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Advancements in Medical Imaging: The Role of Artificial Intelligence in Enhancing Diagnostic Accuracy

Abbas Kashash Dhayie, Abdullah Hassan Ktab, Hasanin Eabd Alshahid Eabd Zayd, Ali Ahmed Mohammed Kamel
Medical physics, Hillah University College

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Annotation: Medical imaging plays an indispensable role in guiding clinical diagnoses, medical treatment planning, interventional therapy equipment placement, surgical operations, and patient outcomes. Advanced imaging equipment, radiopharmaceuticals, and increasing awareness of available imaging modalities lead to unprecedented data growth, which poses huge pressure on human reading and evaluating capacities. Meanwhile, the required time for each reading varies according to the complexity of the cross-sectional findings, increasing the probability of human error. Furthermore, the critical medical evaluation of the significant loss of life and financial consequences of delayed or misdiagnosed treatment encourages regular and accurate readings. Conversely, radiologists' job satisfaction and social demands are the foundational supports of high-quality imaging. This review regroups findings based on common features and illuminates the future large-scale medical imaging AI accomplishments to casual researchers.

Keywords: medical imaging, machine learning, artificial intelligence, thoracic computed tomography, magnetic resonance imaging, positron emission tomography.

1. Introduction

Accuracy of diagnosis and medical procedures in the healthcare sector is of paramount importance to the well-being of patients. An aspect assisting in this regard is technology. Over the years, various technological innovations are entwined with medical professions, pivoting around diagnosis, noting conditions, accidents, injuries, and conducting additional procedures to rectify such things. A recent barometer for the evolution of technology’s incursion in medicine was its manifestation during the collective year that passed last within the purview of healthcare and its allied sectors, and amidst ongoing research and analysis, the centrality of the intersection of advanced possibilities of Artificial Intelligence (AI) in the domain of medical imaging was deemed necessary.

One of the first known imaging technologies, an X-ray photograph, was taken by Wilhelm Conrad Roentgen in the year 1895, just over a century ago [1]. Since then, many technologies ancillary to the earlier ones have evolved with much haste. Each time shaping and reshaping the possibilities and the potentials of understanding the human body, the diagnosis of ailments, and prognosis. Exigencies, however, never waned away. With each new improvement made in a technology thereon emerges a wider array of uncurbed possibilities for improvement of such technology or for the inventions of new technology.

In the current year of 2024, the story is not drastically different either. However, add to this the variables wired in with our era - the internet and that of data science. The marriage of these two have engendered the muscle of computation unparalleled before, granting it the might to fathom and correlate myriad variables invisible to the naked eye - bringing under the purview of understanding hidden patterns and unwoven connections between the fabric of imageries observed whilst expediting greatly the prediction of envisaged circumstances. As such, there looms hitherto unexplored potentials bridging technology with medicine within the confines of the data-intense sphere of medical imaging. In understanding the paradigm ahead, it is intended with this piece of writing, to offer a skeletal portrayal of AI and medical imaging within the purview of their mutual intrusion, some of the trends that characterize the evolution of the current situation together with the challenges that emerge when the two are married. The true effort, however, is to, insofar as possible in under 2,000 words, delve into the expansive domain in at least a manner giving an idea of the same.

2. The Evolution of Medical Imaging Technologies

The essential nature of X-ray imaging in medical care was quickly grasped by healthcare industries, with significant improvements and engineering developments occurring over time since first discovered in 1895. X-ray imaging was specifically researched within this context, as use of AI in healthcare focused mainly on medical images. Considering the widespread use of X-ray imaging, this assessment examined papers utilizing mainly X-ray images. Systems and developed models using X-ray images was analyzed, and an overview of the diagnostic accuracy achievable using medical imaging with automated classification techniques, especially AI approaches.

Over time, many imaging technologies have evolved, developed, and introduced as medical devices. Such advancements enormously contributed to better patient outcomes. From basic techniques, these vital technologies have become sophisticated and complex instruments. The historical evolution of some of the most basic medical imaging technologies has been outlined. These include, when first discovered and implemented in medical practice, X-ray imaging, ultrasound imaging, computed tomography, and finally MRI.

