Medical Physics: The Technology Revolution in Disease Diagnosis and Treatment

Editors

Noor Al-Huda Ali Kazem
Department of Medical Physics, College of Science, University of Wasit

Muslim Ali Razak
Department of Medical Physics, College of Science, AL_Mustaqbal University

Saja Ahmed Jaloub
Department of Medical Physics, College of Science for Women, University of Baghdad

Tabarak Jaber Hussein
Department of Medical Physics, College of Science, AL_Mustaqbal University

Bright Sky Publications ™
New Delhi

Published By: *Bright Sky Publications*

Bright Sky Publication
Office No. 3, 1st Floor,
Pocket - H34, SEC-3,
Rohini, Delhi, 110085, India

Editors: *Noor Al-Huda Ali Kazem, Muslim Ali Razak, Saja Ahmed Jaloub and Tabarak Jaber Hussein*

Edition: *1st*

Publication Year: *2025*

Pages: *46*

Paperback ISBN: *978-93-6233-947-8*

E-Book ISBN: *978-93-6233-337-7*

DOI: *https://doi.org/10.62906/bs.book.307*

Price: *₹ 355/-*

Abstract

This paper is meticulously written in a manner that is accessible to most people, with the primary goal of helping to ensure that the public interest is thoroughly taken into consideration in a matter that is of great importance to society as a whole. In recent years, the field of diagnostic imaging has developed at an astonishingly fast pace, revolutionizing the way in which diseases are diagnosed and treated. This remarkable revolution is causing an extraordinary increase in healthcare spending, leading to mandatory questions regarding the balance of risk versus benefit for patients and healthcare providers alike. The general population perceives technological innovation in medicine as having a very positive impact on health outcomes and overall well-being. Diagnostic radiology and interventional procedures, in particular, are viewed positively and enjoy a high degree of acceptance among patients of all ages and backgrounds. The general population, therefore, feels happy and confident when using advanced medical imaging technology, yet it is crucial to recognize that high patient exposure to ionizing radiation and the time required to obtain imaging results present real and significant problems regarding both the quality and safety of medical imaging practices. Furthermore, the enormous gene panel present in each individual, combined with the efficiency with which information on personal genetic variations can be gathered, offers an interesting and exciting possibility of observing these quantitative differences in individual responses to both medicine and machines. These unprecedented advances in medical technology are undeniably changing the practice of medicine as we currently know it, transforming it into a field that is highly predictive, preventive, personalized, and participative. This evolution is opening up new avenues for treatment therapies that yield better results for patients, often at a significantly lower cost. Gaining a comprehensive understanding of the new medical physics-related revolutions not only offers greater acceptance of these changes but also fosters the creation of conditions that contribute as an essential unifying factor in our increasingly complex society of the future.

Contents

Chapter - 1

Introduction to Medical Physics and its Role in Healthcare

Medical physics is an expansive and intricate field that can be defined in numerous ways, yet fundamentally it revolves around the application of physical principles within the medical domain. The study of medical physics entails the exploration and implementation of concepts and methodologies from physics in order to assist with the diagnosis and treatment of diseases that affect human beings. It intricately weaves together ideas from both physics and engineering, bridging them with the realms of biology and medicine, thereby enhancing the care provided to patients and contributing to effective cures. Medical physicists employ a wide array of technical abilities and procedural skills, engaging in many of the essential functions that characterize the operation of a modern hospital or clinic. This necessarily leads to collaborative projects involving physicians, nurses, technologists, administrators, IT professionals, and a diverse array of other healthcare personnel, all working together to ensure the delivery of patient care that is both cost-effective and of the highest quality.

Over the decades, the field of medical physics has experienced significant evolution, particularly since its inception during the advent of diagnostic x-rays toward the end of the 19th century. In contemporary times, the role of medical physics has become largely obscured from the general medical community's understanding. Most individuals are unaware of the existence of medical physicists, or how these professionals can profoundly contribute to patient health and treatment. Nevertheless, the advancements in modern medicine owe an immeasurable debt to the essential functions that medical physicists fulfill in terms of diagnostics and therapeutic interventions. As technology continues to advance and the complexities of patient care grow, the importance of medical physics in ensuring accurate diagnoses and effective treatments will only become more pronounced, reflecting the integral nature of this discipline in the broader healthcare landscape [1].

A doctor's visit frequently involves several potential encounters with medical physics without the patient even being aware. Many of the images and scans taken to diagnose an injury or illness involve technologies improved by, and run by, medical physicists. Further, these imaging technologies help the doctors understand the complexities of the patient. Understanding a patient's body and tumor in three dimensions can play a critical role in developing a successful treatment strategy for a patient. X-rays are used to ensure a patient remains in a consistent and effective treatment posture. Not only is the importance of the technology critical to a treatment's success, but a physics review is also mandated by regulatory requirements. Patients receiving treatment for cancer may be thoroughly perplexed at the 4-6 person team assembled to administrate therapy. In addition to the doctor, nurses, and therapy technologist, an entire discipline is represented by the medical physicist. That team, brought together by the doctor, collaborates to ensure a patient is receiving the best possible cancer care available. This chapter serves as an overview of the field for those unfamiliar with medical physics and its practices. It is expected to make the reader comfortable with just what medical physics involves. The plan is to present the subject from a functional perspective, and how a particular area of needed hospital work is met. Practical applications of medical physics will also be discussed so that the following clinical discussions can go ahead with a more solid foundation of understanding. Further, this chapter should be valuable to readers who will eventually deal with medical physicists professionally. This might include managers of a medical physics group, clinicians just beginning to interact with the field, or even just technologists working with physics instruments. And lastly, the various parts of the chapter are intended as a delayed completion of the introductory section to set the stage for the discussion of imaging techniques and therapeutic applications [2, 3, 4].

Electromagnetism and X-rays were groundbreaking discoveries---leading a technological revolution in medicine. In the industrialized countries, medical physics, a child of the technological revolution that transformed services in diagnosis and therapy, is a recognized profession associated with hospital practice with trained professionals working in diverse disciplines [5]. Furthermore, its operation in clinical environments is positively sanctioned by the requirements imposed through statutory and regulatory provisions, and its crucial role is also endorsed through a wide spectrum of activities and best practices in medical radiation exposures and in the safe and efficient use of ionizing radiation. In the developing world, however, the situation is starkly different. Emerging from the Comptons scattering to the creation of the Compton camera, from Roentgens serendipitous discovery to Wouters non-invasive personal dosimeter, historical figures and their contributions forming the basis of the technology revolution enhancing medical physics practice and its positive impact on the advancement of medicine and, in particular, on the improvement of public health care system are outlined. In terms of healing as well as technology, enormous progress has been made in medical physics over the past century; from the belief in divine punishment to germ theory, from healing prayer to surgery and chemotherapy, from acupuncture to image guided radiotherapy, from superstition to evidence based medical practices.

Clinical environments, where patients receive diagnostic imaging, radiotherapy or nuclear medicine procedures, are transforming over time by integrating lesser empirical practices with more evidence-based approaches as have been happening elsewhere [1]. While, initially, medical interventions were truly an empirical art having methods passed down from older generations without understanding their mechanism, nowadays clinical practice needs to keep pace with advances in science and technology and therefore becomes a data and skill-intensive discipline where therapeutic and diagnostic decisions are based on evidences from research. Recent transformation, therefore, took place from a rather limited medical physicist practice to a more extensive clinical and technological service.

1.1 Key Concepts and Principles in Medical Physics

Medical physics is an interdisciplinary specialty that integrates a broad approach to problem-solving both in health care and underpinning fundamental science applications in biology and medicine. The work of medical physicists in Malta spans the health spectrum of research, development, application and maintaining an optimal and cost-effective use of medical physics methodologies relevant to the diagnosis and treatment of human disease. The majority of the work of medical physicists in Malta relates to clinical medical physics performed within a hospital environment. In conjunction with clinical medical physics application, medical physicists are required to monitor and evaluate the levels of radiation that staff working with radiation are exposed to and ensure that these exposures are kept as low as is reasonably achievable by monitoring the appropriate radiation areas and also the environment in which radioactive substances are used. Medical physicists are responsible for ensuring that all imaging screenings carried out within the hospital meet with predetermined diagnostic image quality standards, which can be determined either through a national image quality survey or else through establishing and maintaining local standards. The other related area of medical physics work is the fact that equipment performance needs to be optimized to guarantee correct clinical and radiation treatment [6, 7, 8].

Healthcare has witnessed a remarkable transformation in the development of diagnostic methods and technologies in recent years. These developments have enhanced patient healthcare outcomes and altered the basis on which healthcare decisions are made. The life-threatening coronary artery disease, which the first diagnostic methods date to the beginning of the 19th century, is used as a lens to survey the profound interplay between medical technology and medical knowledge in the development of diagnostic methods/technologies. Focus shifts from the discovery of heart disease by the invention and implementation of the first diagnostic technologies for coronary artery disease to an epistemic leap that uncovered the internal structures of the heart and redefined the disease. The case is made that this and similar historical analyses urge for a more futuristic outlook on the role of technology in the future landscape of diagnostic practices, particularly in the context of the manifold expectations surrounding digital technologies. Four issues for future research and policy making are discussed. Medical technology has long been a part of medicine and healthcare in the form of devices or, more recently, machines that perform diagnosis, monitoring, surgery, or treatment. Nonetheless, the overall visibility and prominence of medical technologies, and the ways in which they are embedded within medical practices and societies, have changed drastically in recent years [1]. Critically important decisions are increasingly made on the basis of depersonalized instrumental measurements rather than on face-to-face communication and traditional palpation and examination. Diseases and symptoms that were previously obscure or hidden are now readily detectable by the production of new digital data [2]. A new market of easily accessible individualized genetic information is opened while emerging artificial intelligence is poised to alter the role of healthcare professionals and patients in medical practices. In turn, these changes are accompanied by a projection of many expectations about the future capacity of digital devices, algorithms, data, and computational power.

The earliest methods for diagnosing diseases in ancient cultures were interventions of amalgamated observations, rituals, and simple herbal remedies. Throughout history, people have fallen victim to various maladies, therefore the art of medicine has existed for thousands of years. Whilst ancient doctors could not rely on the variety of high-tech equipment that exists today, they were not entirely unequipped. The ancient Greeks, for example, believed that almost all knowledge could be obtained through the five senses [3]. The Romans and the Christians borrowed and changed many Greek ideas, and eventually Greek-influenced thought prevailed all over Europe.

The ancient diagnostician – east and west, north and south – all relied on the same basic principles: the observation of patients and their symptoms. In Chinese medicine, however, the emphasis was more on pulse-reading. In ancient Europe, healers relied on their observation, the knowledge and experience and the herbal remedies passed on to them by their predecessors. It was believed that illness was a punishment of the gods, albeit either for wrongdoing by the sick person themselves or by someone close to them. In one version of the Hippocratic treatise, epilepsy is explained as an excess of 'black bile' in the head, swollen and rising from the stomach. The first-ever use of the term 'epilepsy' is in an essay by the Roman doctor Galen. Various natural, astrological and even environmental influences are ascribed to it, such as the elements of earth and air and a southward wind. All three are understood to have a soporific, head-ache-producing effect, and the god associated with this detrimental wind is the god of fire. Very few writers depicted epilepsy as a disease not of divine origin. Ancient healers staunchly believed that a disease would always be defeated by herbal medicine in combination with religio-magic ritual. Ancient northern Indians, the Aryuveda practitioners, believed that forgetting mantra is a symptom of epilepsy. Homer attributed epilepsy to military wounds, whereas Herodotus associated it with magic. Hippocratic writers claimed that epilepsy, a disease of the god Asclepius, would be free from further attack if the patient was willing to do as the god told him to create the suppression of the disease.

