Applications of Medical Physics in Health Assistance, Optical Science, Operating Room Technology, Medical Laboratory Science, Nursing, Radiologic Technology, and Biomedical Engineering

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***Abstract*:**
Medical Physics plays a critical role in modern healthcare by applying physical principles to develop and optimize medical technologies and techniques. This interdisciplinary field is essential for the prevention, diagnosis, and treatment of diseases, contributing significantly to patient care across various specialties. Key areas where Medical Physics is applied include diagnostic imaging, radiation therapy, nuclear medicine, clinical engineering, and biophysics. This paper explores the definition, scope, and importance of Medical Physics, providing an overview of its significant contributions to healthcare advancements. Medical physicists are involved in the design, development, quality assurance, and implementation of technologies such as X-ray imaging, MRI, ultrasound, and radiation therapy. Furthermore, they ensure patient safety through adherence to strict safety standards and quality control procedures. The integration of medical physics with other healthcare disciplines has led to revolutionary improvements in diagnostic accuracy, treatment efficacy, and overall patient outcomes. The continued development and application of Medical Physics are crucial in addressing the evolving challenges of modern medicine.

***Keywords*:** Medical Physics, diagnostic imaging, radiation therapy, nuclear medicine, clinical engineering, biophysics, patient safety, medical technology, healthcare innovation, imaging modalities, radiation safety, treatment planning, quality assurance, biomedical engineering.

1. Introduction to Medical Physics

Medical Physics, or Clinical Physics as it is sometimes called, is an important part of modern healthcare. Medical Physics is the discipline concerned with the application of the concepts and techniques of physics in medicine. In a more detailed definition, Medical Physics may be described as the profession that deals with the physical and technical aspects of medicine, especially in the prevention, diagnosis, and treatment of disease. The term “physical and technical aspects of medicine” covers a wide range of fields; it includes all the medical technologies and all the physical and technical methodologies employed in diagnostics and treatment (S. Ibbott et al., 2022). Most people immediately think of X-rays and other radiations in connection with Medical Physics; however, its scope is much broader.

Medical Physicists can be found in hospitals and clinics, research organizations, universities, industry, or in governmental organizations as regulators or inspectors. Within healthcare institutions, they can be employed in the fields of diagnostic imaging, radiation therapy, nuclear medicine, clinical engineering, and biophysics. The employment fields of Medical Physics are usually considered to be diagnostic imaging, radiation oncology, nuclear medicine, and clinical engineering. Having a medical physicist employed in a healthcare institution is usually obligatory, or at least highly recommended, by the international or pan-national guidelines. The importance of Medical Physics has been recognized worldwide, and many efforts are being made to ensure that this field is developed in every country. While Medical Physics training and education, the role and responsibilities of medical physicists, and their employment in healthcare institutions will be outlined here, several specific applications of Medical Physics will be presented in detail.

Medical Physics plays a vital role in improving patient outcomes. Many innovations in medical technology and treatments result from Medical Physics research. Because of their unique skill set, medical physicists often spur advancements that others in the healthcare field may overlook. For example, new cancer treatment technologies were developed partially due to a medical physicist's invention of a specialized computer program. Similarly, medical physicists were crucial in developing widely used echocardiography technologies that let doctors examine heart function noninvasively. (Fraser et al.2022)

1.1. Definition and Scope

Medical Physics is a wide-ranging discipline, largely interdisciplinary in nature, that serves as a bridge between physics and health care. It employs the principles of physics in the service of Medicine and Health. Health technologies that incorporate the concepts of natural science to diagnose, treat, or prevent any disease, illness, or injury are the focus of Medical Physics (S. Ibbott et al., 2022). This discipline plays a key role in the advancement of health care technology. The Medical Physics community is involved in the research, development, implementation, and maintenance of techniques that use the physical concepts of health care. Diagnostic imaging, therapeutic radiology, radiotherapy, radiation safety, biophysics, and other similar areas of health care that use the principles of physics are all included in the scope of Medical Physics. Medical Physics is a broad term encompassing various applications of Physics in Medicine. It should be noted that Medical Physics is not limited to a single discipline; rather, it has a number of applications in a variety of fields. Understanding the definition and scope of Medical Physics is essential in order to appreciate the overall significance of Physics in patient care. As an introduction, some diverse examples of Medical Physics applications are provided. Ultrasound technology used in clinics for pregnant women is a Medical Physics application in obstetrics and gynecology. In orthopedics, X-ray imaging, which uses the principles of optics, is also an example of Medical Physics. Another instance of Medical Physics in the treatment of a diseased organ is the use of radioactivity. In addition, in cardiology, protocols for the safe use of radioactive dyes are determined by Medical Physics. Similarly, in nuclear medicine, a gamma-camera diagnosis of a diseased organ is again an application of Medical Physics. Magnetic Resonance Imaging (MRI) scanners used in clinics for the diagnosis of brain tumors is an example of Medical Physics in neurology. In ENT, the treatment of a diseased ear using endoscopy and fiber optics is also a Medical Physics application. Many other examples abound in various fields of health care. The purpose of this section is to provide a clear overview of Medical Physics by describing its definition and scope so that attention can then be drawn to specific applications in later sections. (Beyer et al.2021)(Zanca et al.2021)

1.2. Importance in Healthcare

Medical Physics is a required discipline in the health care system that makes important contributions to general health, patient diagnosis, and treatment. Medical Physics uses the principles and applications of Physics in diagnosis and treatment methods. It has a strong impact on the proposed health care practices. Physics principles are used in the development of various technologies used in diagnosis and treatment. Medical Physicists are responsible for the design, development, clinical implementation, quality assurance, and research of these technologies. These technologies have changed, improved, and made current healthcare practices possible .

To properly apply these technologies, there is a strong need for Medical Physicists in the health care system. There must be a sufficient number of qualified Medical Physicists with proper training and compliance with international standards. With patient care as the highest priority, Medical Physicists play an important role in routine clinical practice and collaborative research to ensure patient safety and efficacy of diagnostic and treatment procedures. Healthcare technologies widely used today were not even imagined several decades ago, and many dramatic improvements have occurred within the past few years. Technologies that were thought impossible to develop can now be seen as part of daily patient care processes. Many of these technologies are based on innovative methods, which upon implementation have radically improved healthcare outcomes.