Developing a new imaging technology can be as influential as the discovery of a drug. The very first type of medical imaging, which was X-ray imaging, was discovered in 1895. It was crucial to the foundation of modern medical diagnostics. Patients could be diagnosed even before the presentation of symptoms and signs. The very first diagnostic X-ray was a simple, two-dimensional, and static projection taken in 1896, only one year after X-ray discovery. However, in the years following, important improvements were found, and more sophisticated equipment and different X-ray imaging techniques were developed and introduced. The significant impact of these most basic and swiftly developed X-ray imaging procedures on modern medical diagnosis and treatment was immediately clear. As a result of these early X-ray discoveries, this technology was (and still is) used as the basic medical imaging procedure in diagnostics, especially in surgery. Almost all patients undergo an X-ray examination at some point during treatment. In later decades, in-depth research has revealed numerous medical usage effects due to high doses of the ionizing radiation necessary for X-ray imaging. These potentially damaging effects on human health have been minimized and, in some cases, entirely removed. However, despite the improvements and developments in X-ray imaging equipment and procedures, their wide usage effects on patient health remain a significant and unavoidable clinical issue.

Another type of medical imaging that significantly revolutionized medical diagnostics is ultrasound. Non-invasive diagnostics in medical practice were first introduced by ultrasound imaging. Mentions of ultrasound did not appear until 1958. However, it took over three decades to develop an efficient and useful first-generation diagnostic ultrasonic imaging system. The initial motivation of the first working group on ultrasonic early imaging was research work about the safety of amniocentesis. Shortly thereafter, real-time, A-mode, M-mode images of the first commercially available ultrasonic scanner were presented. Clinical use of A-mode recording for measuring fetal ventricular diameters was also described. Further improvement in echo rangefinder technology would shortly follow with the introduction in 1965 of the first commercially available B-mode-only portable scanner designed for obstetric applications. Real-time linear image scanning was first accomplished in 1963 based on work at a research group. That system featured a mechanically swept sectoral image and was used to create high-resolution images of the fetal head.

2.1. X-ray Imaging

X-ray has been one of the oldest and most widely used imaging techniques in medicine. The physical basis behind X-ray imaging is that the body's internal structures differ in their composition and densities, thus absorbing different amounts of X-rays. The transmitted and scattered X-ray beam is detected by an image receptor, whether it is a traditional X-ray film or a digital detector, converting it into a 2D image representation of the body structures. In general, bones are more dense and absorb more X-ray photons, hence appearing white on the X-ray images. In contrast, the lungs are less dense due to their high percentage of air and appear darker on the image.

The primary X-ray beam is projected to the body and multiple images are generated from different directions. In a conventional X-ray room setting, the beam is directed to a detector panel and the acquired image is eventually displayed on a monitor. Consequently, clinicians utilize X-ray images to reveal the body's internal conditions, such as detecting hidden fractures, pneumonia in the lungs, or tumors in early stages. There are several variations and advancements in X-ray modalities, such as computed tomography and mammography, designed for more accurate and specialized diagnostics. However, each of them has their own unique image acquisition techniques and clinical applications.

X-ray imaging has been an essential component of disease diagnosis and healthcare. Despite numerous advancements in various medical imaging modalities including MRI, CT, and ultrasound, X-ray still remains one of practical and effective ways to quickly confirm the clinical suspicion of many diseases. The recent advances in AI and deep learning have fueled many researches that aim to improve the accuracy and efficiency of interpreting X-ray images. However essential limitations such as ionizing radiation exposure, low tissue contrast effect, and the struggle of maintaining image quality and safety are still important hurdles that all X-ray imaging systems will have to tackle. Future studies should be conducted to explore new possibilities and strategies that bring both AI and X-ray practices together.