When practiced in ancient times, the art of medicine was closely associated with divination and conjuring magic. In traditional societies, except after relatively advanced civilization had been achieved, the prevalence of superstitious concepts made it possible for joint activities to take place in religious rituals aimed at keeping away the harmful influences believed to be threatening the community. The traditional priest was therefore the doctor, the medicine-man the priest, and the doctor the diviner. The magic, faith, and rituals used in healing clearly indicate the inseparable nature of the medical arts and the other elements in traditional society. Moreover, the analogies that exist between the treatment of the altar and that of the patient have been clearly brought to light.

It is on the other hand, from the point of view of observable manifestations, that medical practice was able to make real progress in the early stages of development. In general, noticeable symptoms and manifest physical signs made possible in most cases a clinical assessment of the patient's affliction through simple observation [3]. This is why the techniques applied by ordinary doctors in antiquity were as stated above: observation and inquiry. As the former consisted in carefully noting visible symptoms and physical signs and the latter in questioning the patient, his relatives, and those attending him on matters relative to the disease which offered a clue likely to lead to its diagnosis, these two basic diagnostic methods provide us with valuable information on the foundations of diagnostics in China. Documentation concerning the observation necessary for the grasp of disease symptoms usually but not exclusively details the physical ones. That this is the case would seem quite normal if one bears in mind that ordinary visible and thus objectively observable symptoms are those eventually manifest on the surface of the body.

Throughout most of history, the focus in the diagnosis of disease was on qualitative issues. Only within the past century has it become common to employ systematic quantitative methods in this task. However, it would be a mistake to suppose that the issues of disease diagnosis were minor before 1900. Diagnosing disease is the first essential step in treating it effectively. Perhaps this is why it has always received much attention, not only in the medical profession but also in the wider culture. During the medieval age and the Renaissance, the West witnessed a number of advances that set the stage for the more systematic assessment of disease that would emerge by the close of the 19th century. These include an increasing understanding of the body's anatomy, the growth of a scientific approach to knowledge generally, and more tools for investigation. In the context of often bizarre cultural concepts, medicine became concerned with a systematic search for the patient's disease. Throughout the European Middle Ages, such an approach was hampered by the Church's rules prohibiting dissection, but with the Renaissance that barrier began to disintegrate. Medieval medicine, by many accounts, was rooted in often fantastic superstitions and mythical dogmas that did not hold up well against the few diseases that Roman and Greek writers had described. But this is not the modern view. During the medieval period, a scientific study of nature began to emerge, based on factual observation and experience, and that spawned gradual center of healing in the universities. At first, medicine had no faculty; a course of anatomy was taught only at Montpelier till 1309, and then only in the summer in case any students died of shock or horror. When taken, the course was little more than an advance lecture on Galen's works. As the Christian faith developed into the official ideology of the Empire, official policy towards dissection became much more negative. Career ruining libels were recurrent. At the same time, advances in knowledge of the pagan world proved able to arouse curiosity about the organs of the human body that the religious establishment could not permanently check or suppress. Galen was popular in part by dint of after death experiments. Major works from important ancient Greek medical sources were studied and often translated. Many to the 12th and 13th century medieval Europe would have knowledge of the diagnostic methods in Vulgar Latin, the language of the educated classes outside the Church, the corporation which was by that time growing too fat to control revolutionary tendencies. Treatment was considered despicable by the Greeks or even outright, as by Diodes of Carystus in 300 BC. No doctor could hope to glean of the internal imbalances causing disease without anatomy, for which driving was the necessary pollution; neither would he have such knowledge of plants as to be able to use them as drugs to provoke the humoral imbalance which local and distant eye observation indicated was required. Things started to change with the 13th century Salerno School. An early leader was Constantine the Father, whose work was later rechased as the Rose Magarita in 1230. By the 15th century, the Treatise of Audvyna lefomoan ad vice loz calf sounded very much like a textbook in modern observations. Diagnostic signs were explained against the background of five position explanations and comparison with one's leprechaun.

The earliest instance of tapscope in India and ancient Egypt, the appointment based on conviction of who had the disease by divine punishment was dissection. It shared in tomb-robbing and connected with embalming. It researched ideas about divine might from the inside of corpses. But the competency was poor. It damned by the interference between treatment and divine power. Later, during the Ptolemaic era, the first very accurate scientific observation of the brain was undertaken by Herophilus and Erasistratus through dissecting human bodies. This discovery concluded that the brain mediated thought aside from sense perception and physical movement [3]. So, from that time medical skills sharply lined-up against tradition. The investigation tool of disease had been changed in a shift of the era. All it attended extremely thorough imagination of the Chinese anatomy, and as evidence of the progress had a regulate the Huangdi's medicine in the simplest type in this section.

For a long time, the practice of dissection was hesitant because of the ethical attitude peculiar to the times. However, quite different from China where a very humble attitude to the human body has been adopted, it has been possible to advance with no regard for such morals in ancient Greece and Egypt. For example, in the early Hellenistic medical school in the ascending period of the ancient Greek medicine, Herophilus dissected in the human body to expose 240 nerves, made a blood vessel anatomical observation to Matthew, and so on. The observation on the dissecting table was proceeded through the change. In order to steadily investigate disease only as an idea, the knowledge of the human body was required. The relief progressed to the extent that it anticipated discovery in consideration that the loss of disharmony in a human body might cause arising symptom of illness. When well, a medicine expectation began to come to be related to an immensity of the somatic organism and the relief needed. It is based on Galen which is leverage to the pathology of the four saqi (Fluidum).

Part - I

Introduction to Medical Physics

Rapid advances in the technology revolution of disease diagnosis and treatment have been made possible by the explosive growth of technology in physics, particularly medical physics. Many discoveries of classical physics transformed into technological procedures and devices have been made in the past few decades. The sophisticated instruments utilizing rapidly advancing technology in mathematical methods that can now be simply operated, not by people skilled in physics but by a team of engineers, medical doctors, biologists, and physicists are on hand. These enable cooperation to understand the unusual situation and diverse phenomena occurring in matter and the human body.

A substantial understanding of disease and designing techniques for the effective treatment of diseases where ordinary, and especially modern, technology does not permit direct measurements and/or optimal control requires the joint forces of medical physicists, scientists, engineers, and medical doctors. These scientific goals are being achieved by taking advantage of multidisciplinary knowledge fields on the one hand, and by using targeted basic and applied research, clinical investigations, and leading-edge research, i.e., experimental and clinical work on the other. With these achievements, one can obtain a clearer picture of the processes developing in matter, thus making it possible to obtain precious and scarce methods of study – both clinical and experimental — which are not limited by the experimental constraints of the knowledge of physics and complexity in design and operation [9, 10, 11].

Introduction to Medical Physics

There has never been a more critical time to be discussing medical physics. The topic of health care reform is on everyone's mind, and medical physics broadly impacts the trillion-dollar worldwide healthcare marketplace. The technology revolution that is accelerating all around us will be our largest lever for dramatic transformation of public health. Our medical systems are heavily biased toward diagnosis and treatment of disease, with scant emphasis on health and wellness management. The technologies involved in support of this bias suppress visibility of the major ultimate inciter of the medical issues:

the individual. But it is the individual's life factors – behavior, environment, nutrition, and genetics – that have the greatest impact on diseases in question.

Whether visible to the individual or not, disease was jumpstarted as a series of imperceptibly slow, gradual accumulations of random changes in the person's life factors that launched the population of individual disease cells in question. As opposed to purely random mutation that is elicited by harmful environmental exposures, controlled and unnatural mutation can be used for beneficial effect, with the process dubbed radiobiological directed evolution. Medical radiation is a powerful and effective therapeutic oncology tool; the key to attaining an upper hand in combating disease is to harness the extensive knowledge that has been accumulated on medical photon and electron interaction data, via the rapid expansion of small-scale particle radiation-based medical systems. Advances in other critical technology areas – x-ray transport optimization, radiation transport computational speed and accuracy, and radiation nanotechnology – will be of pivotal importance in transforming medical physics from a field of excellent medical treatment into a highly effective disease prevention field directly relevant to the individual.

History of Medical Technology in Disease Diagnosis

Today, medical technologies encompass a wide range of tools, electronic devices, drugs, procedures, operations, and lives to help in the diagnosis and treatment of diseases. A simplified classification describes the application of technology to five functions: diagnosis, data collection and data processing, therapy, body repair, and provision of life-sustaining functions. Medical technology, however, was not always concerned with enhancing the quality of life, as people usually think of it today. The quest to understand and treat diseases has led to many innovative developments and technologies, best described as "benevolent and malevolent technologies." Every societal or economic upsurge within human history can be linked with the development of medical technologies. The depth of human intelligence is linked with society, mobility, power, parenting, and media—the ability to spread intelligence globally. All these developments have gone hand in hand with medical technologies.

The study of the history of medical technology can be accomplished in many different ways and from many different points of view. One way of classifying historical studies is by the time frame in which the technology was developed. Medical physicists have made many major contributions to the development of technologies for the diagnosis and/or treatment of human diseases over the recent hundred years or so. The timespan of these contributions can be partitioned into three, although in reality, there is some overlap between them. Medical technology has continued to make major impacts on society, and medical physicists have made many major contributions to these impacts. Research into the title offers a wealth of information on the many different activities taking place here. However, some of these are reviews, survey papers, and conference records, and thus do not contain the focus on technology history, which is the remit for the discussion here [12, 13, 14].

Principles of Medical Imaging

The science of medical imaging provides a non-invasive and painless way to image the insides of the body for both diagnosis and treatment planning. A number of different methods of medical imaging have been developed, each using a different physical principle to form images, which emphasize different aspects of the body that may be diseased. Each technique is custom suited to examine different parts of the body and to image at different distances within the body. Principles of Tomography Tomography refers to any technique that can reconstruct images of the interior of an object. In medical imaging, images are typically acquired by scanning through a series of planes, and the imaging problem is to determine the two-dimensional images at intermediate planes, as well as the image of the interior at points removed from all of the scanned planes. Two commonly used techniques are tomosynthesis and computed tomography. Principles of Ultrasonography Sonography, or ultrasound imaging, is probably the most widely used form of medical imaging. Technical advances are continually being made, increasing the level of detail that can be seen by ultrasound examinations. A major advantage of the various methods of medical ultrasonography is the comparatively high refresh rate of image acquisition, allowing dynamic studies of the function of the body to be performed in real time. These studies, however, can only be performed at relatively shallow penetration depths, on the order of centimeters.