Medical Physicists have played key roles in the development and implementation of these technologies. Physics principles have been applied to improve current imaging methods, develop new imaging modalities, and implement new treatment techniques. On the other hand, these technologies can adversely affect the patient. For instance, excessive exposure during a diagnostic examination can result in radiation-induced cancer, and an improperly delivered radiation treatment can harm healthy tissue. One recently published international report states that, throughout the world, millions of patients each year encounter adverse events during health care. Most of these adverse events are due to improper use of technology. It is therefore vital to ensure proper use of technology in patient care. Medical Physicists ensure compliance with safety standards and quality assurance in the use of technology. With the increased complexity of current technologies, quality assurance and compliance with safety standards require a higher level of expertise and sophistication. It is therefore important to have Medical Physicists make these possible. (Beckers et al., 2021)(Hanley et al.2021)

2. Health Assistance

Health assistance has been one of the major applications of Medical Physics. With the advancement of technologies linked to health assistance, this discipline has been continuously evaluated and innovative technologies have been developed. Medical imaging techniques play an important role in the accuracy of diagnosis and treatment planning of several diseases. It is a group of methodologies that obtain medical images of the tissues and organs of the human body. Based on the physical principles, apparently distinct imaging techniques including MRI, CT scan, SPECT, PET, and ultrasound can be grouped into some categories. The first group is based on the imaging of the electromagnetic spectrum; a part of it is used either with the transmission of electromagnetic waves or without it. The second group is based on the detection of the emitted particles after the injection of radionuclides. The last group is based on the mechanical wave propagation in tissues (Kumar Singh et al., 2024). Among various advances in imaging techniques, the development of hybrid systems have been a great contribution to the health assistance. The combination of two imaging techniques can provide complementary information which helps to enhance the accuracy of diagnosis.

Radiation therapy is an effective treatment for cancer and various other diseases. This therapy uses the principles of damage to the DNA of the cells induced by the exposure of high energy particles or waves. Understanding the widespread effects as well as the specific effects of DNA damage is important in the progression of this treatment. A treatment plan is determined based on the 3D distribution of the doses prior to the treatment and the doses in the critical organs are minimized. Along with the advancement in the treatment planning technologies, the imaging techniques prior to the treatment play a crucial role in matching the planned and delivered treatment techniques and how to adjust the treatment plan if they do not match. Several technological innovations have been developed such as on-board linac-based systems that incorporate both imaging and treatment delivery systems and the imaging system integrated in brachytherapy systems. (Wang & Tepper, 2021)(Chandra et al., 2021)

2.1. Medical Imaging Techniques

Medical imaging techniques have become an integral part of diagnostics in healthcare. In recent years there has been a rapid growth in the field of medical imaging due to increased demand for the healthcare delivery systems and significant technological developments. There are many diverse medical imaging techniques currently used in the hospitals along with some other imaging techniques which are in research stage and slowly finding their way into the clinical applicability. All of these imaging techniques are based on some physical principles and knowledge of underlying physics is necessary to develop the imaging techniques, improve the image quality and make the images more reliable for diagnostics (K. M Shadekul Islam et al., 2023).

An attempt has been made here to introduce the readers some widely used medical imaging techniques. The basic principles of these imaging techniques are discussed along with the description of image acquisition process. The pace at which the imaging technologies are advancing, improvements in imaging quality are becoming more and more critically dependent on the technological innovations. So there is a brief discussion on the technological advancements relating to certain imaging modality which is believed to enhance the imaging quality as well as the diagnostic reliability of the images. Most of the medical imaging techniques involve some safety concerns especially the ones which use high energy radiations for imaging. Therefore a short discussion is included on the safety issues regarding the medical imaging techniques based on the principles of radiation physics and the possible measures to minimize the risk of exposure of radiation to the patients. Although efforts have been made to provide a balanced view of the strengths and the limitations of each imaging modalities, still it is very difficult for the readers to know about the clinical applicability of each imaging technique because the breadth and depth of clinical requirement is beyond the scope of this article. Some advance imaging technologies like hybrid imaging systems have been overviewed which combine two different imaging modalities on a single platform. Such systems try to take advantages of one modality to compensate the weaknesses of other and image from one modality can be used to enhance the image quality of other modality. Finally the practices in Medical Physics field are discussed in the context of how imaging techniques have gradually transformed hospital patient. To ensure the quality healthcare delivery system it is essential to have medically trained physicists to oversee the imaging operations because the quality of healthcare delivery system is grossly dependent on the expertise of the personnel operating the imaging equipment.

2.2. Radiation Therapy

Radiation therapy has become an integrated part of modern medical care, with an expected global market value of 9.9 billion USD in 2016, expanding to 12.9 billion USD by 2021. Patients treated with radiation therapy comprise 43% of all cancer patients. Cancer, characterized by an abnormal proliferation of malignant cells, is the second leading cause of death worldwide, resulting in 8.8 million deaths in 2015. Ionizing radiation, high energy particles, or waves capable of displacing electrons from atoms or molecules, is used in radiation therapy to damage malignant cells and ultimately kill them. DNA is the primary target of ionizing radiation, leading to the formation of reactive chemical species that cause direct damage to DNA or the impairment of DNA repair mechanisms. When the mechanism of action of a therapeutic agent involves the alteration of DNA, it is classified as a DNA-targeting therapy. Agents that induce DNA double strand breaks (DSBs) are highly cytotoxic, as DSBs are the most detrimental form of DNA damage that cannot be repaired, ultimately resulting in cell death (Collins, 2017). While cancer cells have heightened sensitivity to radiation due to the upregulation of oncogene-mediated signaling pathways that promote proliferation, normal cells are spared through the activation of tumor suppressor gene-mediated antiproliferative signaling pathways.

In external beam radiation therapy (EBRT), high energy beams of ionizing radiation are delivered from outside the patient’s body to the tumor using a linear accelerator (LINAC). Intensity-modulated radiation therapy (IMRT) is a form of EBRT that modulates the intensity of the beamlets, allowing optimization of tumor dose delivery while sparing normal tissues. Stereotactic ablative radiotherapy (SABR) or stereotactic body radiation therapy (SBRT) is an advanced form of precision radiotherapy that utilizes image-guided techniques to deliver very high doses of radiation to localized tumors while minimizing the dose to surrounding normal tissues. In contrast to EBRT, brachytherapy involves the placement of sealed radioactive sources directly inside or next to the treatment site. High-dose-rate (HDR) brachytherapy, using remote afterloaders, allows for precise dose distributions through the movement of a single high activity source along pre-planned paths at specific times.

