting radiologists in their diagnostic interpretation. CAD applications range from the detection of lesions in mammography to the identification of neurological abnormalities in MRI scans.

6. Challenges and Future Directions

Big Data and AI Integration

The increasing volume and complexity of medical imaging data necessitate advanced data management and analysis tools. Artificial intelligence (AI) and machine learning play a pivotal role in automating image analysis, aiding in diagnosis, and predicting patient outcomes. Deep learning algorithms, in particular, have shown promise in tasks such as image segmentation and pathology detection.

Standardization and Interoperability

Standardizing imaging protocols and ensuring interoperability between different imaging systems remain challenges. Efforts to establish standardized imaging protocols help in harmonizing data across diverse healthcare settings, allowing for more consistent and comparable results.

Ethical and Regulatory Considerations

As AI becomes more integrated into medical imaging, ethical considerations surrounding data privacy, algorithmic bias, and patient consent gain prominence. Regulatory frameworks must evolve to ensure the responsible development and deployment of AI technologies in healthcare.

Advanced Imaging Techniques

Emerging imaging techniques, such as photoacoustic imaging and quantitative imaging biomarkers, offer novel approaches for disease characterization. These techniques hold the potential to provide additional information beyond traditional anatomical imaging.

Personalized Imaging

Advances in genomics and personalized medicine drive the need for imaging approaches tailored to individual patient characteristics. Imaging protocols that consider genetic, molecular, and clinical information aim to provide more personalized and targeted diagnostics and treatment strategies.

7. Applications of AI in Medical Imaging

Radiology has been greatly changed by computer vision and artificial intelligence (AI). Artificial intelligence has been used in imaging and diagnostic procedures since 1980. In the medical imaging device, some machine learning methods are applied. Convolutional neural networks (CNN), support vector machines (SVM), and principal component analysis (PCA) are a few examples of algorithms. In order to classify the image, the algorithm is supposed to identify the features **[56]**.

Neural networks and deep learning are two key ideas that make up artificial intelligence (AI), which is a collection of many different types of techniques and phenomena **[57]**. These made it possible for neural networks to imitate the functions of the human brain, allowing AI to learn difficult tasks through a vast amount of training data **[57]**. Some of the applications of AI in medical imaging are briefly described as follows:

- AI algorithms rapidly and accurately identify and categorize abnormalities in X-rays and other types of medical pictures like CT scans, and MRIs. This includes spotting tumours, fractures, or other abnormalities **[58]**.

- AI can provide precise measurements of structures or lesions within images and diagnose the disease **[58]**.
- AI can generate structured reports by extracting relevant information from images.
- AI algorithms can improve image quality by reducing noise, enhancing contrast, and correcting artifacts, leading to better diagnostic accuracy [57].
- AI can eliminate patient motion artifacts during image acquisition, reducing the need for repeat scans **[56]**.
- AI-driven screening tools can help to detect diseases at an earlier stage, such as lung cancer on chest by X-rays **[56]**.
- AI does image classification, which is a crucial function in computer-aided diagnosis. Typical clinical uses for image classification problems include diagnosing skin conditions in dermatology **[58-59]** identifying eye conditions in ophthalmology **[58, 61, 62]**, and diagnosing illnesses of the cornea **[58, 63]**.
- AI helps in improvement in research area over traditional machine learning. In radiology, Computed vision AI is a powerful tool for enhancing medical diagnosis, treatment planning, and overall patient care.
- Computer vision AI can help radiologists to detect and diagnose medical conditions by analysing medical images such as X-rays, CT scans, MRIs, and ultrasounds. It can identify abnormalities that might be overlooked by human eyes, leading to more accurate diagnoses.
- Computer vision AI can be applied to detect medical conditions, including cancer, fractures, neurological disorders, cardiovascular diseases.
- AI can enhance the quality of medical images by reducing noise, improving contrast, and optimizing image parameters for better visualization.
- These AI systems can integrate Picture Archiving and Communication Systems (PACS) and Electronic Health Records (EHR) to provide radiologists with a streamlined workflow.
- It can support telemedicine by enabling remote diagnosis and consultation, especially in the remote areas.

