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RESEARCH CONCEPTS OF MODERN PHYSICS IN MEDICINE

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ABSTRACT

Research includes systematic investigation in a wide range of fields, such as Physics, biology, chemistry, pharmacology and toxicology with the goal of developing new medicines. Many remarkable medical technologies, diagnostic tools, and treatment methods have emerged as a result of modern physics discoveries in the last century-including radiofrequency ablation, PET-CT scan, Linear Accelerator, mechanical ventilation, Ultrasound imaging. The purpose of medical research is to learn how our bodies work, why we get sick, and what we can do to get and stay well. The goal of medical research is to improve our health. Medical research studies often aim to advance our knowledge of a medical condition. Each study tries to answer specific questions. Research relies on scientific and academic innovation. By posing new ideas and suggesting alternative answers to medical and social questions we aim to have evidence based care and practice at the forefront of health delivery. Put simply; research needs to be an integral part of any healthcare environment. Technology and medicine have gone hand and hand for many years. Consistent advances in pharmaceuticals and the medical field have saved millions of lives and improved many others.

KEYWORDS: Radiofrequency ablation, PET- CT scan, Linear Accelerator, Mechanical ventilation, Ultrasound imaging.

I. INTRODUCTION

Ever wonder why physics is great significance in the field of medicine? Well, there are numerous reasons why it is very vital to this field. One reason is "medical physics", it is one of the branches of physics. Medical physics is a branch of applied physics concerning the application of physics to medicine. It generally concerns physics as applied to medical imaging and radiotherapy. Medical imaging refers to the techniques and processes used to create images of the human body for clinical purposes.

Many of the greatest inventions in modern medicine were developed by physicists who imported technologies such as X rays, nuclear magnetic resonance, ultrasound, particle accelerators and radioisotope tagging and detection techniques into the medical domain. There they became magnetic resonance imaging (MRI), computerized tomography (CT) scanning, nuclear medicine, positron emission tomography (PET) scanning, and various radiotherapy treatment methods. These contributions have revolutionized medical techniques for imaging the human body and treating disease.

II. Different types of recent Research techniques in Physics in Medical field

1. Radio Frequency Ablation (RFA)

Principle of Radio Frequency Abalation

Radio Frequency[1] works on the principle of increasing the frequency and voltage while simultaneously decreasing the amperage of alternating current so as to generate oscillating radio waves. These radio waves are further modified to produce different waveforms that are passed into the lesion. Modern high-frequency radio surgical devices transfer electrical energy to human tissue via a treatment electrode that remains cool.[2] The electrical resistance of human tissue helps in converting this electrical energy into molecular energy[3]; this causes the denaturation of intracellular and extracellular proteins, thereby resulting in coagulation or desiccation effects.[4]

Advantages

RFA is a simple, safe procedure with wider applications. It causes less lateral heat spread and tissue damage and provides better control in comparison to electric cattery. The cutting mode of radiofrequency is more effective and versatile in comparison to the carbon dioxide laser. As hemostasis occurs at the same time, the time required for the surgery is less. There are fewer side effects and complications. RFA can be easily combined with other surgical modalities such as cryotherapy and laser for treatment.[5]

Precautions

- RFA should be avoided in unstable cardiac patients and in the treatment of the lesions of the skin overlying a pacemaker.
- Special care should be taken while taking part in a presentation of radio surgery near eye. RFA should not be done in presence of oxygen as there is risk of explosion.
- It should be made sure that patient is in contact with the ground plate during procedure.
- The operator should consider wearing a surgical mask and eye protection when working on lesions containing HPV.[6]

1. Pet – CT Scan

1978 the first commercial PET scanner was brought in 70s and 80s PET was mainly used for research 1990s being used in clinics regularly First approval in 1998.[7]Cancer is one of leading causes of morbidity and mortality in advanced countries. Most radiologic procedures map the anatomy and morphology of tumors with little or no information about their metabolism Positron emission tomography (PET) is a coalition of physics, chemistry, physiology, and medicine united in an effort to measure physiologic parameters noninvasively.[8]

Principle of PET

The theory of PET is to radiolabel a bio-compound, inject it into the patient, and then measure its bio-distribution as a function of time to determine physiologic quantities associated with the bio compound. All PET compounds are radio labeled with positron-emitting radio nuclides. These radio nuclides have decay characteristics that enable localization in the body. A positron is emitted from the nucleus, travels a short distance, and annihilates with its antiparticle (an electron), which results in two 5 I l-keV photons traveling in opposite directions. After both photons are detected, the activity is localized somewhere along the line defined by the two detectors.[9]

A PET study consists of Producing radiotracers Synthesizing radiopharmaceuticals from the tracers administering the radiopharmaceutical to a patient measuring the resulting radioactivity distribution in an organ of interest interpreting activity distribution as a function of physiologic parameters.[10]

Advantages of PET-CT Scan

- Useful in accurate localization of small areas of increased radiotracer activity that would have been difficult or not possible to localize on PET images alone.[11]
- Helps in distinguishing structures that normally show high metabolic activity from those with abnormally increased activity.
- PET-CT combines the advantages of the excellent functional information provided by PET and the superb spatial and contrast resolution of CT
- Finally, attenuation correction for quantitative or semi quantitative assessment of data is possible by using the CT data.