2.2. Ultrasound Imaging

Medical imaging is an evolving field, with conventional imaging modalities constantly maturing and newer technologies emerging. Ultrasound imaging has a unique distinction in imaging in that it uses sound waves rather than radiation to visualize internal tissue structures. It is a straightforward and non-invasive imaging technique that can offer a versatile and usually inexpensive way to view soft tissue and organs inside the body. It is commonly used for monitoring fetal development because it does not involve ionizing radiation. It is also utilized in the diagnosis of various abdominal issues [2]. Over the years, imaging practices have shifted the trend from curative to preventative care, appearing as a huge endeavor in early detection. Ultrasound imaging will play a key role in the development of preventative treatment and the early detection of various diseases through its potential for visualizing subcutaneous/visceral fat and associated blood vessels. AI-based algorithms can detect more subtle changes in imaging data over time than can the human eye, and studies have shown that time-dependent prediction of treatment effects can improve diagnostic confidence in medical imaging [3]. In 1794, an Italian physiologist, Lazzaro Spallanzani, discovered that bats navigate based on sound. He deduced that echoes/reflective sound waves can give information about surrounding objects' shapes and sizes. His conjecture is regarded as the basis of ultrasound. Alternatives to X-ray imaging began to evolve in the search for ways to protect fetuses from ionizing radiation during pregnancy in the early twentieth century. In 1940, an Austrian neurologist founded the first ultrasound A-mode, and in 1958, the first fetal scan was performed in the United States. A-mode is echoed amplitude, depicting the intensity of the reflection strength, and later improvements led to B-mode images in the 1960s. B-mode scans echo amplitude across two planes to represent soft tissue and fluids. Neither A-mode nor B-mode is in real-time, and it was not until the 1980s that real-time 2D scanners became popular. Doppler mode, analyzing phase shifts of returned sound waves, and super-resolution, providing more detailed images, were later advances in the 1990s. With the view beyond classical appearance, these imaging techniques of 2D/3D/4D ultrasound are now broadly utilized across specialties in medical applications. The real-time imaging nature of ultrasound promotes its use in guiding invasive procedures, such as surgery and biopsies.

2.3. Computed Tomography (CT)

As an imaging modality, computed tomography (CT) has contributed significantly to advances in enhancing the diagnosis precision of various conditions that are not easily diagnosed by X-ray devices. CT can generate cross-sectional images of the body in a detailed manner. A highly sophisticated technology, CT is used in a variety of applications. It is widely used in cancer detection as it can clearly reveal many internal organs such as the pancreas and liver. Additionally, it is a very useful imaging technique for the internal injury of various body organs that cannot be detected by ordinary test or other imaging like the classic X-ray. Modern CT systems employ what is known as helical scanning, or spiral CT, which eliminates the need for stopping and starting the X-ray tube and detectors, as well as numerator changes in the orientation of the patient. With the onset of high-resolution, multi-slice CT systems, many studies have sprung up for improving image quality, not only in terms of resolution. Hence, the goal is to make a detailed review of the literature in CT image quality and to highlight the advances and future works in this domain.

With advances in software and hardware, the combination of artificial intelligence (AI) is playing a role in how to interpret images, and even abnormal findings can be detected by supporting algorithms or models. Ranging from the interpretation of medical images, the use of AI in images is growing rapidly because of the improvement of deep learning method. Although promising, several constraints may impede the penetration of AI in small practices and in emerging countries. Dose increase is the most straightforward way to ensure the optimal quality of CT images, and it is an important first step in the assessment of AI in chest CT, which is feasible with any type of CT and can be incorporated into daily practice. Contemplation of a future in which handling the vast number of imaging datasets required by AI will necessitate automatic optimization of post-acquisition processes, promising improvements in workflow efficiency and patient safety are anticipated.