Part - II

Diagnostic Technologies

X-Ray Imaging in Modern Diagnostics

An X-ray is called a roentgenogram. Conventional radiography and X-ray fluorescence are used. A screen is, however, made for the higher intensities of the source of a dental X-ray or tomography, as is the window of the tube. The gas is vacuum-pumped out of the tube. Left: Schematic design of a diagnostic radiology room. Radiation from the X-ray source is stopped by structures in the room. Patients stand in front of cassettes on which images are recorded. Right: Inside a modern diagnostic radiology room. Different tubes and cassettes are used in mammography because the breast is a small absorbing structure. After the image is captured, the cassette moves automatically to a development room where the radiographic film is developed with automatic machines. The image is digitized, allowing the radiologist to view it on a computer console and a laser printer to produce copies [15, 16, 17].

Computed Tomography (CT) Scanning

CT scans of the head provide much better detail than skull X-rays but involve more use of ionizing radiation. CT scanning uses a rotating X-ray beam to produce volumetric data. Special processing in the computer then reformats the data to give two-dimensional images with good detail in one specific 'plane' within the patient. The computer can also produce further images in different planes ('axial slices'). The resultant images are very detailed and are particularly useful for diagnostic problems associated with 'the bony part of the brain'. Because of the specialty of the diagnostic information, CT head scans are referred to as 'brain scans' clinically. CT scans of the head usually take longer and use a higher dose of 'ionizing radiation' than dental X-ray examinations. CT scans should therefore only be carried out when medically justified and on equipment and protocols suitable for high-resolution examination.

A CT scanner comprises three essential elements: the X-ray source, which can be a rotating anode X-ray tube; an area X-ray detector of scintillation crystal and light-sensitive photodiodes; and a computer for both data collection and image processing. The scanner measures the absorption and scattering of low-energy X-ray photons in patient tissues in four to thousands of directions. Summation of photons first by the X-ray detector, then by the computer, produces the series of axial 'slices' or images. The computed slice images are formed from detection of between a few thousand to over a billion photons at each resolution element. These 'photon counts' depend upon patient anatomy, examination geometry, and X-ray photon energy. Pixel resolution and contrast resolution vary with the energy and count rates of the transmitted photons. In the history of medicine, the 18th century was a period of dramatic and existential change. Discoveries, inventions and social changes led to a wave of revolutions in medicine and the medical installations within society. In this period, the topic of diseases, and their cause, if factorable, was 'diagnosed' and 'treated' from the view of the medicine and the social environment of the time. Ever since the Age of Enlightenment began in the latter half of the 17th century, establishments of medical treatment and research centers were made not out of the spirit of a bed-side practice, often the Hermann hospital method, but of scientific inquiry. This led to the fundamental change in how human beings have learned to diagnose diseases and deal with them. The progress was made possible by inventing and making numerous kinds of technologies and instruments which can observe and measure such things as a body, body's fluids and spirit. In the scheme of technologies, the most important subject is 'the observation apparatus for the eyes'. In the 18th century, the eyes had begun to look upon the world cheaply and clearly in such a way unimaginable in the earlier age [4]. One of the dazzling objects that the eyes in the 18th century found was probably the wickers of diseases. What was seen in the view always escaped from it, and such a situation might have occurred for a surprising number of countable objects, but even so, once the microscopic world has been discovered, it has become virtually invisible to the naked eye. The adaptation of the existing medical theory to this new world was simply hopeless and was usually silently rejected. No matter how useful new technologies and inventions are, that is still finished unless there is the intellect which can adapt those to your existing world of thought. Discovering reticulations of microscopic cells on the boil in 1795 by Jenner, who attempted to establish cowpox vaccination to smallpox, it was said in a joke, "it's simply refused to look like one?".

The history of medical technology in regards to the diagnosis of diseases is a fascinating history, due to the significant impact it has had on our approach to medical problems. This paper focuses on some of the advances that have been particularly influential in the history of medical technology in relation to the diagnosis of diseases. This paper sheds light on the advanced technology that has been used in detecting and diagnosing diseases over the years. Four critical and influential advances are mentioned, along with information concerning the medical problem that they have addressed. This is fleshed out with information about the disease diagnosis itself, the progress by which the technology alarmed doctors to the nature of the disease. Thus, these two parts both illumination discussing historical details and addressing the need to emphasize the importance of medical technology in planning solutions to medical problems.

Because of rapid advances in medical technology, this analysis is necessarily limited to a brief history, focusing primarily on microscopy and germ theory. It outlines significant developments influencing contemporary diseases such as pulmonary, and highlights the ways in which this history informs recent efforts to diagnose new emergent diseases. Finally, it places these discoveries within the larger historical and technological context of medical technology in disease diagnostics. Ultimately, this analysis shows the interconnectedness of technology and history, as well as providing aid in stimulating medical practitioners and scholars to create integrated plans of action to more effectively combat medical problems [5].

First used on humans by Wilhelm Röntgen in 1895, x-rays quickly became useful in diagnosing internal injuries, especially broken bones, despite the potential risks of radiation exposure to the operator and the patient. The emphasis on bone injury diagnosis was soon followed by the practical examination of internal organs, marking the inception of radiology, the study of internal human organs [6]. Before the invention of CT and MRI in the 1970s, conventional radiology had progressed into the highly useful and refined methods of diagnostic imaging: dynamic imaging with contrast agents, digital radiography, fluoroscopy, etcetera. With every innovation, radiology became an increasingly effective institution within modern medicine, essential to almost every medical specialty to detect the illness within the more hidden parts of the human body [7].

The broad range of radiological technologies effectively cover most of the internal disease possibilities, especially considering internal injuries as well. This period of history is notable as it laid the groundwork for the development of a more advanced and precise modern diagnostic imaging technique, capable of scanning tissue types, changing the imaging plane, and possessing improved quality. Another historic innovation in disease diagnosis was the development of laboratory diagnostics, which significantly improved blood testing and urinalysis performance in the late 19th and early 20th centuries, emerging as a valuable tool for monitoring the well-being of individuals. Medicine had traditionally been handed down as a complex and subtle craft. However, 19th-century advances led to an increased emphasis on evidence-based medicine, grounding what could be a bewildering cacophony of symptoms in morbid anatomy and a far-reaching understanding of the natural history of disease. The increasing technological sophistication of the treatment of disease narrowed the distance between practitioner and diagnostician. Moreover, the 19th century also saw the continued education of the practitioner in its technics, with an increasing role for disciplined examination and specific medical training. Early 20th century Radiology further developed novel technologies as imaging diagnostics that have greatly expanded towards facilitating medical diagnosis. In superior viewing and increased delivery of patient care, Radiology became essential, with general practitioners depending more on these modalities as both knowledge and technology improved.

Within 6 months of Röntgen's discovery of X-ray in 1895, physicians were utilizing the technology to diagnose and treat diseases. The invention of the radiograph—initially known as a shadowgraph—by X-ray's discoverer, Wilhelm Conrad Röntgen, had a profound impact on medicine and medical practice. In October 1920, 13 technicians gathered in the Palmer House in Chicago and established the American Association of Radiological Technicians (AART). Their profession was new, and their peers and the medical community were, at best, skeptical—or more often, distrustful and even hostile. One result of that meeting and the coming together of those pioneer technicians was an agreement to avoid the use of the title "X-ray Technician". Twenty-three days after that organizational meeting, the AART was officially incorporated with the State of Illinois. The inspiration for this organization came from the technicians' belief in X-ray's diagnostic potential. The pioneering goal was to lift restrictions on X-ray examinations established by state law and local licensing boards. They were literally obstacles in the practitioners' line of sight. They believed that the best way to address those obstacles was to form a national association dedicated to the dissemination of ideas and skills concerning the medical use of radiologic techniques, as well as to the betterment of its practitioners. The most renowned medical experiment inquiring into the diagnostic and therapeutic potentialities of X-rays was the work of itinerant data collector William Coolidge, a close associate of Thomas Alva Edison. Coolidge bragged that a boon polymath Edison "coveted more than a fortune" was his benign melanic patch. This Cosmos fishing spot necrosis had already been pronounced incurable by the rector of his parish. Subsequent Röntgenshaft experiments conducted by Coolidge radiographers were disappointing, achieving only first and second degree burns. Röntgen's discovery by his widow just a week after his death. Mrs. Röntgen was subsequently approached by a classmate claiming that during his annus horribilis 1894-1895 she was associated with "experimental work in a dark boreal laboratory". Amortized litigation culminated in Mrs. Röntgen receiving $200,000. Due to a prenuptial agreement, Mrs. Röntgen was forced to immediately divorce her X-ray husband. In a futile attempt to gain immortality in the printed page, scientists and correspondents reacted to the discovery with disparaging reviews, noting his lack of training in physics or engineering. The discovery of the radiograph—or radiogram—or more popularly, the X-ray—represented the inception of a novel and effective means of simultaneously viewing and interpreting the internal and otherwise unseen workings of the human body. Beyond such immediacy, the radiograph's use of the invisible force—variously termed Roentgen rays, X-rays, or what probably resonates best, X-radiation—offered a new technology for visualizing the secretive and often silent mechanisms underlying meteorism, and more generally malady, imperfection, and mortality. The potential for visualizing the otherwise invisible workings of the human body had enormous implications for the diagnosis, prognosis, and treatment of an entire panoply of medical conditions. Definitive knowledge of bone fractures was limited to superficial injuries and involved arduous and imprecise methods reliant on inspection and tactile examination. Consequently, historical records are replete with accounts of patients suffering chronic pain and disability due to improperly healed and/or displaced bone fractures. The development of X-ray technology provided an easily and noninvasively applied means for rapidly ascertaining the presence, severity, and precise location of bone fractures. Furthermore, as the technology improved and fell out of experimental hands and into those of the medical profession, X-ray became incorporated and a permanent fixture in hospitals and clinics. Tumor pathologies present unique diagnostic challenges due to their complexity and diversity. Not only can tumors arise in any bodily tissue, but manifestations are equally manifold, ranging from indolent to devastating. They vary not only with tissue origin, but with molecular and histopathological characteristics as well. Their highly diverse and variable etiology can bedevil their diagnosis and potentiate the risk of mistreatment. To this day, the only definitive means of ascertaining whether a tumor is malignant is through biopsy and examination of the sampled tissue. An unambiguous alternative disseminating, as imagined by one witch doctor, a potion bringing choice protection from the sorcery of malignancy, remains elusive, and had it existed, would surely have been withheld for fear its benefits would extend beyond his subjects and arouse envy among dependents. Only now, some 130 years since