Conversely, low-dose-rate (LDR) brachytherapy uses permanently implanted low activity seeds that continuously deliver a low dose rate of radiation over several months by utilizing the inverse square law. Medical physicists are vital for the safe and effective clinical applications of radiation therapy. They perform routine quality assurance tests on machines to ensure safety and accuracy, develop treatment planning software, establish treatment protocols, and provide treatment techniques to oncologists. Physicists are a part of the team responsible for the planning and execution of treatment regimens using the knowledge and understanding of physical principles and clinical implementation of radiation therapy. To ensure an optimal distribution of the prescribed dose, medical physicists must balance the competing factors of maximizing dose conformity to the tumor while minimizing dose delivery to adjacent normal tissues. Treatment verification processes to protect patients from misadministration of radiation therapy are performed routinely by medical physicists. Considering strict quality assurance measures and patient safety protocols in place in developed nations, the global technological advancements directly improve treatment precision and efficacy, resulting in better patient outcomes. As nations continue to develop and cancer care becomes a priority, higher funding increases accessibility and upgrades equipment. Rapid advancements in technology result in improved treatment modalities that require knowledge comparisons, such as treatment superiority, efficacy, practicality, accessibility, and associated risks. Across the United States and Europe, cancer is the second leading cause of death, with 1.7 million new cases and 600 thousand deaths. In 2013, an estimated 20.8 billion USD was spent on radiation therapy in the United States alone. 68% of cases in the United States are treated with 2,476,950 total procedures. 72% of patients treated with radiation therapy are treated with EBRT, comprising 1726038 total procedures. CT simulation accounts for 1,051,562 total procedures. There were 969,555 IMRT procedures, 141,466 3D-CRT procedures, and 237,455 other external beam procedures. 20% of cases treated with radiation therapy are treated with brachytherapy, comprising 470,171 total procedures. 247,169 HDR procedures, 203,753 LDR procedures, and 19,249 PDR procedures were performed in 2013. Overall, 74% of procedures were EBRT, 19% brachytherapy, and 7% other types of radiation therapy. (Newhauser et al.2023)(Chong et al.2021)

3. Optical Science

Optical science, or the science of optics, deals with the principles underlying the behaviour of light and its interaction with different materials. The various properties of light such as reflection, refraction, total internal reflection, dispersion, transmission, absorption, scatter, and diffraction are routinely used in several healthcare delivery systems. Light is the invisible part of the electromagnetic spectrum, which has oscillating electric and magnetic fields. In vacuum, it propagates at a velocity of 3 x 10^8 m/s. It can travel in a straight line in a homogenous medium. However, its path may be altered or changed when it comes across a different medium. This change of path due to the difference in two media is called the reflection or refraction of light (S. Litvinova et al., 2017). Unlike a wave, the particle nature of light consists of a number of packets called photons. Each photon has a particular energy that depends on the wavelength. The shorter the wavelength, the higher the energy. Usually, the light source is a tungsten filament bulb that emits white light through which a glass prism can separate it into seven colours. This phenomenon of splitting the light into various components is called dispersion. Water droplets in the atmosphere after rain work as a prism and cause the formation of a rainbow in the sky. The sky appears quite blue due to Rayleigh scattering.

Using the above principles of optics, a plethora of passive optical instruments like endoscopes, otoscopes, laryngoscopes, microscopes, ultraviolet (UV) spectrophotometers, fluorescence spectrophotometers, Fourier transform infrared (FTIR) spectrophotometers, optical coherence tomography (OCT), laser interferometers, and several active laser-based systems find their applications in diagnosis and therapeutic purposes such as laser surgery. All these optical devices used in healthcare delivery are designed and developed with the basic objective of ensuring the accuracy of the procedure as well as the minimal invasion to the patient. The time has come to integrate such optical technologies into the treatment protocols as required to ensure high standard healthcare delivery. After meticulous planning, the general medical physics research programme of the institution was started with a vivid hope to extend the expertise developed in the design and development of research-based devices to the general healthcare sector and with a belief to bring forth visible changes to the existing facilities. Such a hope has given rise to the development of a few optical medical devices and a number of devices are in various stages of implementation, as randomly highlighted here. One area of concern in any hospital is to ensure an optically safe clinical environment wherein lasers are used for treatment or diagnosis. It is equally important to ensure the safety of the patients and the staff from improperly disposed laser endoscopes as they can act as weapons of damage to an eye from accidental exposure. Recently, the standards for the laser ocular hazards in the healthcare environment have been incorporated. The preliminary results of the optical safety measures undertaken in the clinics where laser devices are used are presented here. Thousands of lives can be saved every year if cancers can be detected and treated at the earliest possible stage. A significant research effort has gone in to develop several innovative optical devices based on either the absorption of light or its fluorescence properties for the early detection of malignancies in different organs. A few of them are nearest to clinical trials, say, a digital imaging system based on the principles of wide-field endogenous fluorescence for the early detection of dysplasia in the bronchial epithelium. Some other photonic devices such as Raman spectrometer or endoscope, UV or fluorescence based endoscope, one or two photon confocal endoscope microscopes, OCT, and laser Doppler are expected to bring about some revolutionary changes in medical practice. Depending on the device, the optical healthcare delivery systems can be either passively used with a low energy light source or necessitate the active involvement of photonic devices. Most of the minimum interference passive optical devices are used in the diagnosis of the disease whereas the active surgical devices are used primarily for treatment although a few can be used for both purposes. A passive optical endoscope based on the total internal reflection principle has been designed to look for the anatomical details of the internal organs. However, its inability to provide magnified images has necessitated the development of a few actively used confocal endoscope microscopes to carry out cellular level investigations on tissues. In addition to the widely used approach of scanning the focused beam on the tissue surface either with a single mode fibre or free space focusing optics, a simple non-scanning confocal endoscope microscope has been designed which basically exploits the spatial filtering technique to overcome the tissue generated uncomfortable background noise. (Hackshaw et al.2021)(Sebastian & Peter, 2022)(Health Organization, 2023)(Gupta, 2022)(Allugunti2022)

3.1. Principles of Optics in Healthcare

Fundamental principles of optics play an important role in healthcare settings. Healthcare applications that are designed using optical principles are diverse. Therefore, key optical principles directly related to healthcare applications are introduced. The basic behavior of light, types of lenses, and their applications are discussed first. Then, basic microscopy techniques are elaborated on. Healthcare applications based on these optical principles, especially imaging and treatment modalities, are discussed subsequently. Optical coherence tomography, one of the promising imaging modalities in the medical field, is elaborated on in detail along with other imaging systems. In addition to imaging, treatment methodologies using the principles of optics are presented, with a particular focus on laser treatment. Furthermore, a discussion on optical sensing technologies is included. The relevance of optical sensing technologies in non-invasive diagnostics is emphasized (Vavrinsky et al., 2022). Overall, these sensing technologies illustrate the important role of healthcare applications based on the principles of optics. Some emerging optical technologies that are not yet implemented in medicine but have potential future applications in the medical field are also mentioned.

Thus, the importance of research and development in advancing the optical science of healthcare applications is highlighted. There are also simple optical setups implemented in laboratories that facilitate common optical experiments. Accurate optical performance of imaging systems is crucial for patient safety and effectiveness of treatment. An optical system typically consists of several optical components that should be designed ideally but in practice are not; hence each optical system introduces unintentional aberrations in addition to those from the optical components themselves

(Lee, 2008). Therefore, the design of corrective components is necessary to ensure that imaging systems meet the required performance criteria in the medical field.