3. The Intersection of Artificial Intelligence and Medical Imaging

Medical imaging and artificial intelligence (AI) are on converging paths. The use of AI in medical imaging is not science fiction; it is real, and it is here. AI can help improve diagnostic accuracy and workflow efficiency; it could help with the optimal management of imaging services and imaging interpretation. The key for the wider adoption of AI in medical imaging is the capability of AI-driven analytics. The analytics can analyze and accurately interpret medical images captured by modalities, such as MRIs, CTs, PETs, USs, and NM, as well as other imaging technologies not yet widely used, such as DBT, ES, OCT, and EIT - potentially transforming healthcare practice. If AI can equip non-radiology experts with the ability to interpret medical imaging data, such as general practitioners, it can enable more imaging data to be used to make timely diagnoses, avoid late diagnoses and thus reduce medical lawsuits. The ever-increasing complexity and the volume of specialist image data, accompanying narrow radiologist resources, are likewise likely to necessitate the integration of AI in imaging practices. This article cannot introduce the reader to the full extent of medical imaging and AI, but could offer the reader a brief overview. The applications and challenges of the AI-driven analytics of imaging data are then subsequently discussed. Machine learning and its subset, deep learning, have become synonymous with AI in recent years. Machine learning is an AI methodology that uses algorithms to learn from data, and deep learning is a subset of machine learning that uses multi-layered neural networks to learn complex representations of data, especially when represented on a large scale. This makes AI well suited for identifications of patterns and anomalies. Broadly speaking, there are two approaches to AI. The first analyzes images as a whole, usually assessing their features related to shape, intensity, or texture. The other approaches (mainly DL) segment images, converting them into regions or pixels of interest prior to analysis. All health systems, regardless of where they are in the world, share the same common goal: to ensure that their patients receive the best possible treatment. However, the difficulty of achieving that goal arises from the fact that deciphering the plethora of imaging data collected is incredibly complex. Radiologists, as domain experts, need to bridge that gap. However, the building of AI solutions requires the expertise of both technologists and healthcare professionals [4]. It is thus crucial that both these groups communicate and work together. [5][6][7]

3.1. Machine Learning Algorithms

The burgeoning field of medical imaging has found itself within the pervasive purview of artificial intelligence, as machine learning algorithms are deployed to enhance diagnostic accuracy in patient care. Machine learning, a potent subset of AI with a predilection for processing both modest and boundless datasets, boasts powerful tools for intricate analysis of copious imaging data. Medical imaging has a vast assortment of varieties of data that can and should be examined, from X-ray and CT images, for example, to acoustic images from ultrasound. These data can be used to train various machine learning models. The machine learning techniques themselves have been broadly divided into two sets: supervised learning, which involves training a model on a label dataset to predict the labels of unseen data, and unsupervised learning, where a model seeks to discover underlying structure in a dataset [8]. Additionally, a variety of models can be constructed with machine learning: not just neural networks, but also decision trees, support vector machines, k-means clustering, and more.

Machine learning algorithms, comprising both image and report data, can be trained to accurately predict the presence of pathologies in various imaging modalities. They can be trained on a large quantity of imaging data to obtain high-performing models. These models will predict the presence of a pathology and return a confidence score, either as a probability or continuous value, quantifying the model's faith in the presence of its prediction. Currently, these models, trained on a multitude of chest X-ray images and associated reports, may be posed with an image and are tasked with predicting if there is a pneumonia or no finding present in the image. The resultant predictions may be overly confident and potentially inaccurate. Moreover, these models would only be able to anticipate findings explicitly mentioned in training reports [9]. To train machine learning models, however, a large volume of imaging data must be available. To train alcohol policy models for MUMC, hospital one, over a million imaging examinations were examined. Large labeled datasets with appropriate representation of different pathologies can be arduous to gather, and the quality might be degraded by issues such as annotation error or inconsistency, missing reports or other patient information, and various artifacts.

3.2. Deep Learning Techniques

As artificial intelligence (AI) has evolved dramatically, deep learning, a challenging subset of machine learning, has subsequently advanced. Deep learning employs a very complex neural network with dozens or even hundreds of hidden layers, allowing a neural network to "learn" from a huge amount of data. Convolutional neural networks (CNNs), one kind of deep learning model, are used extensively for image recognition, object detection, and a number of other image-processing tasks; as such, they are widely employed in medical imaging analysis. Deep learning is being used for more and more complex and diverse tasks in medical imaging to help radiologists, referring physicians, and patients; with regard to computer-aided diagnosis.