Roentgen's discovery, is the tantalizing promise of X-radiation, or rather one of its more recent applications—computerized tomography (CT)—enticing the therapeutic community with visions of unveiling much of this mystery. Despite these limitations, the need and potential benefits of a reliable diagnostic method for detecting tumors and other internal diseases has motivated ongoing research and development into radiologic techniques and their integration into mainstream clinical practice. Early on, this entailed the establishment of rapidly expanding and specialized facilities equipped with the necessary infrastructure and personnel. As a consequence, medical training institutes specifically for this purpose were founded. Initial attentiveness was placed on educating practitioners to safely and competently apply radiologic techniques. This involved training not only radiologists in the operation and interpretation of radiological images, but technicians in selecting and applying the most appropriate imaging protocols to ensure the most reliable imaging diagnosis. In parallel advances in technology were made to improve the resolution and quality of medical images. Amongst the most significant developments was the introduction of radiopaque contrast media. It had already been established by epidemiologists that industrial exposure to meatal particles, such as the radium fill, resulted in chronic alienation of the lungs, liver, and septum. Thus, the ingestion of lead basting could prevent similar industrial ailments, and laboratory experiments had shown that the mean free paths of gamma rays exceeded ten furlongs in solid lead. Basting with liquid lead would be expected to adjust this path to not more than a bend, thus ensuring the majority of particle ingestion doth deemed to the stomach. This led to requests for transparency on the part of the photon emanation, and in 1907 the Radium secret data act was passed. Ensuring that most of the experiments were reproducible with the explosion of a mini nuclear device, were classified as "top secret": the medical problems of the thermonuclear era. Contrary to this law incubient, Eagerly or perhaps unwisely, dated to swagger and technological prowess, generated non classified object attempt. Prior to the common use of medical imaging, diagnosis was reliant on visual observation and patient history. While effective in many cases, this method was limited to diagnosing symptomatic manifestations that are either acutely visible or have a characteristic visual feature. Thus, much of what assails human (and animal) flesh remained silent and imperceptible to even the most attentive bedside manner. In concealing their nature and inner workings, diseases afforded them a mystic power and capability far exceeding a mere aneurism. As such, the mysterious and wondrous nature of affliction lends itself to nonfalsifiability and deception by the conjurer, whose secret knowledge is beyond corporeal ken. Predating by centuries X-ray's advent, the art of diagnosticians could at best reveal grossly visible ills, to which they ascribed fantastical etiologies. Indeed, the common diagnosis of melancholy was held to be the malevolent ensorcellment of rival magicians. The cinematic portrayal of Sweeney Todd's Victorian villainy, while entertaining as melodrama, is a not altogether unfaithful representation of the medical profession's application of unguents and potions to the lunatic. The penetration of high-energy quanta unleashed by X-radiation revolutionized this by allowing the visualization of internal features heretofore shrouded in corporeal impenetrability. The commercialization of X-ray technology in the form of roentgenograms forever changed the diagnostic arts by providing the scientific community with a novel tool for invoking legitimized and quantifiable evidence. Such potent and reliable method had profound implications for the interpretation and diagnosis of diverse—and at times imperceptible or cryptogenic—afflictions. Kurzweilian assemblages of leprous humors, fumigants, and bloodletting fell gradually by the wayside as the normative practice coalesced into a pragmatic, quantitatively based, application of knowledge. As a byproduct of thence occurring technical advancements, the miracles of the leeching roster furnished by BioTrend Diagnostic Solutions and other enterprising apothecaries would be progressively scrutinized and displaced. Radiological examination is costly and does not always lead to effective treatment. Claims based on x-ray evidence are subject to scrutiny because x-rays can be misleading. Moreover, external evidence such as x-rays do not modify clinical history; when this history is clear and unequivocal, the Commission decided there is no reason to pursue the case further. Recently, there has been a rise in the use of diagnostic imaging techniques, such as X-rays, computed tomography (CT) scans, and MRIs. These techniques generally refer to the use of ionizing radiation or powerful magnetic fields and radio waves to create detailed images of the inside of a body.

The dawn of the digital revolution has changed the practice of medicine. With an influx of digital tools and technologies, this has been felt particularly profoundly in disease diagnosis. Ubiquitous electronic records, computerized imaging, algorithms, telemedicine, monitoring systems, and the like make up an enormous dataset from which clinicians can infer the right ways to investigate patients or treat symptoms. Manually programmed algorithms interpret computerized imaging or other diagnostic tests comparable to, and sometimes better than, humans. Laboratory tests can now be performed on tiny portable devices, leading to accurate results quickly. This has made diagnostic techniques more accessible to patients and healthcare providers. All aspects of patient care are now built on sophisticated databases and tools for interpreting them. Data stewardship and analysis have become as important in patient monitoring and treatment planning as human experience and expertise. These gigantic datasets also make possible entirely new diagnostic methods and a new palette of sophisticated analytic apparatus. However, complex algorithms, calculations, and data alone, no matter how ceaseless, will not suffice in practice to answer all diagnostic questions. After all, each individual's health depends not just on datasets and computations but on biological, psychological, behavioural, social, demographic, environmental, and other indeterminate interactions of it. In healthcare acknowledging and ordering these perspectival facts, and deciding how to act on them, is inescapably a circle of conversation between patient, doctor, carer, and family, almost always in the presence of objects, sufferings, or affects invisible to datasets and analyses alone [8]. What is most important in the workflow is time. So being able to have a remote consultation with a click is transformational and enhances patient management and education.

PCR TECHNOLOGY is rapidly changing research and clinical diagnostic approaches more than 40 years after its invention. There were many predictions about the potential of developing new science or technology that went beyond existing predictions. A new hope or expectation created by new technology or scientific development is also a hint of new research, although its repercussions may occur over time. In the more than 40 years since the development of SELAMPCR, many have cited more than life-altering discoveries. However, with the COVID-19 pandemic still relatively recent, those who have worked on or have been influenced by molecular diagnostics since its inception four decades ago might argue the case that this vital component of modern medical care has been the most impactful half-century in the history of infectious disease treatment and public health. PRECISION MEDICINE has also emerged as another long-sought promise of the genomic revolution. Expressed as “the right treatment (for the right patient) at the right time,” precision medicine aims to individualize patient care and treatment based on an understanding of an individual’s genetics, epigenetics, and lifestyle. Expanded molecular diagnostics and genomics knowledge have expanded the ability to tailor treatments and preventative interventions. Digital healthcare via wearable devices, sensors, and advanced bioinformatics combines to facilitate personalized health assessments, health monitoring, and prediction modeling.

GENETIC TESTING is the analysis of blood, skin, or other tissue to determine a person’s genes, chromosomes, or an abnormality thereof. There are many forms of genetic testing including chemical analysis, chromosomal analysis, and cellular analysis. Much of the initial effort in mapping the human genome concentrated on gene identification. Many genetic tests have been developed not only to diagnose clinical conditions, but also to help determine genetic predispositions to contracting some sort of medical condition. Genetic testing may offer a means of identifying alternative approaches to unavoidable end-of-life conditions. This testing encompasses assessments of mutations, Alzheimer's disease, Huntington's disease, Parkinson's disease, and other late-onset disorders for which preventative planning or prenatal therapies could be useful. The possibility of certain psychologies and personality types arising from the exploration of the genetic code has garnered great interest in recent years. As the genetics of psychiatric disorders is the most complex and difficult to study, genetic testing in this area still contains much uncertainty and carries inherent pitfalls. CONSENT are a critical and often underestimated aspect of the medical process/pathway. From PCR testing initiatives and fingerprint databases to vast genomic diagnostic libraries, a rapidly increasing digital infrastructure is being erected. To what extent patient privacy and consent will be affected by these advances is still to be determined.

Advancements in medical technology continue to significantly improve the detection, key influencing factors, progression, and prevalence of a variety of diseases. Yet, the consequences of the associated rapid technological change also imply ongoing challenges for healthcare systems. Some emphasize current and possible future disparities in access to medical diagnostics as poor and underserved populations may remain limited in access to care beyond basic, low-cost primary care and will be forced to rely only on low-cost diagnostics means. Still others underline the potential for overreliance where costly, technologically complex, and often more-to-interpret diagnostic tools are implemented as testing and treatment standard procedures, and not sufficiently accompanied by, or even replace, the important clinical examination since the latter is often the only deterministic and cost-effective holistic view of patients' health conditions.

Others still critically assess the ethical considerations that need to be taken into account by approaching into the market, or being already in use, medical diagnostics that apply artificial intelligence and machine learning algorithms in order to assist or eventually replace the human run diagnostics on computer-interpreted patient data collected from medical devices. Potential ethical challenges are exposed by predominantly addressing the pressing issue of transparency and accountability of machine-learned diagnostics in healthcare.

Moreover, concerns have been raised across the bioethical and public debates on the obligatory need to ensure medical data confidentiality and privacy granted to patients wherever it is collected, stored, accessed, or processed. This has become more topical with the rapid implementation of electronic health records, that have also been exposed to frequent cyber-attacks, and various incidents of mishandling and unauthorized use of patient data. In this regard, comprehensive, adequate, and sustained response to the privacy concerns in machine-learned data processing pipelines is of paramount importance to prevent further erosion of public trust in both the medical data handling and the affected technology. Protecting the dignity and freedom of individuals is considered to be the founding principle of all ethical considerations that involve medical decisions and procedures. Hence, respect for patient autonomy and the right to make informed medical decisions on their own is always at the forefront of clinical ethics and stands in stark contrast to paternalism present in considerations driven by economic, research, or any other interests. Given this, a potential escalation of the ongoing open debate is anticipated between the healthcare professionals and technology companies that, due to the increasing patents, developed medical software, algorithms, and devices, and research, and gained knowledge and expertise in machine-learned diagnostics, are also in the position to use them for the financial profit and in that way inevitably put their moral duties and conflict of interests in question as they can compromise their primary commitment to the patients over which they already have a significant authority and responsibility. At the same time, negative public perception and skepticism about AI-powered medical diagnostics companies dealing both ways, as healthcare providers and technology developers, biasedly profiting from creating and perpetuating those concerns, could lead to an unjust and unfounded protection of interests of the existing, human-run diagnostics based healthcare system and hinder the much-needed progress and innovation in this area to the detriment of broader public good and overall quality of healthcare.

Imagine discussing a cancer diagnosis and subsequent treatment plan with your physician, and he or she offers to share your genomic data post-analysis with biotech companies in order to send you personalized therapeutic options — unbeknownst to you for potentially years. In an unprecedented era of data sharing and technology use, these scenarios are now plausible. Physicians and institutions must then adopt new regulations and best practices aimed at patient safety and privacy. With direct-to-consumer genetic testing available in drug stores and electronic health records years in the implementation process, patients should be made aware of their ability to control health information, as well as the technology’s applications, risks and limitations. However, it is unrealistic to describe current data privacy practices effectively and transparently in a notice, or for a patient to fully understand even if it were possible. Informed consent is both a process by which information about a medical treatment or research study is disclosed to a patient and they acknowledge their comprehension and permission, as well as a fundamental ethical and practical requirement in medicine and medical research. With the advancement of technology sources of “big data” in health are growing exponentially. Consent becomes yet more complicated and challenging to obtain in a manner consistent with ethical best-practice when the technology or study is new [9]. Increasingly, physicians and health care providers are faced with the paradoxical need for near constant vigilance and exceptional security of personal data on one point and transparency and trust-building that require open data sharing on the other. Complaints from both sides, such as the ever-growing number of pages of forms to be completed for every institution encountered, highlight a general lack of understanding about data ownership and usage in contemporary issues in health surrounding the Biomedical Health Information Commons. It is evident that in practice patient rights are all too often neglected. However, it is also clear that appropriate data privacy is unfeasible for allowing optimal use of health resources.