4. Operating Room Technology

Operating rooms are one of the most technologically advanced areas in modern hospitals. A variety of equipment and advanced technology can be found in operating rooms, which have a profound impact on how surgeries are performed. Currently, most surgeries have moved on to a different paradigm, where surgery is more about technology than the actual surgeon performing the operation. Technology has transformed surgical practice from removing the diseased tissue from the patient to a sculpturing art where the surgeon gets to mold the anatomy using technology. This chapter looks into some of the technology present in surgical operating rooms that are applied during surgery. A special focus is given to surgical navigation systems, which enhance the precision of surgery and assist in the effective removal of diseased tissues while reducing the surgical risks (Mezger et al., 2013). This technology has paved the way for a different kind of surgery known as pre-planned surgery.

Implantable hardware such as screws, plates, and stents is often used to stabilize, repair, or augment human anatomy. To enable accurate placement of these devices, intra-operative imaging is often used to visualize the anatomy and overlay the pre-operative planning information. The use of imaging technologies to see inside the patient during surgery is also discussed, as these technologies allow surgeons to have a real-time view of the anatomy and the surgical tools, which improve the surgical outcomes. Studies on how medical physicists are involved with the operating room technology are presented, focusing on how medical physicists optimize the technology to assist the surgical team (Alfredo Siochi et al., 2009). Most of the operating room technology requires close collaboration with the surgical team, where medical physicists must take part in the surgeries to properly develop the technology and ensure that it is safe and effective for patient care. Major focus areas when developing operating room technology are how to apply safety protocols to ensure the proper usage of equipment and the monitoring of patient safety during the operation. There also needs to be a high standard of care when operating room technology is used, as there is always a risk of causing significant harm to the patient and even death.

4.1. Surgical Navigation Systems

Surgical navigation systems are a breakthrough technology in the operating room. Similar to the automotive navigation systems that have become ubiquitous in modern cars, new technologies are available to surgeons and hospitals that provide navigational assistance during the surgical procedure. Like automotive navigation systems, surgical navigation systems rely on proven physics principles that enable navigation using a combination of imaging and spatial tracking. However, the complexities of the human body, the surgical procedure, and the need for high accuracy in surgical navigation require a custom approach to imaging and tracking. Several different types of navigation systems that rely on different approaches to imaging and spatial tracking are currently commercially available, each with its own advantages and disadvantages concerning the surgical procedure for which the system is applicable (Mezger et al., 2013).

The implementation of the different navigation systems in the operating room is similar in concept. Preoperatively or intraoperatively, the surgical site is imaged using the approach chosen by the navigation system. The surgeon then uses special navigated surgical instruments that can provide spatial measurements to the navigation system. These spatial measurements correlate with a position and orientation defined in the surgical site coordinate system, allowing the surgical site to be reconstructed in the navigation system. Use of the navigation system during surgery significantly enhances the accuracy of surgical procedure and allows for the performance of less invasive procedures. The surgeon is presented with the reconstruction of the surgical site and its anatomy as well as the navigated instrument position, which significantly reduces the likelihood of an error occurring during the surgical procedure. The adoption of surgical navigation systems by hospitals and surgeons has the potential to revolutionize a certain class of surgeries, offering numerous benefits to the patient as well as the hospital. In particular, it will become possible to perform surgical procedures with enhanced accuracy while at the same time reducing invasiveness, resulting in superior patient outcomes. The need to bring such advanced technologies to clinical routine involves the joint effort of surgeons, medical physicists, and engineers. Beyond collaboration, there are also important considerations that must be taken into account when implementing such technologies. Like all medical devices, surgical navigation systems must be safe to use. Safety issues to consider include device calibration and maintaining the accuracy of the patient's position and the spatial tracking coordinate system throughout the surgical procedure. As technology advances, it is expected that new surgical navigation systems will be developed using innovative approaches to imaging and spatial tracking. Nevertheless, currently available systems could satisfy the present need for navigational assistance in the operating room while also providing a solid foundation on which upcoming innovations could be built. (Tao et al.2022)(Rawicki et al.2021)(Wei et al.2021)

5. Medical Laboratory Science

Medical Laboratory Science is a pivotal component of modern healthcare, focusing on the analysis of bodily fluids and tissues to aid in diagnostics and patient management. Laboratory tests are critical for the accurate identification of diseases and the effective monitoring of patient health states. This is especially apparent in the ongoing COVID-19 pandemic, where the success and failure of large-scale testing efforts have profound consequences (Meike, 2016). Countless other medically relevant laboratory diagnostics occur daily, from blood tests and biopsies to microbiological cultures. Health screening and diagnostic testing are typically performed at clinical laboratories, which process samples sent from various healthcare facilities and sites. In recent years, the field of laboratory diagnostics has made significant technological advancements, enhancing patient care efficacy through the rapid and precise analysis of biological samples.

Medical laboratories employ a diverse array of technological tools, several of which are based directly on the principles of physics. The simple yet ingenious principles of physics can greatly enhance the analytical accuracy of laboratory techniques, often in ways not readily visible to the untrained eye. Laboratory scientists must have a sound understanding of these physical principles and devise ways to adapt existing technologies or create new ones to improve diagnostic processes. This is particularly relevant in tightly integrated laboratory settings, where the development of new tools and techniques can greatly enhance overall health-system function and patient care (R. Karam, 2009). In many cases, laboratory scientists must work with medical physicists to achieve desired outcomes, as the latter have specialized training in the physical principles underlying technology design and function. This collaboration is especially crucial in ensuring the quality control of laboratory technologies and the reliability of diagnostic results. The basic safety protocols within laboratory environments can be as crucial as those involving potentially hazardous chemical reagents. Various laboratory techniques involve handling high-risk materials that can endanger not only laboratory scientists but also the wider community if mishandled. Consequently, all laboratory facilities must have an extensive and meticulously adhered-to set of safety standard operating procedures. Carefully considering all potential risks is crucial when establishing new laboratory techniques, especially those involving high-risk materials. This field's many past, present, and future advancements will have long-lasting impacts on healthcare outcomes, from the discovery of quantifying and impartial laboratory tests to the development of rapid point-of-care screening tools. Medical Laboratory Science is integral to the effective delivery of modern healthcare. (Khatab and Yousef2021)(Church and Naugler2022)