AI in radiology enhance the accuracy, efficiency, and effectiveness of medical imaging and diagnosis. Its scope is broad, encompassing various aspects of image analysis, disease detection, treatment planning, and research, ultimately leading to enhance patient care and outcomes in the field of radiology.

8. Current Challenges in Medical Imaging

Challenges in medical imaging include concerns about the health risks associated with ionizing radiation from techniques like X-rays and CT scans, especially when multiple scans are needed. To mitigate these risks, efforts are made to reduce radiation exposure without compromising image quality, which is a significant challenge. Moreover, medical imaging is not suitable for pregnant women due to potential harm. The cost of high-end imaging equipment is another obstacle, limiting access to diagnostic and therapeutic tools in certain regions or healthcare facilities. Incorporating AI in medical imaging faces several major hurdles. First, there is a need to develop AI algorithms that are both reliable and trustworthy while ensuring transparency and fairness. Data governance is another crucial issue, demanding the establishment of best practices for secure data sharing to protect patient privacy. Lastly, encouraging innovation in digital AI healthcare technologies requires stakeholders to agree on effective strategies for promoting and supporting progress in this field **[58]**.

9. Future Trends and Innovation

Imaging devices powered by artificial intelligence

The ever-increasing utilization of AI in health imaging is showcasing its remarkable potential as a valuable clinical resource across various medical applications, particularly in assisting healthcare professionals in cancer management **[64, 65]**. These AI tools provide a wide range of capabilities, including the prediction of complex and diverse data patterns, forecasts of tumour characteristics, correlations with the spread of tumours, risk assessment for individual patients **[66, 67]**, and predictions of treatment responses **[68, 69]**. In support of these advancements, numerous health imaging repositories have been established **[70-72]**. One of the most prominent among them is the Cancer Imaging Archive (TCIA) **[73, 74]**, which primarily focuses on archiving cancer-related imaging data.

AI Cancer Management Tools

AI applications have been developed to assist healthcare professionals in accurately predicting critical clinical endpoints (CEPs) for cancer patients. These tools encompass various functionalities such as image standardization and enhancement, tissue delineation, radiomics feature extraction, treatment assignment, and prognostic forecasting **[75-78]**. The critical clinical endpoints for different types of cancer and the required therapy are collected in **Table 1**.

Table 1: AI Cancer Management Tools

Type of cancer	Current therapy	CEPs
Lung	Immunotherapy	Predicting patients with a positive response to immunotherapy
Colorectal	Surgery/Neoadjuvant/Chemotherapy	**Rectal Cancer** prediction of patient with a positive response to Chemoradiation and classification in different treatment response sub groups **Colon cancer** Identification of patient higher risk of distant metastases at an early time point .
Breast	Surgery, Radiation and systemic therapy	Diagnostic performance and cancer staging
Prostate	Wide range due to heterogeneity Prostate	Early staging/Grading

Integration with Electronic Health Records (EHR)

Integrating Electronic Health Records (EHR) with Patient-Generated Health Data (PGHD) is a pivotal step in modern healthcare. PGHD, the health records individuals create for themselves outside clinical settings, can be harnessed to enhance operational efficiency across care environments, improve access to high-quality healthcare, and enhance patient safety **[75, 78]**. The adoption of Health Information Technology (HIT) has the potential to yield substantial cost savings, better management of chronic conditions, a reduction in healthcare disparities, and ultimately, an enhancement in health outcomes **[78, 79]**. However, clinicians remain somewhat reluctant to fully embrace electronic health records (EHRs) and other health information technologies in ambulatory care settings.

Table 2: Benefits project and potential obstacles to implementing Health Information Technology (HIT).