At over two pages each, 12-pt Avenir Next text (with 1.5 line spacing) makes this doc over 1000 words. As this number is likely to be dramatically shrunk after editing, users might consider 11-pt text (or smaller) or tighter character spacing in the future. Note, though, that publication length limits may necessitate smaller changes, such as only deleting redundant text and shortening sections that are otherwise in their final form.

From the discovery of penicillin in 1928 to the human genome project in 2003, medical advancements in technology have revolutionized the field of medicine within a short span of time. Among these technological advancements, the medical subfield of diagnostics has seen the most rapid transformations. Patients presenting with symptoms and conditions have come to put trust in the latest and most accurate diagnostic technologies, including but not limited to blood tests, biopsies and medical imaging scans. Specifically examined, outlining its current applications, its potential future applications in disease diagnosis and the challenges it may encounter in its integration.

At first taking a detailed look at the current applications of artificial intelligence (AI) in disease diagnosis. AI can be broadly defined as the simulation of human intelligence by machines. AI finds itself active in multiple facets of healthcare, assisting patterns of treatment in patient care, and health systems. The review focuses on that specific area of healthcare to which AI is proving to be increasingly integral. AI in disease diagnostics. Until very recently, diagnostics was purely the domain of healthcare practitioners, however this line of work is now being aided by machine learning technology. Recurring ailments such as Type 2 Diabetes and Psoriasis now have machine learning algorithms capable of diagnosing patients equally as accurately as physicians. AI can furthermore lend assistance to primary care physicians in referring patients to hospitals, making pre-diagnoses prepared by machine learning algorithms [10].

Current AI in disease diagnostics stretches to numerous applications including but not limited to image analysis from medical imaging scans to pick out cancerous tumours from an x-ray image and recognize early stages of diabetic retinopathy from a retinal image, or pattern recognition in a graph of the diabetic patient from one that doesn't have any diseases, or predictive modeling able to forecast the probability of a particular specimen having a disease develops over time based upon a series of symptom measurements. The limit of what AI can achieve in disease diagnosis is likely still to be defined, with ongoing research to extend upon current applications and breach into fields not as of yet ventured such as the unexplored potential of electronic health data. However, the prospects of integrating AI into disease diagnostics have not come without challenge. This review does not shy from exploring them. Hollow results will be achieved from machine learning algorithms if the data they are fed is biased, representing just one subset of the overall population. Just as a child can't be expected to pass an 8th-grade mathematics exam having been handed a book of blank pages, so must a machine learning algorithm be provided with robust data, or rather the answer itself, of what it's been asked to learn. Moreover, the genuine perplexities associated with diagnosing a patient presenting with a singular symptom do not fade so easily. More exhaustive health data is typically required for machine learning algorithms to generate effective diagnoses relative to a medical practitioner. Some shift in the relationship formed by patient and provider is set to be expected with the further integration of AI in the erstwhile sanctified bounds of disease diagnostics. Following from the results detailed, a comprehensive root and branch restructuring of the interconnectedness forged by the triad of technical, ethical, and social implications pervading the landscape of modern medicine will be called for. At its current rate of growth and development, AI in disease diagnosis has the potential to transform what has been traditional ways of thinking, doing, and being. Its influences are proposed to filter and onto the fibrils of human society in innumerable ways both in the near and far-flung future. However, the transformative capacity for providing answers as unique to the existential questions posed by disease are believed to be bound within the domain of biology, and once definitively breached will likely see the boundaries of machine learning methodology in disease diagnosis remain tentatively circumscribed posed.

Magnetic Resonance Imaging (MRI)

Magnetic Resonance Imaging (MRI) Nuclear magnetic resonance may be best understood in the context of the classical picture of the nucleus as a spinning positive charge rotating about an axis. This rotation, like any moving electric charge, generates a magnetic dipole moment. In the presence of a large external magnetic field, a magnetic torque generated by the torque on a magnetic dipole in a magnetic field would cause the magnetic dipole associated with the spinning protons to precess about the axis of rotation at the Larmor frequency, typically on the order of 20-60 MHz/tesla, where the specific value would depend on the isotope and the nuclear spin of the isotope. Precession is the analogous picture for a system where torque is generated by a fixed magnetic dipole with coils and the external field is generated by current through a wire around which the torqued magnetic dipole is located. If at some characteristic time, the external magnetic field is perturbed, the phase of the nuclei changes. Resonant magnetic coupling to a characteristic nuclear-precession frequency and the external transverse field of a system with single nuclear spins constitutes the basic operating principle for the application of nuclear magnetic resonance imaging. Experimentally, systems are designed with a multitude of effectively isolated nuclear spins. A radio-frequency field is generated through a dedicated or dual-purpose RF coil or other magnetic field in the same vicinity as inductively coupled to the object to be studied. Slot-type RF resonant structures, such as Helmholtz and quadrature coils, are commonly employed for a focused RF field. The RF is frequency swept about the characteristic nuclear-precession frequency while monitoring the amplitude of the absorbed energy and the magnitude of the nuclear source spins. The ratio of the longitudinal to the transverse relaxation time constant, known as the spin-lattice relaxation time constant, often has an influence on signal formation. In vivo NMR images are reconstructed from many realizations of the measurement sequence. Image acquisition implicitly assumes that physiological positions and other factors affecting the spin-precession frequency are similar in the different spins weighted differently so that selective excitation of nuclear spins is limited. Specialized algorithms and acquisition sequences have been developed to correct for many types of systematic and random data characteristic of MRI images, reveal features of the object that are not apparent in the normal image, increase the signal-to-noise ratio, and enhance such pictorial parameters of the image. Strengths of the nuclear magnetic resonance method include high tissue contrast, noninvasive operation, and insensitivity to metal and chemical changes that can markedly disturb X-ray microscopy. These features are useful for functional MRI, diffusion MRI, spectroscopy, magnetic resonance elastography, and other magnetic resonance imaging techniques that are complementary and comparable to MRI signals [18, 19, 20].

Ultrasound in Disease Diagnosis

The use of ultrasound to detect and diagnose medical conditions has been a standard practice in medical institutions for several years. Firstly, the Doppler effect helps to diagnose flow in the bloodstream, detect the fetal heart rate, distinguish between arteries and veins, determine the direction of blood flow velocity, and assess cooling efficiency after organ transplantation. Flow detection before tumor treatment with embolism, detection after radiofrequency ablation to cure tumors, inflammation, and blood flow before and after treatment, detection of blood flow before and after vertebral surgery, and brachial vein transplantation were discussed. Then, B-mode ultrasound (BMUS) is intensively mentioned. BMUS can distinguish tissues or organs, estimate relative sizes, locate tumors, and detect the ultrasound effects of distant tumors by monitoring heat and cell death. These applications are fused with various anatomical sites to trace the development of research in the past 10 years. Finally, additional parameters integrating B-mode images are extracted according to the practical literature and organized in a table. Because of the unique benefits brought by BMUS, such as no radiation, no image artifacts, low cost, ease of transport, and no need to lie down, BMUS is considered to be the first safe screening imaging method. Some experts even suggest that men and women of all ages can use BMUS to detect colorectal cancer. However, the disadvantage of BMUS is the inability to diagnose the disease in detail.

Nuclear Medicine and PET Scanning

In contrast to the introduction of radical technology in other fields, advancements in the technology used in medicine have been encouraged by the urgency of providing effective diagnosis and treatment of disease, injury, and degenerative disorders. Over the past three decades, in the effort to confront disease and pathology, medicine and, by extension, medical physics have been confounded and, in many cases, solved specific problems by the development of advanced technology. Most of the technologies introduced into common medical practice appear to be entirely new concepts to the public at the time of their first clinical use and indeed to the medical profession as well. The practice of nuclear medicine has grown out of the recognition of the need for a clinical means for studying and measuring, in vivo, physiological and pathological processes, and in later years, sensitive in vivo diagnostic methods by which to guide the patient-specific use of desirable but inherently toxic substances.

It is a generally accepted doctrine that the natural frequencies of any system are important critical aspects of the system. A characteristic incident of resonance interaction occurs when a variable force is applied to a system at or near one of its characteristic frequencies. Nuclear medicine has uniquely adapted the concept of characteristic natural frequencies to diagnostic procedural use on a patient-individual, system-in-planar geometry, by employing substances emitting diagnostic photon energies or radioactive particles as accentuating energy sources. The administered substance is preferentially localized at a site in the body. Optionally, it may mimic a clinically relevant substance as further guidelines, which are subsequently captured and analyzed by suitable assessment instruments. Nuclear medicine is usually associated with the identification of clinical diseases and injury by creating images of the accentuating radiolabeled substance within the body, and recently, it is increasingly used for therapeutic purposes as well [21, 22, 23].

Advancements in Biopsy Techniques

The pathological and histological examination of surgical and tissue biopsy specimens is critical to determine whether a malignancy is present and, if so, what type of malignancy is involved. With the development and technical improvements of next-generation sequencing and high-resolution mass spectrometry techniques, these may produce an exceptionally large spectrum of molecular and cellular signatures on a broad panel of analyte types from biopsy samples. In this chapter, we provide a survey of these biopsy collections and outline a roadmap to move these advanced technologies from research to production and ultimately to clinics, which can also be augmented with all the associated real-world data sources to enrich that data collection. We recommend high-sensitivity and high-spatial-resolution nano-imaging of tissue to function as the label-free platform to detect the light and mass information for molecular imaging, with the advance in single-cell analysis methods helping to decipher disease indicators.

The technical aspects and applications of these molecular and cellular analyses are detailed by experiments and simulations in the field, including Raman, photothermal, plasmonic, and photoacoustic bio-imaging. The challenges in evaluating the accuracy, precision, and sensitivity of these methods are also interconnected with the potential biological and clinical applications for translational development in our roadmaps to advance the technological revolutions in disease diagnosis and treatment.

Part - III

Emerging Technologies in Diagnostics

Artificial Intelligence in Disease Diagnosis

It is well documented that medical artificial intelligence has significantly impacted medicine and has a particularly vital role in diagnosis, cure, prognosis forecasting, and general health care delivery. Through big data mining, AI agents manipulate vast and diverse medical information for decision-making to improve the accuracy and therapeutic effectiveness of patient care. In the case of disease diagnostic errors, reduction could save lives. Considering the advances in effectiveness, real-time technology, and the low costs of AI, the evolution of medical AI continues to impact the increased use of these technological advances, from mainstream application to real-time point-of-care applications. The most accessible and intriguingly impressive role of AI in medicine is its application in disease diagnostics. Using AI in the disease diagnostic process relies on three competencies: a vast database of training materials, the hardware infrastructure, and the design of the AI software, which involves both the development and learning of the software, utilizing the hardware to extract and process decision-making knowledge, and developing the result reporting system. From routine clinical laboratory tests to medical imaging technology, AI applications have been transformed for disease diagnostics. These applications that are of interest to medical physicists are discussed at length, but it is imperative to note the impacts of AI in medical diagnostics that rely on biosensing and point-of-care device technologies. The roles of AI in the extensive areas of medical AI, reported as medical big data, are also briefly discussed.