5.1. Laboratory Diagnostics

Laboratory diagnostics consist of in vitro tests performed on laboratory specimens to assist in disease detection, confirmation and monitoring, or to assess health status. Most laboratory diagnostics are quantitative and comprise a series of measurements of physical and chemical parameters, including electrochemical, spectral, microscopic or chromatographic techniques. Specimens may include blood, urine, faeces, tissues or other pathological materials. The most common laboratory diagnostic is haematology, followed by clinical biochemistry, immunology and microbiology. Despite the rapid advances in imaging, endoscopic and other non-invasive techniques, laboratory diagnostics are still irreplaceable in clinical practice. Most diseases, especially chronic and systemic diseases, can only be detected and monitored through laboratory change of biochemical and cellular parameters (S. Ibbott et al., 2022). Clinical decisions, therapeutic efficacy and disease prognosis are impossible without laboratory results. Reliability and accuracy of results received from laboratory diagnostics are paramount for proper patient management and care. The reference intervals for most clinical parameters are defined on a population basis; thus, information about the laboratory method used is essential for result interpretation and comparison. Nowadays, significant improvements in laboratory technology are made possible by the introduction of automation, robotics and digital imaging. Sample pre- and post-analysis handling, as well as most routine biochemical and haematological tests, are now fully automated. Automation improves workflow, diminishes human error and increases the throughput of laboratory tests, which is crucial for time-sensitive tests, including intensive care, stroke or myocardial infarct diagnostics. Digital imaging allows wide field screening, automated detection and quantification of cells, tissues and other particles in microscopic control. The most prominent examples are the developments in pathology, where digitized tissue preparations can be examined by computer algorithms. Quality assurance is critical in laboratory diagnostics to guarantee that diagnostic processes are performed safely and standards are met. Quality standards for laboratory diagnostics aim for the accuracy, reliability and timeliness of results critical for patient care. External and internal quality controls are widely applied to ensure precision, and testing is mandatory for all measurement methods before the laboratory results can be reported. Medical physicists play an essential role in quality assurance for laboratory diagnostic equipment, particularly in microscopic and imaging methods. The interplay between medical physicists and laboratory diagnostic professionals is particularly emphasized for optimal collaboration in developing, implementing and measuring precision testing. Emerging trends in laboratory diagnostics include point-of-care testing, home care testing, micro-systems and lab-on-a-chip techniques, as well as individualized and personalized medicine approaches. Nonetheless, despite intensive research testing new diagnostic procedures, laboratory diagnostics essential to the healthcare ecosystem remain overlooked. (Health Organization, 2021)(Calderaro et al., 2022)(Marais et al.2021)

6. Nursing

Technology is an integral part of how nursing care is offered. There is a wide range of different technologies in use within nursing practice that assist nurses in looking after patients. Medical Physics helps implement these technologies to be used by nurses in enhancing nursing care. The advances in technology associated with monitoring have bettered nursing care for patients. Telemetry was a famous example of this, where cardiac monitoring of patients was taken to the next level. Following the simple application of technology, treating patients with nursing care became easier and more effective. Patients being looked after post-surgery in ICUs receiving telemetry cardiac monitoring became more manageable for nurses (Woo & Ng, 2008). The advances in nursing technologies continued, where vital sign tracking was embedded in the patient's bedding, which was a very modern approach to monitoring patients for the nursing care team.

There is a wide range of medical devices that nurses use, directly or indirectly, on patients daily. For example, infusion pumps are quite popular for administration safety for other types of medication, with a variety of available infusion pumps in clinical applications. Patient safety alarms are another running example of nursing technologies used to look after patients' safety. These alarming devices have several applications; some alarms are crucial for monitoring a patient's life, and being turned off on purpose could mean patients' death. These technologies indeed help nurses provide safer care to patients. Technology in nursing helps nursing care run more safely and effectively, but it brings on a lot of responsibilities in utilizing the technology. The outcome of technology is not always positive; it could also harm patients while using the technology incorrectly. Therefore, education on nursing technologies is just as important as having the technologies available for nursing care. Furthermore, as the technologies of monitoring are advanced, so does the education in nursing technologies. It is a must for nursing education to include teaching on the monitoring technologies, and nursing students should gain experience in this area. Continuous professional development has to be in place for nursing staff for the nursing technologies in use.

6.1. Technology in Nursing Care

This subsection discusses the various technologies used in nursing care and how they help ensure better outcomes for patients. It focuses on devices that help nurses monitor and deliver patient care. As technology continues to develop in various fields, many types of technologies have emerged in nursing care. Electronic health records (EHRs), telehealth services, and mobile health applications are examples of technologies that facilitate effective and coordinated care (Aarts et al., 2017). Considering many different technologies, it is important to understand how technological advancements have impacted nursing care workflows and how efficient nursing care is achieved with the technology available.

Nursing care plays critical roles in many responsibilities, including observing, monitoring, and recording patient conditions; implementing treatment plans; and attending to patient hygiene, comfort, and nutrition. Generally, a wide variety of devices are used to monitor patients in one place in intensive care units (ICUs) or other wards. With technological advancements, a number of devices are now available to help nurses to effectively provide patient care. These technologies might have transformative impacts on nursing workflows. However, many nurses felt that comprehensive training for nurses using these technologies was necessary. Proficiencies in the technologies used for nursing care are essential to improve efficiency in nursing care; thus, training for these technologies should be emphasized. There are also discussions on patient safety issues and ethical aspects regarding the use of technology in nursing care. It is also possible to see examples of working together with nurses and medical physicists to make the best use of the technologies. Overall, technology greatly enriches the nursing profession and improves the delivery of patient care. (Alshammari & Alenezi, 2023)(Nes et al.2021)(Zareshahi et al.2022)

7. Radiologic Technology

Radiologic technology is a major discipline in the Medical Physics broad area, largely contributing to Diagnostic Imaging. The term "Radiologic Technology" defines a profession where radiologic technologists operate different kinds of imaging equipment but also concerns quality patient care aspects, such as explaining the exam procedure, positioning the patient correctly, or monitoring for vital signs (I. Bluth et al., 2022). Good communications skills, caring attitudes, and a good sense of ethics are indispensable for these professionals who usually work in hospital or clinic settings. On the other hand, a good technical understanding of the equipment that is being used is also important to be effective in this profession. Generally speaking, different kinds of technology operate using the principles of physics. Such technologies are also used in Radiologic Technology. Therefore, it is useful to discuss the physics principles that govern these technologies. There are different modalities in Radiologic Technology, such as Conventional Radiography, Computed Radiography, Digital Radiography, Fluoroscopy, Computed Tomography (CT), or Magnetic Resonance Imaging (MRI). They all produce images of the human body to help diagnose a possible medical condition. Most imaging modalities in radiology rely upon ionizing radiation or non-ionizing radiation. X-ray and gamma-ray are examples of ionizing radiation, and so are particle radiation such as electrons, protons, or neutrons. On the other hand, visible light and sound waves are examples of non-ionizing radiation. In general, the imaging modalities that utilize ionizing radiation create a picture to demonstrate an internal structure model of an object by analyzing how this object interacts with the radiation. This interaction is described in terms of physics principles such as absorption, scattering, or reflection. These technologies are heavily physics-based. In order to create good quality images, technologists need to understand the physics principles behind the technologies being used. So, accuracy in the operation of these technologies requires some basic understanding of the physics principles that govern these technologies. Patient safety is a major concern regarding the operation of any radiologic equipment, especially with the technologies that use ionizing radiation. This concern comes not just from an individual dose of radiation, but also the possible risks from accumulated doses over time. Therefore, there are established practices regarding the management of radiation dose given to the patient. Generally, a minimum dose to the patient during the examination should be achieved while maintaining an acceptable quality of the diagnostic image. In order to achieve this goal, it is essential to optimize the procedure prior to the examination. This requires an understanding of how different factors affect the dose and the image quality. There are some common dose management strategies being implemented in most hospitals, such as setting up the protocol based on the patient's body size or routinely monitoring the radiation dose applied to the patient. How the dose to the patient is managed in a radiologic exam procedure is one of the important aspects to be considered in this operation. With how rapidly technology is advancing, this section may be outdated within a few years. Therefore, it is important for any radiologic professionals to continue education regarding the recent advances in technology used in medical imaging. Imaging equipment will continue evolving with new technology nowadays and in the future. Therefore, continued education will be a necessity for radiologic professionals to keep up with the imaging equipment being used in the medical field. Imaging equipment used in Radiologic Technology involves elaborate technologies designed to obtain good quality images while ensuring the safety of the patient. Good quality imaging services bring a good quality to diagnosis. There is a great concern in carrying out an accurate imaging procedure that would help with diagnosis. This concern is generally shared by all the professionals involved in the process of imaging, but each professional has a different perspective. For example, a good quality image does not provide a good diagnosis if this image is obtained from an excessive experimentation where the patient's health has been compromised. These two different aspects of imaging services concerned by the radiologic technologist and the medical physicist, respectively, could be better addressed if there was a better collaboration between these two professionals. (Beyer et al.2021)(Adler et al., 2022)(Newhauser et al.2023)