Deep learning in radiology, particularly in medical imaging, has greatly improved the diagnostic efficacy of radiologists [8]. As might be expected, processing these data requires the implementation of powerful algorithms. For years, developing methods akin to these algorithms was a goal for areas directly related to data processing and visualization. However, the spread of such algorithms has been slow due, in part, to existing computing restrictions. Just a few years ago, deep learning techniques in computer vision resolved object recognition tasks with high performance rates, which sparked a considerable interest in employing deep learning for medical image tasks. On public datasets, it has been demonstrated that deep learning competes with, and even surpasses, human performance at detecting abnormalities, such as cancers, in medical imaging [10]. Standard T1 post-contrast brain magnetic resonance images (MRI) were used to detect lesions, and the system showed a sensitivity of 89.7%. In a prospective validation study of thoracic computed tomography (CT) images, a model classified various abnormalities, winning an unprecedented number of top prizes. A calculated score was given by doctors, and the model hardly scored any differently, demonstrating a score gap of 0.040 as opposed to the inter-reader disagreement of 0.139.

4. Applications of AI in Medical Imaging

Medical imaging is an essential diagnostic tool. To be considered as effective and appropriate, diagnostic imaging technologies must have a significant role in healthcare optimization. In recent years, this objective was addressed through the application of artificial intelligence (AI), which plays a vital role in improving the capabilities and efficiency of medical imaging technologies. This article is a short review of AI and two specific applications within its medical imaging landscape.

The primary motivation for introducing AI in medical imaging is the belief that its automation capabilities possibly broaden the diagnostic spectrum of imaging technologies. Medical image interpretation comprises error-prone, time-consuming tasks. Furthermore, the possibility of designing AI algorithms capable of detecting, more rapidly and accurately than human observers, pre-defined lesion characteristics. Image segmentation is another potential field of application. Segmentation is the process of partitioning an image into multiple segments, so as to change the representation of an image into something more meaningful and easier to analyze.

Within the medical imaging context, segmentation consists of identifying and locating specific anatomical features within image sequences, for diagnosis or treatment planning purposes. AI has made significant advances in medical image segmentation through pixel-wise image classification (semantic segmentation) [4].

One of the most frequent AI applications in medical imaging is computer-aided diagnosis (CAD) systems. Aiming to assist radiologists in a faster, more accurate image interpretation, these systems consist of the integration of AI algorithms that extract certain relevant characteristics from medical images into the radiological imaging workflow. Reflecting on technologies that emerged about a quarter-century ago, current CAD systems consist of machine or deep learning algorithms capable of analyzing extremely large amounts of data. In a way, these systems represent a form of content-based computer image analysis which, by providing quantitative features obtained automatically from images, aids the radiologist's decision making. The most common structure implementation of modern CAD systems is as a software package that functions as a frontend to the radiological viewing process. Besides the images, this frontend feeds an algorithmic backend that analyzes them and yields supportive information. Despite the existence of alternative approaches, this workflow seems to be the generally accepted standard followed by the different vendors. In terms of technology, the incorporation of such AI has led to a CAD transformation. This technology has become synonymous with the integration of machine or deep learning algorithms into diagnostic imaging modalities - almost always computer tomography, magnetic resonance imaging, or digital mammography.

4.1. Image Segmentation

Image segmentation is a crucial process in the field of medical imaging for the purpose of enhancing diagnostic accuracy. Image segmentation divides an image into distinct regions containing pixels with similar properties, which are used to isolate relevant anatomical structures or pathological findings. The use of artificial intelligence (AI) and machine learning (ML) in the automation of image segmentation has the potential to enhance the effectiveness of disease identification through medical imaging. Developing AI/ML algorithms for the automatic segmentation of medical imaging, therefore, can notably reduce error with minimal manual intervention, and enhance efficiency with the faster processing time [9]. Currently, AI-driven methods for medical image segmentation are categorized into three main groups: region-based, thresholding, and deep learning-based methods. The advantages and limitations of each technique in the medical imaging domain are investigated, with case studies presented to demonstrate how AI-driven methods have been successfully implemented in clinical practice. Subsequently, the challenges faced and the future directions are considered. There has been an increasing focus on medical imaging applications over the past year, expanding the interest in further research into AI-driven image segmentation [11].