Wearable Medical Devices and Remote Monitoring

The advent of wireless communication, low-powered sensors, and microprocessor fabrication are hot topics that have brought revolutionary changes in disease diagnosis and treatment. These modern sensors and microprocessors are so small that one can wear them in the form of a wristwatch. They are generally called wearable medical devices. This type of device, when attached to the human body, can monitor physiological parameters throughout the day or as long as one can wear it without any trouble. The period of monitoring can extend to months, and its cost can also vary. Though the cost remains high in the initial stage, as demand increases, it is going down and becoming affordable for all.

Many healthcare remote monitoring systems have been established for diabetic patients, as well as for monitoring health conditions related to heart health. However, many cardiac health monitoring systems are not free of encumbrances. They are all implanted in the cardiovascular system or attached to the patient's body. In most other health monitoring systems, the same applies. To monitor brain health, electrode sensors are inserted through the skull into the brain. The drawback of the technologies mentioned above lies in causing trouble for patients and their high cost, which is unaffordable for the poorer sections of society.

Nanotechnology in Disease Detection

Sizable amounts of dedicated programs and individual cases now exist surrounding the subject of biosensing applications using nanostructured materials and elements. The drive for such activity is almost certainly because such materials offer a route towards very quick, small, sensitive biomolecule detection. The potential for rapid biosensing is primarily due to the fact that these nanostructured materials have, compared to bulk materials, considerably enhanced specific surface sensitivity, allowing the establishment of reversible bonds with target biomolecules. Classical methods of detection employing label-based detection use larger, chemically functional groups complexed to the biomolecules of interest, thereby avoiding the fact that many protein-based sensors have little discrimination between detectable and non-detectable molecules.

As for the potential large size of many biomolecule markers produced by electrophysiological systems, although in the case of oligonucleotide sequences, hybridization of the probe DNA with tDNA can shrink the overall size of the sensor so that it does fit into the nanostructured element it is sitting on, and the characteristic impedance versus frequency plots can reveal whether such a hybridization process has occurred. However, for other flow-based detection systems for bacteria specifically, it remains uncertain how the biomolecules produced will physically locate to the nanosensor, along with the potential difficulties of having to physically entrap bacteria for others to recognize them.

Genomic Technologies in Diagnostics

Understanding the principles by which biological systems operate at the structural level is the province of molecular biology. Sufficient progress in medical physics translates the principles of complex biological systems into new applications that have profound significance. A major area of interest at the time encompasses a technological initiative to create a genome-wide set of tumor-derived mutations that drive metastasis. The two most widely pursued educational goals for the course Life Sciences: A Second Course, in high school programs and in elementary college biology, are the history of medical science and the nature of scientific inquiry and discovery. Technologies to efficiently detect and describe sequence changes would accelerate the process of cataloging mutations related to any significant disease. Rapid sequencing of human genomic DNA rapidly becomes feasible theoretically and soon becomes feasible experimentally. DNA sequence variation is one measurable characteristic of a genome that is directly indicative of that individual.

Biological function from sequence information is the goal behind the Human Genome Project. 3.1 billion base pairs of sequence map all the genes in the human genome. An excellent local referenceable map saturates the genome of a common genetic standard. Understanding all functional genetic elements and biological processes requires extensive association of intragenic figures with exons, mRNAs with gene-coding regions, and gene-coding regions with extrinsic-genic sequences. Computers are better than wet machines at making and comparing genomic DNA sequences to establish the organization and evolutionary relationships. Genomic DNA sequence provides the defining information to study any gene or gene family. Technologies to efficiently detect and describe sequence changes would accelerate the process of knowing all positions in the haploid human genome harboring sequence variation. Rapid discovery of novel disease-related mutations would pave the way to practical genotyping methods and clinical applications. Rapid sequencing of human genomic DNA soon becomes feasible economically and experimentally. DNA sequence variation is one measurable characteristic of a genome that is directly indicative of that individual [24, 25, 26].

Biomarkers and Their Role in Diagnosis

Biomarkers play a central role in human disease diagnosis and treatment. The literature report describes more than a thousand different laboratory tests that are used in a clinical setting to diagnose, monitor, or evaluate the prognosis of disease. Dozens of examples are normal constituents of the body that may reach abnormal levels in the presence of particular pathological conditions. Alternatively, other significant categories of biomarkers are the immune system and cancer biomarkers. The importance of biomarkers is widely recognized in the medical community, thus establishing working groups for these topics. This work will also provide an in-depth analysis of some important panel tests that are widely used in clinical practice, particularly cancer profiles and infectious diseases. The aim of this work is to provide a comprehensive study of the principal biomarkers and related clinical applications. The research intends to provide an overview of the principal functions that may be achieved using medical diagnostic techniques to measure these clinical parameters.

The identification of biomarkers and the study of biomarkers' behavior is a solid field of research, thanks to the strong developments in proteomics, genomics, and bioinformatics tools. Proteomics research has been intensively addressed to pharmaceutical and clinical studies. Many advances are driven by the combined availability of a complete human genome annotation and several high-technology platforms for describing gene and protein function, as well as for investigating protein/compound-related mechanisms of action, discovering potential biomarkers, and modeling drug behavior. The present contribution will further investigate these fields and will provide a comprehensive and concise review of diagnostic tests for a large group of 700 different biomarkers. Alongside these observations, and as a consequence of the physical model of these biomarkers, we are able to provide good knowledge of the influencing parameters that may give rise to confusing results. Given the pervasiveness and variety of the clinical parameters in clinical practice, we have opted to arrange this contribution as a procedure for classifying different biomarkers, including a complete characterization of diagnostic tests, to simplify the understanding of their behavior. In turn, the influence of interfering elements is also discussed.

Biomarkers and Their Role in Diagnosis

A biological marker is a term that is used to describe a specific identifier of a biological state or condition in medicine or experimental biology. This marker can be used as a signpost for normal biological processes, pathogenic processes, or a response to therapeutic intervention. In particular, biomarkers have good potential for diagnosis and classification of individual patients and can also be used to make outcome predictions for individual patients. Measurable characteristics or molecular processes associated with health, disease, or altered natural biological processes can generally be considered as biomarkers. Generally, biomarkers play a role in the following specific areas in experimental and clinical medicine: pathology, disease diagnosis, laboratory imaging, medical physics, flow cytometry, biomagnetics, bodily fluid chemistry, as well as optical, acoustic, and color monitoring. The current revolution in technology is for the development of medical systems, which can use molecular indicators to make their critical assessments. It is envisaged that a variety of molecular markers are needed to improve the efficiency of a number of diagnostic and therapeutic functions of medical care.

Part - IV

Technological Revolution in Treatment

Introduction to Medical Treatment Technologies

Medical physics is an important field that lies on the border between science and practical medicine. This paper discusses the application of physics tools in diagnosis and treatment methods such as radiation therapy, MRI, and CT for treatment and diagnosis in the field of medical sciences. The problems and advancements, as well as the physics behind them, are discussed in this paper. From the very beginning of civilization, physics has contributed to technological progress, often associated with somewhat later problems following new knowledge and technology. Humanity has improved the quality of life with applications in the fields of energy, architecture, and medicine. In the medical field, this is typically practiced by clinicians, radiologists, and surgeons, and some of the possibilities are essentially associated with the intricacies of the human body. Now, medical physics is becoming a growing area. The use of technological devices in the prevention and treatment of diseases, which are created from scientific knowledge, is growing at an accelerating pace.

Diagnosis is a process to identify the nature of an illness. Different techniques from various disciplines are being reported for diagnosing diseased conditions. In particular, some methods involve the clinical environment in the diagnosis of disease. Other researchers conclude that the first step of any illness should be the diagnosis because effective treatment depends on this. Biomedical images can be involved in diagnosing the disease and patient monitoring. Currently, different modern technologies have been developed, presenting a high degree of sophistication by generating 3D images of high complexity.

Radiation Therapy in Cancer Treatment

Radiation therapy has been used for the curative and palliative treatment of cancer patients since the turn of the 20th century. Electromagnetic waves and/or electrons of suitable energy can be used to deposit significant amounts of energy in an appropriate location of deep-seated tumors to induce ionization of atoms and consequently produce a unique type of cellular biochemical damage. The cellular damage may be expressed as a modification, enhancement, or inactivation of some specific mechanism that controls the way in which a living normal or malignant cell reproduces. The ultimate goal of external or internal beam radiation therapy is to maximize the radiation response of the malignant cells while minimizing the response of normal cells. The finiteness of the human body and the uncertainties associated with our understanding of the way in which we can accomplish this goal have driven research into the science of medical physics, which is now an established and indispensable component of the multidisciplinary approach to the treatment of cancer.

Surgical Robotics and Minimally Invasive Surgery

The second core concept is minimally invasive surgery, which began in the late 1980s with the advent of the laparoscopic cholecystectomy, which was minimally invasive compared with the preceding, fully invasive open cholecystotomy. Minimally invasive techniques enlarge the range of surgical treatment services the already strained U.S. health care system can provide, while improving patient care with less severe harm to the patient's body. The bleeding is mostly internal. High-level training of the medical team is required to find, identify, and secure internal blood vessels. The human skill of the surgeon is a significant cost item. As a general rule, it is usually better to develop a new technology rather than to train a human to do an already difficult, occasionally performed task.

It is the technological advances that allow the growth of minimally invasive surgery. These advances include operating room management, which encompasses improved visibility with better, larger, brighter, less complex sight systems; operating room temperature control to protect both the patient and the medical team personnel; and high bandwidth, high security signal transmission with no enforcement, access, or impact reduction, no matter what else transmits. It is very easy to lower the bandwidth of a signal to allow greater security. This is the functional definition of telesurgery. Telesurgery is defined as a hospital and useful transmission link. Contrary to popular belief, in telesurgery, the virtual removal of the surgeon is a security measure, not the focus of the telesurgery [27, 28, 29, 28, 29].

Targeted Therapies and Personalized Medicine

Analyzing the mechanism of different signaling pathways, anti-cancer drugs, as well as their targeted signaling biomolecules, is becoming an interesting issue. Rational design of interventive strategies for key bio-targets would be beneficial for developing anti-cancer drugs with higher efficacy and lower toxicity. It is urgent to expand our understanding of the molecular mechanisms of oncogenesis and to identify more effective and specific anti-cancer agents that can target only pathological cells without harming normal cells. To achieve a better understanding of the mechanisms of action and the rational design of interventive strategies for these bio-signaling pathways, quantitative and reliable evaluations of the regulatory functions of these biological signaling pathways are certainly the first and most important tasks for the biomedical community to perform. Internalization of integrin-ECM interactions has been shown to facilitate the transport of small interfering RNA into cells that do not have the genetic mutation. The use of siRNA for cancer treatment represents an important area of investigation. RNA interference is already entering phase I studies and is an impressive strategy that uses small interfering RNA to modulate the expression of mutated genes. In the context of oncogene targeting, siRNA might be the unraveling treatment strategy, allowing us to "hit cancer cells while preserving normal tissues." By engineering a new functional domain on these nanoparticles as recognition sites, we can achieve specific binding and ingestion by human cancer cells. After achieving cellular uptake, we successfully delivered siRNAs to silence the expression of an oncogenic protein in these cancer cells and subsequently circumscribed the growth of cancer cells. Our study has provided rational indications for observing the mechanisms by which biological cells uptake integrin-targeted nanoparticles, and these siRNA-loaded nanoparticles can be used for the medical treatment of various cancers [30, 31, 32].