7.1. X-ray Imaging

X-ray imaging is one of the most widely used imaging techniques in medical practice. It is based on the use of ionizing radiation and is thus classed into the group of radiological examinations. As with other imaging techniques, it relies on the interaction of specific waves and the body to obtain information about it. In the case of X-rays, they are produced in a special chamber and focused on the detected area of the body, with a detector receiving the transmitted X-rays on the other side. Effective imaging relies on the understanding of the underlying physics principles involved in the production and detection of X-rays (K. M Shadekul Islam et al., 2023). There are various types of X-ray examinations with very different applications in medicine. Most people are familiar with the diagnostic use of X-rays in the radiology departments of hospitals. Usually, a photograph of the detected area is undertaken with the patient positioned between the X-ray source and the detector. The ionizing radiation passes through the body and is partially absorbed by it due to the different densities of the tissues composing it. Aiming to improve the examination process, therapeutic uses of X-rays have also been developed in medicine. Using focused X-ray beams, tumor regions in the body can be irradiated to destroy the cancer cells while leaving the surrounding healthy cells intact. X-ray imaging is an essential tool in modern medicine. Like other healthcare technologies that make use of potentially harmful effects of physical agents, the use of X-ray imaging in medicine is strictly monitored, with quality assurance procedures and compliance with radiation safety standards in place in all hospitals. These regulations aim to ensure that the good medical practice is not compromised and that the safety of patients undergoing X-ray examinations is prioritized. Simple X-ray photographs represent the most commonly used type of examination. Nevertheless, many advanced imaging modalities have also been developed, such as computed tomography, digital radiography, and digital fluoroscopy, improving the image quality and the diagnostic capabilities of the imaging units. The role of the medical physicist in hospitals is applied research and daily quality control of the operation of the imaging devices. The design of new or significantly improved devices is usually carried out by research institutions and industry. The study emphasizes the importance of training radiologic technologists to examine X-ray imaging devices and the detected images. Proper use of the equipment is crucial, as poor imaging cannot be improved later without re-examination of the patient. Although basic training is often provided, many hospitals neglect the need for regular retraining. Besides the basic principles of X-ray production and detection, applications in medicine, and descriptions of advanced imaging modalities, attention is also drawn to emerging technologies and ongoing research. Although still in proof-of-principle development stages, these might significantly alter the approach to X-ray imaging in the future. X-ray imaging is one of the oldest and most widely used medical imaging modalities. With the arrival of computer technology, it has rapidly evolved over the last several decades, becoming the backbone of diagnostic medicine in the hospital environment. It greatly assists clinicians and medical doctors in planning the treatment of patients. X-ray imaging is currently a vital tool within the arsenal of diagnostics possible today in modern medicine. (Hussain et al.2022)(Lu et al., 2021)(Çallı et al.2021)

8. Biomedical Engineering

Biomedical Engineering is an indispensable field of science and technology that intersects engineering principles with medicine to promote health. Biomedical engineering is the art of designing and developing devices that will mitigate medical problems or enhance patient care. Medical devices are engineered products that help solve clinical problems. There is a diverse range of biomedical technologies, including surgical devices and tools, monitoring systems, prosthetics, rehabilitation devices, imaging systems, etc. Biomedical devices are classified as critical, semi-critical or non-critical based on the level of risk of infection transmission involved in their use (Quansah Amissah et al., 2013). Critical items penetrate tissue and are expected to be free of all living microorganisms. Semi-critical items contact mucous membranes, where the risk of infection transmission is high. Non-critical items come in contact with intact skin and pose the least risk of infection transmission.

Biomedical Engineering is a highly interdisciplinary field, and partnerships among engineers, clinicians, and medical physicists are essential to its success. Engineers design and develop devices used to care for patients, and clinicians prescribe and use devices. Medical physicists ensure that devices operate safely and optimally. The close collaboration between these professions helps bring innovative, high-quality, and critically needed biomedical technologies to health care. Medical devices are subject to safety and regulatory standards that govern their design, development, and use. Federal agencies enforce compliance with standards for medical devices, which ensures patient safety and well-being (F. Silva et al., 2023). Failure to meet a standard may result in serious adverse consequences, including injury or death of a patient. Research and innovation efforts drive advancements in biomedical technology. Practical problems in health care provide opportunities to develop new technologies that can create innovative solutions to clinical problems. These developments can result in improved devices that augment the capabilities of existing technologies or completely new devices that will have a profound impact on health care. Biomedical engineers typically work in hospitals, industry, government, or academia. In hospitals, they are involved in the daily management of medical devices and the development of solutions to clinical problems. In industry, engineers create new devices or innovate improvements on existing devices. In government or regulatory agencies, engineers help shape policies governing the safety of medical devices. In academia, biomedical engineers conduct innovative research and train the next generation of engineers. There is a growing demand for biomedical engineers due to aging populations, increasing prevalence of chronic diseases, and proliferation of sophisticated medical devices. (Avanzo et al.2021)(Kumar and Choudhary2023)

8.1. Medical Device Design and Development

In broad terms, the design and development of medical devices is a complex process that requires careful consideration of engineering, clinical need and regulatory burden. A medical device, as defined by the FDA, is “an instrument, apparatus, implement, machine, contrivance, implant, in vitro reagent, or similar article, including any component, part, or accessory that is intended for use in the diagnosis of disease… which does not achieve its primary intended purposes through chemical action within the body.” As such, medical devices range from simple thermometers to complex machines such as MRI systems. Regardless of complexity, every medical device must go through similar stages of design and development to ensure that it is safe and effective.