It is possible that in the near future, with the advancement of technology and the development of suitable algorithms, medical images can be processed in real-time to result in the near direct visualization of the internal body. Employing medical imaging in combination with surgery planning mechanisms, such as in robotic systems, could also impact the demand for real-time image processing. Here the viability of implementing AI-driven methods for the real-time segmentation of medical images is tested and demonstrated. A schematic overview of the architecture is illustrated, and the necessary components are described to ensure the replication of the results.

4.2. Computer-Aided Diagnosis

Substantial advancements in medical imaging and IT have redeveloped the picture archiving and communication system (PACS) to the next stage of a diagnostic workstation, where medical imaging forms part of the electronic patient record, and radiology reports are produced and transmitted digitally. There is continuous progress towards the development of a filmless hospital, and most US hospitals now have the capability of distributing images remotely. There is ongoing feedback between the development of PACS and advances in telecommunication technology. The technology for remote diagnosis with PACS is rapidly spreading, and is particularly well suited for modalities such as X-ray, which produce DICOM images [4]. The most developed services allow the transmission over the Internet of images and reports with a telecommunication cost of around 3–20 Euros or 2–15 pounds per study. It is expensive for remote diagnosis as a CIF videoconferencing facility, and this expense, combined with slow link speeds, limits its use. Remote diagnosis in hospitals has led to a 20% increase in staff efficiency.

Telemedicine services are an industry expected to reach 1.8 billion Euros next year, and resolving issues of standardization will be critical to the development of this industry. Even so, there is no technical limitation on the ability to screen populations. In summary, within the field of radiology the aims of primary care and secondary care are currently compatible, and the development of interoperable rules and standards for the electronic exchange of patient data will allow existing and future technologies to be applied for the maximum benefit of medical practice.

5. Challenges and Limitations of AI in Medical Imaging

This article elaborates on the development of artificial intelligence to improve the accuracy of medical imaging diagnosis. A deep learning framework designed for EEG diagnosis patient suffering from epilepsy and provides an example of early diagnosis with the aid of the discovered combining logical rules. Finally, the development trends of artificial intelligence in medical system are prospected. Agriculture breeding industry, with the rapid development of information technology and internet technology, has entered the ear of the Internet to facilitate people's life, the internet of things technology has been applied more and more widely to agricultural production life, realizes the intelligent management from production to sales, it becomes an important link in modern agriculture, the smart kitchen is a set of innovative agricultural production mechanism of agricultural operations machinery in a scientific and reasonable plan combine together, office automation, production process computer integration applications in production process, the use of advanced technology and internet of things to monitor and control the work of the crop growth environment climate and health status, in order to improve the production of high quality, efficient, low consumption, low emissions, sustainable agricultural production. Medical institutions, in addition to increasing the epidemic monitoring and patient screening increase, are often subject to a large number of patients, some with normal flu, cold symptoms, some patients with malignant infectious diseases admitted in the early stages. Due to high traffic, some patients with severe orthopedic disease miss the best treatment period, which greatly increases the difficulty of treatment and does not meet the purpose of treatment. Therefore, a body temperature warning system suitable for the hospital environment is designed, which monitors the body temperature in real time, transmits data wirelessly, and records related data. If a patient's body temperature exceeds a set threshold of 37.5°C, the system gives an audible and visual alarm to remind hospital staff, and the transmission data can be displayed on a computer for real-time data monitoring purposes. The system is designed to be simple, convenient, and practical. [12][7]