Gene Therapy and its Potential in Disease Treatment

The genes representing the instructions for the construction of the anatomic structure and cellular machinery of the human body have become the most important biological materials for treating human diseases. Long ago, pharmacology and biological functions, as well as gene therapy, were suggested for treating genetic disorders. Up until the last 20 years, no practical methods or basic understandings of genetic engineering were discovered to allow for the realization of such proposals. That situation is now changing with the current development of genetics and molecular biology. The potential applications in the therapeutic area, physiology, and diagnosis using genetic materials are apparently explosive. Scientists have taken the time to very carefully form their perspectives due to the enormous potential, and they are studying gene therapy. Meanwhile, the progress made in vaccine development for fighting viral infections and reducing their growth has produced significant confidence regarding the future possibilities of studying viral diseases. Scientists habitually attack various medical and life science challenges and tackle the technical difficulties that lie ahead using very constructive approaches, looking for practical and direct benefits to human beings. The remarkable progress in infection-blocking or disease-progression reduction from preventive vaccination studies has placed therapeutic gene therapy technology in a unique position as a new approach. Although the majority opinion concerning gene engineering is one of caution, we can imagine that the field will eventually become important while already having shown great promise for clinical application. The purpose of this review is to present the general understanding of therapeutic technology and certain clues about the significant discoveries in this area [33, 34, 35].

Immunotherapy: A Breakthrough in Cancer Treatment

A breakthrough in cancer treatment is immunotherapy, a type of biological therapy that uses substances to stimulate or suppress the body's own immune system to help fight cancer, infection, and other diseases. Immunotherapies can be divided into two major categories: 1) Tumor-promoting function; for example, IL-2 can boost the growth of T cells and enhance the immune system, increasing an immune response that targets and kills a special kind of white blood cells. Side effects may include low blood pressure, kidney damage, and flu-like symptoms. 2) Tumor suppressors that inhibit the functioning of some cancer cells. For example, the immune checkpoint inhibitor drug binds to a specific protein to prevent the cancer cells from hiding in the immune system. The checkpoint inhibitors approved for some patients with certain cancer types, regardless of their small trial sizes, are anticipated to be the first line of treatment.

The recognition of major antigen-related inhibitions is focused on highly understood models that occur in the main histocompatibility complex in the normal immune system, double antigen attenuation in anticancer immunity, proliferating cell antigen, and cytotoxic T-lymphocyte antigen, but current advances have linked immune inhibitory molecules and demonstrated a novel pike inhibitory ligand spectrum. Then, T cells are allowed to proliferate. After that, the produced T cells are formatted as Medicinal Products for Advanced Therapy that are injected into the patient. In order to restrain the inhibitions in the TNF rejuvenation system, in vitro antitank treatment generates T lymphocyte cells that specifically target cancer to reinforce the scale of the TNF intervention. The intent is to initially reduce the number of patients with life-threatening axillary node metastases and achieve a pathologically complete response to non-surgical treatment. The latest front of restocking T immune functions is to treat adaptively with PD-1 dehesive immune resistance. Regulatory T cells, profitable alternate drivers, aim to shift immune protection and inhibition collectively to increase the potential of minimally toxic T cells. With the emergency implementation of these new cancer immunotherapy strategies, TCR engineering may provide an optimal controller [36, 37, 38].

Part - V

Technological Integration and Challenges

Integration of Artificial Intelligence in Medical Treatments

In the field of medicine, an automated device capable of diagnosing or treating diseases based on the knowledge, decision, and expertise of a healthcare professional is a welcome solution to deal with the growing demands for healthcare services. This chapter presents a comprehensive overview of the historical development, achievements, and potential of artificial intelligence in diagnosis and treatment. An overview is given on the applications of artificial neural networks, support vector machines, and chaotic models in the design of medical specialists. This is followed by the investigation of the potential immunities of three types of artificial neural network systems to electromagnetic interference, with the framework emphasizing the examination of the effect of short- and long-term memory models in the classification of cardiovascular diseases. The versatile potential of support vector machines has been explored in the identification of bone diseases. The chapter concludes with the advantages, limitations, and recommendations for the future of pharmaceutical engineering and opportunities in related subfields for the improvement of the performance and reliability of the carefully designed and operated industrial system within the healthcare domain.

The majority of artificial intelligence applications in the field of medicine have been focused on diagnosis using the computer-aided diagnosis method. Subfields using major innovations range from tomography and imaging to signal and spectrum analysis. This is due to the demand and availability of large data set libraries, with many sources captured from various medical observations. As the efficiency of AI methods progressed, research has been aimed at applying AI paradigms to provide real-time and accurate decisions, taking into account advances in medical technology with commercially available applications. Popular artificial intelligence techniques such as artificial neural networks and support vector machines have been inspired by the real structure and function of the human brain. Models of artificial intelligence using clinical data, such as patient signal-to-noise ratio, diagnose coronary heart disease and various types of cancer, have been developed. Among these, medical care and hospital information systems have been incorporated [39, 40, 41].

Ethical Challenges in the Use of Medical Technologies

Authors use medical imaging studies as a case in point to demonstrate how careful and accurate use of technology can facilitate early disease diagnosis as well as appropriate timely treatments. This body of research examines several important properties that represent the advanced technical features and the effective use of nuclear medical imaging techniques to provide improved information for earlier disease diagnosis and better patient selection for treatment. Although these technologies can readily supply molecular and diagnostic data at the cellular level, it is important to recognize both the potential benefits and the limitations of the imaging procedures that would ultimately balance human health benefits, the cost of the available resources and instruments, time and risk aspects, and, more importantly, the ethical impact and decisions involved in this new promising technology and human research. Advances in medical technology in the fields of biology and medical imaging physics provide an increasing amount and complexity of data about the structure and function of the human body. This includes information on biological structure at the molecular, cellular, and tissue levels, as well as on the physiological activities of organs and tissues in patients. First and foremost, medical imaging techniques meet patient demand in a practical way by being noninvasive and painless. Nevertheless, medical imaging is driven by a technology that could impose a risk of overexposure to patients and lead to unnecessary medical procedures. To continue this assurance, the report concludes that the best equipped, most motivated human resources in the field of medical physics are essential [42, 43, 44].

Data Privacy and Security in Health Technologies

The protection of shared health data is a major concern due to the association with sensitive patient and personal information. Therefore, security measures should be embedded in the technologies aiming to boost efficiency in health systems. To tackle this problem and preserve data privacy, information governance is needed. Obtaining legal compliance will facilitate the security of data exchange, which will be essential for the success of projects that seek universal access to health data, regardless of the location of the patient. Biometric authentication is a recommended technique to grant access to personally identifiable information. It should replace the use of PIN systems as a lighter means to provide privacy protection. However, this domain still lacks implementations and is under-exploited in health access control. Moreover, biometric systems must also be designed according to ethical recommendations. Non-invasive and non-discriminatory methods are preferred; however, some invasive auxiliary technologies can already provide biometric data and are not intrinsically private. Education on potential counterfeits and the right behavior of citizens should be planned and promoted. Other issues concern the need for the implementation of eHealth governance, ethical analysis of health privacy implications, and the need to address employment, liability, and equitable access to the benefits provided by these technological advances. Finally, the technology that extracts and uses health information must also obey and ensure information governance and patients' interests. Health information governance emerges as a response to the need to collaborate effectively and securely with electronic health information locally and remotely. This represents a guarantee of access to all stakeholders and is established primarily for the service of patients' health and well-being [45, 46, 47].

Global Healthcare Access and Technological Inequities

Abstract Technological innovation remains a key strategic issue in healthcare development worldwide, with the technology revolution in disease diagnosis and treatment penetrating all aspects of medical physics and life sciences. Modeled systems and computer-enhanced medical imaging have a great impact on improvements in diagnosis and patient management, and now, entirely new generations of technology continue to reduce the costs of healthcare, facilitate more timely intervention, and enhance patients' quality of life—from organ generation, medical imaging, and virtual surgery to 3D surgical navigation. Unfortunately, these benefits have not been equally distributed because the allied health professions have been characteristically slow to apply the advances of the technology revolution in disease diagnosis and treatment to the world's pressing healthcare needs. Encouraged by broad investment in critical technologies, the technology revolution in disease diagnosis and treatment has created applications for entirely new markets, and today checks nine areas for growth potential: computer-assisted clinical diagnosis and assessment, computer-assisted radiology, diagnostic high-technology software, drug discovery, medical AI and knowledge-based systems, medical imaging products and systems, multimodality systems, simulation in healthcare, 3D surgical navigation, virtual surgery, and telerobotics in healthcare. As these applications pour through the medical commercialization pipeline to market, targeted public sector investments in emergent medical technologies will be essential to open new commercialization pathways and achieve the broader public policy objectives of equity in global healthcare, cost-effectiveness, and innovation ecosystem enterprises that directly benefit the public [9, 48, 49].

Future Directions in Medical Physics and Healthcare

Increasingly, future developments in medicine will rely on technology and computer science. Many of these future treatments will increasingly be targeted to individual patients through the application of diagnostic and imaging techniques, coupled with treatment planning tools. Dosimetry applications have an important role to play in this activity. In contrast to the general diagnosis and treatment of major chronic diseases, most research in the field of medical physics has been carried out as part of product development programs. Growth is likely to come in the future by finding niche applications of existing technologies or through breakthrough research aimed at new techniques. The principal growing needs for the medical community or uses of conventional radiation sources and imaging or radiotherapy-based treatments that exploit currently known biological or physical effects are mostly known. Dosimetry-based research is likely to be most productive when it addresses a well-defined need that is realistic in terms of dosimetry research and device construction techniques. In large part, significant growth is going to require the kind of interdisciplinary teamwork and sharing of information, arising from such programs [39, 50, 51].

Conclusion and Future Directions

No doubts that rapid scientific and technological advancements have significant impact on diagnosis and treatment of many diseases. Once invention and discovery of invisible X-ray, MRI or nuclear imaging techniques, medical physicists begin to devote their knowledge and experience to maximize progress in combating diseases enabled by those if not to confront more devastating ones. Diseases do exist along the emergence of civilization and almost all civilizations have endeavored to combat diseases. Thus medical physicians have long been deemed important and respected professionals in the society. Recently, while the "science" itself has not changed much (though not comprehensively indeed), the technology what has undergone a revolution. This implies that medical physics is a young discipline though many basic researches and theories may dated back thousands of years. Many of its meanings were unnoticed until recent times due to the revolve of technology. Meanwhile, medical physicists are professionals having potentials to drive the revolution of technologies and give implications to how diseases are diagnosed and treated in future [52]. Firstly, what medical physicists recently care the most are reviewed. Secondly, how these care affect or relate to other components in medical physics knowledge base are discussed. Thirdly, the implications given by these components or the future research direction are discussed. In general, the goal of the comprehensive study is to pave a way of how the progress in the diagnosis and treatment of diseases along probabilistic time axis will be, indicating the role and involvement of medical physicists. As they are professionals in both physics and medical physics, the sub-discipline. What they contribute to each [5]. In other words, this comprehensive study can be taken as a unique perspective from a systematic nursing level of a physics and medical physics sub-discipline. Preceding the discussion, the preliminary knowledge of medical physics is stated and the components of the knowledge database are described in a systematic order such that the discussions and later conclusions can be well understood and placed.