The first stage in the design process is to identify a clinical need. This need could stem from an in-house request by clinicians for a new device, or the idea for a new device could be generated externally. In this scenario, extensive dialogue between the engineers and the clinicians who would be using the device is necessary to clearly define the clinical need and establish design inputs for the device (L. Martin et al., 2012). Once a need has been identified, concepts of the device are created. Early concepts are usually in the form of simple sketches and are often subjected to a "peer review" process, where other engineers and clinicians comment on the viability of the concepts. Once a concept has been agreed upon, more detailed designs are created, often using computer-aided design (CAD) software. With the detailed design completed and reviewed, the next stage is to construct a prototype of the device. Ideally, the first prototype constructed would be a "proof-of-concept" prototype that tests whether the device works as intended. However, due to financial constraints, the prototype built may only be a subset of the fully designed device. Once built, the prototype must go through rigorous testing to ensure it meets safety standards and design inputs. If the prototype passes testing, it can be deemed an acceptable design, and the necessary documentation for device production is created. This documentation includes assembly procedures, design specifications and quality assurance procedures. With documentation completed, device production can begin, either in-house or externally. Once a device has been produced, it cannot be used until it has been formally accepted in a "validation" process. However, it should be noted that the above description is a very simplistic summary of the medical device design process, and each stage can be extremely complex in its own right. In addition, several stages are often interwoven; for example, device prototyping and testing often occur in parallel to the design finalisation. Finally, it should also be noted that the safety of medical devices is paramount and that without adequately trained professionals, the risk of harm to patients can be greatly elevated. The design, development, maintenance and quality assurance of medical devices should be conducted by, or closely supervised by, professionals with a thorough knowledge of both engineering and medicine. (Sastri, 2021)(Jin et al., 2022)

References:

1. S. Ibbott, G., Chougule, A., Damilakis, J., Tabakov, S., K. Wu, R., G. Orton, C., & Kron, T. (2022). Medical physicist certification and training program accreditation. ncbi.nlm.nih.gov
2. Fraser, A. G., Monaghan, M. J., van der Steen, A. F., & Sutherland, G. R. (2022). A concise history of echocardiography: timeline, pioneers, and landmark publications. European Heart Journal-Cardiovascular Imaging, 23(9), 1130-1143. oup.com
3. Beyer, T., Bailey, D. L., Birk, U. J., Buvat, I., Catana, C., Cheng, Z., ... & Moser, E. (2021). Medical Physics and imaging–A timely perspective. Frontiers in Physics, 9, 634693. frontiersin.org
4. Zanca, F., Hernandez-Giron, I., Avanzo, M., Guidi, G., Crijns, W., Diaz, O., ... & Kortesniemi, M. (2021). Expanding the medical physicist curricular and professional programme to include Artificial Intelligence. Physica Medica, 83, 174-183. physicamedica.com
5. Beckers, R., Kwade, Z., & Zanca, F. (2021). The EU medical device regulation: Implications for artificial intelligence-based medical device software in medical physics. Physica Medica. physicamedica.com
6. Hanley, J., Dresser, S., Simon, W., Flynn, R., Klein, E. E., Letourneau, D., ... & Holmes, T. (2021). AAPM Task Group 198 Report: An implementation guide for TG 142 quality assurance of medical accelerators. Medical physics, 48(10), e830-e885. wiley.com
7. Kumar Singh, R., Priyadarshini Nayak, N., Behl, T., Arora, R., Khalid Anwer, M., Gulati, M., Gabriela Bungau, S., & Cristina Brisc, M. (2024). Exploring the Intersection of Geophysics and Diagnostic Imaging in the Health Sciences. ncbi.nlm.nih.gov
8. Wang, K. & Tepper, J. E. (2021). Radiation therapy-associated toxicity: Etiology, management, and prevention. CA: a cancer journal for clinicians. wiley.com
9. Chandra, R. A., Keane, F. K., Voncken, F. E. M., & Thomas, C. R. (2021). Contemporary radiotherapy: present and future. The Lancet. binasss.sa.cr
10. K. M Shadekul Islam, S., Abdullah Al Nasim, M. D., Hossain, I., Md Azim Ullah, D.,

Kishor Datta Gupta, D., & Monjur Hossain Bhuiyan, M. (2023). Introduction of Medical Imaging Modalities. [PDF]
11. Collins, C. (2017). Radiation Therapy Medical Physics Review – Delivery, Interactions, Safety, Feasibility, and Head to Head Comparisons of the Leading Radiation Therapy Techniques. [PDF]
12. Newhauser, W. D., Gress, D. A., Mills, M. D., Jordan, D. W., Sutlief, S. G., Martin, M. C., & Jackson, E. (2023). Medical physics workforce in the United States. Journal of Applied Clinical Medical Physics, 23(Suppl 1), e13762. nih.gov
13. Chong, L. M., Tng, D. J. H., Tan, L. L. Y., Chua, M. L. K., & Zhang, Y. (2021). Recent advances in radiation therapy and photodynamic therapy. Applied Physics Reviews, 8(4). [HTML]
14. S. Litvinova, K., E. Rafailov, I., V. Dunaev, A., G. Sokolovski, S., & U. Rafailov, E. (2017). Non-invasive biomedical research and diagnostics enabled by innovative compact lasers. [PDF]
15. Hackshaw, A., Cohen, S. S., Reichert, H., Kansal, A. R., Chung, K. C., & Ofman, J. J. (2021). Estimating the population health impact of a multi-cancer early detection genomic blood test to complement existing screening in the US and UK. British Journal of Cancer, 125(10), 1432-1442. nature.com
16. Sebastian, A. M. & Peter, D. (2022). Artificial intelligence in cancer research: trends, challenges and future directions. Life. mdpi.com
17. Health Organization, W. (2023). … cancer initiative implementation framework: assessing, strengthening and scaling-up of services for the early detection and management of breast cancer. google.com
18. Gupta, S. R. (2022). Prediction time of breast cancer tumor recurrence using Machine Learning. Cancer Treatment and Research Communications. sciencedirect.com
19. Allugunti, V. R. (2022). Breast cancer detection based on thermographic images using machine learning and deep learning algorithms. International Journal of Engineering in Computer Science, 4(1), 49-56. researchgate.net
20. Vavrinsky, E., Ebrahimzadeh Esfahani, N., Hausner, M., Kuzma, A., Rezo, V., Donoval, M., & Kosnacova, H. (2022). The Current State of Optical Sensors in Medical Wearables. ncbi.nlm.nih.gov
21. Lee, K. S. (2008). Extended Focus Range High Resolution Endoscopic Optical Coherence Tomography. [PDF]
22. Mezger, U., Jendrewski, C., & Bartels, M. (2013). Navigation in surgery. ncbi.nlm.nih.gov
23. Alfredo Siochi, R., Balter, P., D. Bloch, C., S. Bushe, H., S. Mayo, C., H. Curran, B., Feng, W., C. Kagadis, G., H. Kirby, T., & L. Stern, R. (2009). Information technology resource management in radiation oncology. ncbi.nlm.nih.gov
24. Tao, B., Feng, Y., Fan, X., Zhuang, M., Chen, X., Wang, F., & Wu, Y. (2022). Accuracy of dental implant surgery using dynamic navigation and robotic systems: An in vitro study. Journal of Dentistry, 123, 104170. [HTML]
25. Rawicki, N., Dowdell, J. E., & Sandhu, H. S. (2021). Current state of navigation in spine surgery. Annals of translational medicine, 9(1). nih.gov
26. Wei, S. M., Zhu, Y., Wei, J. X., Zhang, C. N., Shi, J. Y., & Lai, H. C. (2021). Accuracy of dynamic navigation in implant surgery: A systematic review and meta-analysis. Clinical Oral Implants Research, 32(4), 383-393. researchgate.net
27. Meike, E. (2016). A Presentation Promoting Medical Laboratory Science. [PDF]
28. R. Karam, L. (2009). Radiation-based quantitative bioimaging at the national institute of standards and technology. ncbi.nlm.nih.gov
29. Khatab, Z., & Yousef, G. M. (2021). Disruptive innovations in the clinical laboratory: Catching the wave of precision diagnostics. Critical reviews in clinical laboratory sciences, 58(8), 546-562. tandfonline.com
30. Church, D. L., & Naugler, C. (2022). Using a systematic approach to strategic innovation in laboratory medicine to bring about change. Critical Reviews in Clinical Laboratory Sciences, 59(3), 178-202. [HTML]