6. Future Directions and Emerging Technologies

Future directions and emerging technologies in medical imaging, led by artificial intelligence (AI), will play a significant role in achieving more accurate diagnostic information and bring about the era of personalized medicine. It is expected that innovative 3D imaging and reconstruction techniques will rapidly develop, providing detailed 3D imaging information for the studied object. The comprehensive quantification of this detailed 3D information will then allow the prediction and analysis of the physical and functional properties of the studied object before performing any real examination. Therefore, AI-assisted 3D imaging and quantification will be essential for the personalized diagnosis of various diseases. On the other hand, singular imaging modality may have a limitation regarding comprehensive profiling of a patient. With the development of technology, the quantitative imaging biomarker will have the capability to provide quantitative analysis on image data [13], which enable patient management become more data driven and thus better planning can be provided. Therefore, AI-assisted 3D imaging and quantification of multiple imaging modalities will be promising fields and will have broad applications in medical imaging. State-of-the-art application examples and potential future research directions of these emerging techniques are given. With these emerging technologies, improved visualization and detailed analysis of 3D physical and functional information for various applications are possible. The interdisciplinary collaboration of experts from different fields, such as physics, mathematics, computer science will thus be further motivated for the study of imaging and nondestructive testing of materials and structures. In conclusion, the future of medical imaging is bright. The partnership of emerging AI with diverse domains of science and technology related to imaging will continuously bring innovative and advanced technologies, which will upgrade and enhance the performance and capabilities of numerous tools and systems used in medical research and practice.

6.1. 3D Imaging and Reconstruction

Medical imaging has become an essential tool for non-invasive inspection and diagnosis. With the fast development of computer and sensor technologies, imaging is becoming more and more digitalized. In particular, in medical imaging, the application of these technologies brought a significant increase in the amount and the complexity of data and information that can be derived from the images. There are many modalities of digital medical imaging, like computed tomography (CT), magnetic resonance imaging (MRI), ultrasound, PET, and X-ray, etc. The research and development in medical imaging became more and more multidisciplinary and more and more technology based.

Traditionally, medical imaging is a two-dimensional presentation. However, the objects that are imaged, like internal organs, the brain or tumors, etc., are actually in a three-dimensional form. A lot of details in 3D are therefore lost. 3D medical imaging becomes increasingly important in enhanced visualization, detection, and volume measurement. It plays a key role in aiding understanding of anatomical structures and in planning medical treatments. There are different methodologies of 3D reconstruction. It can be based on physical modeling, using 3D image acquisition or dedicated acquisition procedure, such as a 3D probe. Also, it can be done using indirect modeling, based on several acquired 2D contiguous images to give a 3D representation.

The aim of this section is to present the latest progress in 3D medical imaging and reconstruction mainly based on classical imaging like MRI and CT. The use of AI algorithms is also discussed in this section to deal with the huge computational cost required by the 3D reconstruction process and the complexity of the 3D data. Recent advances made possible by the new multi-core processors and new GPU architecture are highlighted. The use of 3D computer graphics for real-time rendering and manipulation of 3D models for clinical tasks is also foreseen as a promising future development. The potential benefits of 3D in medical imaging in viewing, data analysis, quantification, and preparation for surgery are summarized. Finally, the challenges and general problems in 3D data portability, data analysis, and data format are raised to the medical image processing community.