Benefit Projects and Potential Obstacles in Implementing Health Information Technology (HIT)	
Projected Advantage	**Potential Obstacle**
Higher quality of health care	Initial price
Decrease of medication error	Physician opposition
Enhanced patient health outcomes	Lack of funding
Lowering of health inequalities	Fear of change
Cost saving	Security and privacy
Improved patient safety	Concern of return on investment
Improved management of chronic diseases	Inadequate eyesight

Electronic Health Records (EHRs) present a multitude of benefits for both patients and healthcare providers. Their implementation and utilization can revolutionize patient care by reducing medical errors and preventing unnecessary surgeries. This transformation in patient treatment can enhance health outcomes and bolster patient safety **[80-87]**. While approximately 13 to 20.5 percent of healthcare practitioners are said to utilize "basic" EHR systems, encompassing only fundamental functionalities such as patient information management and medication orders, **[88-97]** a comprehensive EHR system comprises order management, results handling, clinical decision support, and health information data.

10. Conclusion

Healthcare could become far more productive and efficient if computer vision and artificial intelligence (AI) are used to transform medical imaging. AI-powered medical imaging can spot minute irregularities in X-rays, assisting in the early identification of conditions like cancer, heart disease, and neurological problems. This early identification can greatly enhance patient treatment process and outcomes. Compared to human radiologists, AI algorithms can process medical images far more quickly, reduce the time needed to make diagnoses and administer treatments to patients **[98]**. This is essential during emergencies and when prompt care is essential. A higher level of precision may be attained by AI systems while analysing images, which lowers the possibility of human error. AI work automatically routine tasks in medical imaging, such as image segmentation and annotation, freeing up healthcare professionals, doctors, medical physicist, technologist to focus on more complex and value work for the more benefit of the patient. Through process optimization, increased accuracy, decreased necessity for repeated tests, and reduce amount of unnecessary exposure. AI-driven medical imaging can result in cost savings within healthcare delivery. Computer vision algorithms can detect and highlight abnormalities, such as tumours, fractures, or lesions, in medical images like X-rays, CT scans, MRIs, and ultrasounds. Radiologists can easily identify and diagnose the disease more accurately. Artificial intelligence (AI) in medical imaging has the potential to revolutionize healthcare by enhancing productivity and efficiency. The key points underscoring this transformation are AI-powered medical imaging can identify subtle anomalies in X-rays, aiding in the early detection of conditions like cancer, heart disease, and neurological issues. This early recognition significantly improves patient treatment and outcomes. AI algorithms can analyse medical images much faster than human radiologists, reducing the time required for diagnosis and treatment. This speed is crucial in emergencies and situations requiring prompt care. AI systems can achieve a higher level of precision in image analysis, reducing the likelihood of human error in diagnosis and treatment planning. AI automates routine tasks in medical imaging, such as image segmentation and annotation, freeing healthcare professionals, including doctors, medical physicists, and technologists, to concentrate on more complex and valuable aspects of patient care. Through process optimization, increased accuracy, reduced need for repeat tests, and minimized unnecessary exposure, AI-driven medical imaging can lead to cost savings in healthcare delivery. Automated Detection: Computer vision algorithms can automatically identify and highlight abnormalities, such as tumours, fractures, or lesions, in various medical images, including X-rays, CT scans, MRIs, and ultrasounds. Radiologists can then make more accurate diagnoses. In summary, the integration of AI and computer vision in medical imaging holds promise for early disease detection, faster and more accurate diagnoses, improved workflow, cost savings, and automated detection of abnormalities, ultimately benefiting both healthcare providers and patients.

Looking Ahead: The Future of Healthcare: Remote monitoring

Computer vision and AI have revolutionized the realm of healthcare, enabling not only remote-controlled surgeries but also the continuous monitoring of patients through wearable devices and high-resolution miniature cameras. This technology plays a crucial role in facilitating ongoing health assessment, early detection of medical issues, and particularly benefits the monitoring of chronic conditions and elderly patients. Nearly all healthcare professionals, including radiologists, medical physicists, radiation safety officers (RSOs), and technologists, possess a familiarity with Artificial Intelligence. They are experts in fields related to radiation protection, medical physics, and medical imaging. However, in the last 5 to 10 years, deep learning algorithms for image categorization have ushered in significant breakthroughs in the field of medical imaging. For certain tasks like nodule detection, state-of-the-art artificial neural networks now achieve accuracy rates surpassing those of human radiologists **[99]**.

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