31. Health Organization, W. (2021). … and use of essential in vitro diagnostics: report of the third meeting of the WHO Strategic Advisory Group of Experts on In Vitro Diagnostics, 2020 (including the …. who.int
32. Calderaro, A., Buttrini, M., Farina, B., & Montecchini…, S. (2022). Respiratory tract infections and laboratory diagnostic methods: a review with a focus on syndromic panel-based assays. Microorganisms. mdpi.com
33. Marais, G., Hsiao, N. Y., Iranzadeh, A., Doolabh, D., Enoch, A., Chu, C. Y., ... & Hardie, D. (2021). Saliva swabs are the preferred sample for Omicron detection. Medrxiv, 2021-12. medrxiv.org
34. Woo, M. & Ng, K. H. (2008). Real-time teleteaching in medical physics. ncbi.nlm.nih.gov
35. Aarts, S., Cornelis, F., Zevenboom, Y., Brokken, P., van de Griend, N., Spoorenberg, M., ten Bokum, W., & Wouters, E. (2017). The opinions of radiographers, nuclear medicine technologists and radiation therapists regarding technology in health care: a qualitative study. ncbi.nlm.nih.gov
36. Alshammari, M. H. & Alenezi, A. (2023). Nursing workforce competencies and job satisfaction: the role of technology integration, self-efficacy, social support, and prior experience. BMC nursing. springer.com
37. Nes, A. A. G., Steindal, S. A., Larsen, M. H., Heer, H. C., Lærum-Onsager, E., & Gjevjon, E. R. (2021). Technological literacy in nursing education: A scoping review. Journal of Professional Nursing, 37(2), 320-334. sciencedirect.com
38. Zareshahi, M., Mirzaei, S., & Nasiriani, K. (2022). Nursing informatics competencies in critical care unit. Health Informatics Journal, 28(1), 14604582221083843. sagepub.com
I. Bluth, E., P. Frush, D., Elizabeth Oates, M., LaBerge, J., Y. Pan, H., D. Newhauser, W., & A. Rosenthal, S. (2022). Medical workforce in the United States. ncbi.nlm.nih.gov
39. Adler, A. M., Carlton, R. R., & Stewart, K. L. (2022). Introduction to Radiologic and Imaging Sciences and Patient Care E-Book: Introduction to Radiologic and Imaging Sciences and Patient Care E-Book. [HTML]
40. Hussain, S., Mubeen, I., Ullah, N., Shah, S. S. U. D., Khan, B. A., Zahoor, M., ... & Sultan, M. A. (2022). Modern diagnostic imaging technique applications and risk factors in the medical field: a review. BioMed research international, 2022(1), 5164970. wiley.com
41. Lu, L., Sun, M., Lu, Q., Wu, T., & Huang, B. (2021). High energy X-ray radiation sensitive scintillating materials for medical imaging, cancer diagnosis and therapy. Nano Energy. polyu.edu.hk
42. Çallı, E., Sogancioglu, E., van Ginneken, B., van Leeuwen, K. G., & Murphy, K. (2021). Deep learning for chest X-ray analysis: A survey. Medical Image Analysis, 72, 102125. sciencedirect.com
43. Quansah Amissah, R., Kwesi Atchurey, A., Appiah, L., Kofi Fiakumah, E., Gyapong-Korsah, E., Boadu, J., Tetteh, E., Offei, E., & Effah Kaufmann, E. (2013). BIOMEDICAL ENGINEERING IN GHANA. [PDF]
44. F. Silva, D., L. P. Melo, A., F. C. Uchôa, A., M. A. Pereira, G., E. F. Alves, A., C. Vasconcellos, M., H. Xavier-Júnior, F., & F. Passos, M. (2023). Biomedical Approach of Nanotechnology and Biological Risks: A Mini-Review. ncbi.nlm.nih.gov
45. Avanzo, M., Trianni, A., Botta, F., Talamonti, C., Stasi, M., & Iori, M. (2021). Artificial intelligence and the medical physicist: welcome to the machine. Applied Sciences, 11(4), 1691. mdpi.com
46. Kumar, R., & Choudhary, R. K. (2023). Calibration of Medical Devices: Method and Impact on Operation Quality. Int Pharm Sci 2023; 16 (1): 128. doi: 10.31531/2231, 5896. edwiserinternational.com
47. L. Martin, J., J Clarke, D., P Morgan, S., A Crowe, J., & Murphy, E. (2012). A user-centred approach to requirements elicitation in medical device development: a case study from an industry perspective. [PDF]
48. Sastri, V. R. (2021). Plastics in medical devices: properties, requirements, and applications. [HTML]
49. Jin, Z., He, C., Fu, J., Han, Q., & He, Y. (2022). Balancing the customization and standardization: exploration and layout surrounding the regulation of the growing field of 3D-printed medical devices in China. Bio-design and Manufacturing. springer.com