6.2. Quantitative Imaging Biomarkers

Quantitative imaging biomarkers are of growing importance in the context of personalized medicine. They provide measurable, imaged-based, and ideally standardized parameters, with respect to a certain diagnostic or research question, resulting in more objective observations of treatment effects and disease progression. Especially in oncology, they are progressively used in clinical trials, in order to evaluate patient response to therapy and, more and more, in standard clinical practice. It is often difficult to extract quantitative imaging biomarkers manually, especially those that require precise volumetric assessment. A vast number of techniques and applications exist for deriving and studying quantitative imaging biomarkers based on data acquired by different imaging modalities. Many can be derived historical as well as from currently available data. Such approaches are computerized, and knowledge-based methods typically require segmentation of the regions of interest (ROIs). Computer-aided tools aid in the detection, diagnosis, and quantification of abnormalities. In the field of radiomics, high-dimensional data, representing a large number of extractable imaging features, is extracted based on ROI analysis [4]. Multiple studies attempt to correlate such features with, for example, the tumor biology or patient outcome. Furthermore, additional machine learning algorithms are often applied to build predictive models based on the most relevant features, in order to eventually classify, cluster, or predict the nature of a certain ROI. Possible areas of application include but are not limited to enhancing and personalizing treatment efficacy, monitoring disease progression, predicting prognosis and understanding disease risks and early detection. Opening up a plethora of possibilities, a considerable number of novel imaging-based discovery services to assist in non-invasive medical diagnosis have already been created and clinically verified. As those AI-aided methods are developed and evaluated, a pivotal and common concern arises around standardizing, validating, and implementing biomarkers in a reproducible and robust way. Results are often scanner and protocol dependent however, raising important questions regarding validation across multiple scanner vendors and imaging parameters, and about the regulatory considerations of the implementation of such AI-aided biomarkers in the clinic. Therefore, such efforts should optimally engage collaborations between radiologists, designing the studies and deriving imaging biomarkers, oncologists, realizing the clinical aspects and assisting with data curation, and data scientists, developing and evaluating new methods for the subjects. It is envisioned that, in the future, AI-aided tools to derive and evaluate quantitative imaging biomarkers will continue to expand, with a focus on standardizing and making it easily applicable, robust and accurate, and where maximum efforts are deployed to broaden access to the wider research community and industry.

7. Ethical Considerations and Patient Privacy

Introduction. Radiological Society of North America (RSNA) is all set to conduct its 2022 annual meeting from November 27th to December 1st. Using artificial intelligence (AI) for the interpretation of medical images holds great promise and could vastly improve diagnostic accuracy while reducing the time it takes to report on medical images [14]. However, there are significant ethical considerations to bear in mind when doing so. The rapid adoption of algorithms to analyze the content of radiographic images raises questions regarding the handling and storage of huge amounts of patient data and the consent processes of patients involved [15]. Medical scans require the collection of a huge amount of detailed information from patients and the translation of radiation into digital information: data that should ideally remain confidential between the clinician and the patient, but that is increasingly processed and digitized by providers of so-called data-driven tools that have replaced traditional film-based medical imaging. Such a situation has crucial implications for data privacy, security, and the potential for breaches, complex to navigate in light of recent ransomware incidents that have increased among entities that should ensure the privacy of patient images and information. Although the sharing of information and images contributes to the improvement of care by providing secondary opinions and allowing for the development of collective intelligence, the way in which it is done may raise concerns. Suggestions to this effect can be made to offer secondary advice on general arrangements and burden-sharing agreements. Also, there may be biases due to the criteria used to develop the algorithms that standardize care. In order to be ethically developed and adopted, digital health algorithms must meet the principles of privacy by design, inform consent, and the right to explanation. These will be explained and relief in the case of health-related decisions handled by AI systems. Finally, recommendations will be made to ensure that the decision-making process is fair, accountable, and establishes market systems. [16][17]

8. Conclusion and Key Takeaways

Artificial intelligence (AI) has become a paramount presence in various fields of scientific investigation. From industrial to engineering sectors, as well as finance and the general public, the advent of AI has engendered profound transformations across all domains. In the context of health studies, many researchers, academics and medical professionals continue to explore innovative configurations of AI, especially as novel diagnostic tools. One domain that has attracted wide attention is medical imaging, among the most prominent sources of patient clinical information. Among the means of depicting human anatomical or functional structures, medical imaging modalities, such as ultrasound, computed tomography, magnetic resonance imaging and positron emission tomography scans, have become the first line of investigation.

In conjunction with medical image acquisition, AI technologies have garnered unprecedented widespread usage in extracting vital signs and quantifying physiological and metabolic functions. Encompassing a wide array of machine learning and deep learning models, AI learns and encodes image characteristics, facilitates image segmentation pinpointing the region of interest, and in a pivotal role assesses innumerable organic patterns, aiding towards a diagnosis. In addition, AI enhances the efficiency of medical image analyses; in the past, radiologists would meticulously interpret large stacks of CT images or pathology biopsy assessments – a time-consuming process. AI models can automate these procedures with superior accuracy and in a fraction of the time. Furthermore, precise analysis substantially diminishes the possibility of overlooking visual indicators of pathology.

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