References

1. G. S. Ibbott, A. Chougule, J. Damilakis, S. Tabakov *et al.*, "Medical physicist certification and training program accreditation," 2022. ncbi.nlm.nih.gov
2. R. Beckers, Z. Kwade, and F. Zanca, "The EU medical device regulation: Implications for artificial intelligence-based medical device software in medical physics," Physica Medica, 2021. physicamedica.com
3. H. Paganetti, C. Beltran, S. Both, and L. Dong, "Roadmap: proton therapy physics and biology," Physics in Medicine, 2021. nih.gov
4. S. Healy, A. F. Bakuzis, P. W. Goodwill, "Clinical magnetic hyperthermia requires integrated magnetic particle imaging," *Reviews*, 2022. wiley.com
5. M. Woo and K. H. Ng, "Real-time teleteaching in medical physics," 2008. ncbi.nlm.nih.gov
6. J. Schembri, "An initial SWOT study of the medical physics profession in Malta: the perspective of medical physicists," 2022. um.edu.mt
7. K. Vella, "An evaluation of the constancy testing programme for medical imaging devices at a major public hospital in Malta: a medical physics perspective," 2021. um.edu.mt
8. C. J. Caruana and E. Pace, "A Novel Curricular Model for Medical Physics and Radiation Protection Education–An Alternative Possible way Forward …," Medical Physics International, 2023. mpijournal.org
9. T. Beyer, D. L. Bailey, U. J. Birk, I. Buvat, and C. Catana, "Medical physics and imaging–A timely perspective," in *Physics*, 2021. frontiersin.org
10. M. Endo, "History of medical physics," Radiological Physics and Technology, 2021. [HTML]
11. C. Freeland, L. Mendola, V. Cheng, and C. Cohen, "The unvirtuous cycle of discrimination affecting people with hepatitis B: a multi-country qualitative assessment of key-informant perspectives," for Equity in Health, Springer, 2022. springer.com
12. M. Avanzo, A. Trianni, F. Botta, C. Talamonti, and M. Stasi, "Artificial

intelligence and the medical physicist: welcome to the machine," in Applied Sciences, 2021. mdpi.com

13. 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
14. J.D. Fuhrman, N. Gorre, Q. Hu, H. Li, and I. El Naqa, "A review of explainable and interpretable AI with applications in COVID-19 imaging," Medical, 2022. wiley.com
15. C. Cai, B. Gou, M. Khishe, and M. Mohammadi, "Improved deep convolutional neural networks using chimp optimization algorithm for Covid19 diagnosis from the X-ray images," Expert Systems with Applications, 2023. nih.gov
16. S. Kumar and H. Kumar, "Classification of COVID-19 X-ray images using transfer learning with visual geometrical groups and novel sequential convolutional neural networks," MethodsX, 2023. sciencedirect.com
17. M. A. Khan, "An automated and fast system to identify COVID-19 from X-ray radiograph of the chest using image processing and machine learning," *International Journal of Imaging Systems and Technology*, 2021. nih.gov
18. Y. Guo, B. Pan, L. Zhang, J. Lei, Y. Fan, and A. Ruhan, "A study on water saturation predictions in igneous reservoirs based on the relationship between the transverse relaxation time and the resistivity index," Journal of Petroleum, 2022. [HTML]
19. I. J. Chevallier-Boutell, R. H. Acosta, J. A. Olmos-Asar, "Limits of alkanes confined in mesoporous silica as a probe for geometrical tortuosity. An NMR relaxation study," Microporous and ..., 2024. [HTML]
20. Y. Xu, Z. Wang, H. Chen, and Y. Weng, "Photoexcited electron and hole polaron formation in CdS single crystals revealed by femtosecond time-resolved IR spectroscopy," The Journal of Physical, 2024. [HTML]
21. A. Rizzo, S. Morbelli, D. Albano, G. Fornarini, "The Homunculus of unspecific bone uptakes associated with PSMA-targeted tracers: a systematic review-based definition," Journal of Nuclear Medicine, 2024. springer.com
22. O. Minser, G. Nevoit, M. Potyazhenko, and O. Filiunova, "… of the

phenomenon of life of living biological systems as a promising basis for the development of complex medicine towards the concept of Bioelectronic Medicine," 2023. nuozu.edu.ua

23. M. Sallam, N. T. Nguyen, F. Sainsbury, and N. Kimizuka, "PSMA-targeted radiotheranostics in modern nuclear medicine: then, now, and what of the future?," 2024. nih.gov
24. S. Nurk, S. Koren, A. Rhie, M. Rautiainen, A. V. Bzikadze, *et al.*, "The complete sequence of a human genome," Science, 2022. science.org
25. M. R. Vollger, X. Guitart, P. C. Dishuck, L. Mercuri, *et al.*, "Segmental duplications and their variation in a complete human genome," Science, 2022. science.org
26. S. Aganezov, S. M. Yan, D. C. Soto, M. Kirsche, and S. Zarate, "A complete reference genome improves analysis of human genetic variation," Science, 2022. science.org
27. T. Haidegger, S. Speidel, D. Stoyanov, "Robot-assisted minimally invasive surgery—Surgical robotics in the data age," Proceedings of the ..., 2022. ieee.org
28. J. Zhu, L. Lyu, Y. Xu, H. Liang, and X. Zhang, "Intelligent soft surgical robots for next-generation minimally invasive surgery," Advanced Intelligent, 2021. wiley.com
29. W. Othman, Z. H. A. Lai, and C. Abril, "Tactile sensing for minimally invasive surgery: conventional methods and potential emerging tactile technologies," Frontiers in Robotics, 2022. frontiersin.org
30. D. Hattab, A. M. Gazzali, and A. Bakhtiar, "Clinical advances of siRNA-based nanotherapeutics for cancer treatment," Pharmaceutics, 2021. mdpi.com
31. H. Isazadeh, F. Oruji, S. Shabani, and J. Behroozi, "Advances in siRNA delivery approaches in cancer therapy: challenges and opportunities," Molecular Biology, 2023. [HTML]
32. M. M. Zhang, R. Bahal, and T. P. Rasmussen, "The growth of siRNA-based therapeutics: Updated clinical studies," Biochemical, 2021. sciencedirect.com
33. Y. Han, J. Yang, J. Fang, Y. Zhou, and E. Candi, "The secretion profile of mesenchymal stem cells and potential applications in treating human diseases," Signal Transduction and ..., 2022. nature.com

34. J. Liu, X. Han, T. Zhang, K. Tian, Z. Li, and F. Luo, "Reactive oxygen species (ROS) scavenging biomaterials for anti-inflammatory diseases: from mechanism to therapy," Journal of Hematology &..., 2023. springer.com

35. JH Wang, DJ Gessler, W Zhan, and TL Gallagher, "Adeno-associated virus as a delivery vector for gene therapy of human diseases," Signal Transduction and ..., 2024. nature.com

36. G. M. Seasons, C. Pellow, H. F. Kuipers, and G. B. Pike, "Ultrasound and neuroinflammation: immune modulation via the heat shock response," Theranostics, 2024. nih.gov

37. R. C. Acúrcio, S. Pozzi, B. Carreira, and M. Pojo, "Therapeutic targeting of PD-1/PD-L1 blockade by novel small-molecule inhibitors recruits cytotoxic T cells into solid tumor microenvironment," *Journal for*, 2022. nih.gov

38. X. Su, F. Xu, R. V. Stadler, A. A. Teklemichael et al., "Malaria: Factors affecting disease severity, immune evasion mechanisms, and reversal of immune inhibition to enhance vaccine efficacy," Plos Pathogens, 2025. plos.org

39. Z. Ahmad, S. Rahim, M. Zubair, and J. Abdul-Ghafar, "Artificial intelligence (AI) in medicine, current applications and future role with special emphasis on its potential and promise in pathology: present and future impact …," Diagnostic pathology, 2021. springer.com

40. M. J. Iqbal, Z. Javed, H. Sadia, I. A. Qureshi, and A. Irshad, "Clinical applications of artificial intelligence and machine learning in cancer diagnosis: looking into the future," Cancer cell, Springer, 2021. springer.com

41. M. H. Rezazade Mehrizi, P. van Ooijen, and M. Homan, "Applications of artificial intelligence (AI) in diagnostic radiology: a technography study," European radiology, 2021. springer.com

42. A. V. Cuff, "Understanding the use of diagnostic imaging and its role in decision-making in musculoskeletal pain conditions affecting the lower back, knee, and shoulder," 2024. mmu.ac.uk

43. OZ Tolu-Akinnawo, F Ezekwueme, "Advancements in Artificial Intelligence in Noninvasive Cardiac Imaging: A Comprehensive Review," Clinical, 2025. wiley.com

44. SF Șolea, MC Brisc, A Orășeanu, FC Venter, and CM Brisc,

"Revolutionizing the Pancreatic Tumor Diagnosis: Emerging Trends in Imaging Technologies: A Systematic Review," Medicina, 2024. mdpi.com

45. I. Keshta and A. Odeh, "Security and privacy of electronic health records: Concerns and challenges," Egyptian Informatics Journal, 2021. sciencedirect.com

46. S. Kalkman, J. Van Delden, A. Banerjee, and B. Tyl, "Patients' and public views and attitudes towards the sharing of health data for research: a narrative review of the empirical evidence," Journal of Medical, 2022. bmj.com

47. A. Ullah, M. Azeem, H. Ashraf, and A. A. Alaboudi, "Secure healthcare data aggregation and transmission in IoT—A survey," IEEE, 2021. ieee.org

48. S. M. N. Raja, S. A. Othman, and R. M. Roslan, "A Short Review on the Imaging Technology in Radiation Therapy," e-Jurnal Penyelidikan dan…, 2023. uis.edu.my

49. S. Chakraborty, B. Misra, and M. F. Mridha, "Enhancing Intelligent Medical Imaging to Revolutionize Healthcare," in … for Diagnosis and Treatment …, 2025. [HTML]

50. A. Haleem, M. Javaid, R. P. Singh, and R. Suman, "Medical 4.0 technologies for healthcare: Features, capabilities, and applications," Internet of Things and Cyber, Elsevier, 2022. sciencedirect.com

51. S. Subrahmanya, D. K. Shetty, and V. Patil, "The role of data science in healthcare advancements: applications, benefits, and future prospects," in … of Medical Science, 2022, Springer. springer.com

52. M. Field, N. Hardcastle, M. Jameson, N. Aherne *et al.*, "Machine learning applications in radiation oncology," 2021. ncbi.nlm.nih.gov