Limitations of PET-CT Scan

- Patient movement may cause confusion as to the correct position of the origin of the detected photon
- Attenuation (transmission) correction artifacts highly attenuating objects in the path of the CT beam, such as hip prostheses, pacemakers, dental devices, and contrast-enhanced vessels

3. LINEAR ACCELERATOR

In 1962 Kaplan and **Saul Rosenberg** begin trials using the linear accelerator with chemotherapy to treat Hodgkin's disease, an approach that dramatically improves patient survival. A linear accelerator also known as linear particle accelerator has many applications such as they generate X-rays and high energy electrons for medicinal purposes in radiation therapy, serve as particle injectors for higher-energy accelerators, and are used directly to achieve the highest kinetic energy for light particles (electrons and positrons) for particle physics.[12]

A **linear particle accelerator** (often shortened to *linac*) is a type of particle accelerator that greatly increases the kinetic energy of charged subatomic particles or ions by subjecting the charged particles to a series of oscillating electric potentials along a linear beamline; this method of particle acceleration was invented by Leó Szilárd. Ionizing radiation in medicine works by damaging the DNA of cells including cancer cells.[13]

How does a linear accelerator work?

Ion source gives bunch of electrons which are then accelerated towards the first drift tube an account of their negative potential and drift tube’s positive potential. When electrons come inside the tube, at that moment RF source shifts its polarity. First drift tube then becomes negatively charged and second drift tube positively charged. Electrons come outside of the tube because of its inertia and at that moment they are pushed with the first drift tube and attracted by the second one in the same direction.

As electrons are accelerating, their velocity becomes bigger and they travel a longer distance in the same time. That is the reason why drift tubes must be longer as electrons come closer to target because of their greater velocity. If the very great velocity is needed, because of long drift tubes and a big number of drift tubes, linac must be very long.[14]

4. MECHANICAL VENTILATION

Mechanical ventilators began to be used increasingly in anesthesia and intensive care during the 1950s.[15] Mechanical ventilator is an automatic machine designed to provide all or part of the work the body must do to move gas into and out of the lungs. The act of moving air into and out of the lungs is called breathing, or, more formally, ventilation.

Types of Mechanical ventilators

- **Transport ventilators** — These ventilators are small and more rugged, and can be powered pneumatically or via AC or DC power sources
- **Intensive-care ventilators** — These ventilators are larger and usually run on AC power (though virtually all contain a battery to facilitate intra-facility transport and as a back-up in the event of a power failure). This style of ventilator often provides greater control of a wide variety of ventilation parameters (such as inspiratory rise time). Many ICU ventilators also incorporate graphics to provide visual feedback of each breath
- **Neonatal ventilators** (Bubble CPAP) — Designed with the preterm neonate in mind, these are a specialized subset of ICU ventilators that are designed to deliver the smaller, more precise volumes and pressures required to ventilate these patients
- **Positive airway pressure ventilators** (**PAP**) — These ventilators are specifically designed for non-invasive ventilation. This includes ventilators for use at home for treatment of chronic conditions such as sleep apnea or COPD.
- **Transport ventilators** — these ventilators are small and more rugged, and can be powered pneumatically or via AC or DC power sources

In general, mechanical ventilation is instituted to correct blood gases and reduce the work of breathing.

Common medical indications for use include:

- Acute lung injury, including acute respirato ry distress syndrome (ARDS) and trauma
- Apnea with respiratory arrest, including cases from intoxication
- Acute severe asthma requiring intubation
- Acute or chronic respiratory acidosis, most commonly with chronic obstructive pulmonary disease (COPD) and obesity hypoventilation syndrome
- Acute respiratory acidosis with partial pressure of carbon dioxide (pCO_2) > 50 mmHg and pH < 7.25, which may be due to paralysis of the diaphragm due to Guillain–Barré syndrome, myasthenia gravis, motor neuron disease, spinal cord injury, or the effect of anaesthetics and muscle relaxants.
- Increased work of breathing as evidenced by significant tachypnea, retractions, and other physical signs of respiratory distress[3]
- Hypoxemia with arterial partial pressure of oxygen
- Hypotension including sepsis, shock, congestive heart failure
- Neurological diseases such as muscular dystrophy and amyotrophic lateral sclerosis (ALS)

4. ULTRASOUND IMAGING

Medical ultrasound is based on the use of high-frequency sound to aid in the diagnosis and treatment of patients. Ultrasound frequencies range from 2 to approximately 15 MHz, although even higher frequencies may be used in some situations. Ultrasound transducers contain a range of ultrasound frequencies, termed bandwidth. For example, 2.5-3.5 MHz for general abdominal imaging and 5.0-7.5 MHz for superficial imaging. Ultrasound waves are reflected at the surfaces between the tissues of different density, the reflection being proportional to the difference in impedance. If the difference in density is increased, the proportion of reflected sound is increased, and the proportion of transmitted sound is proportionately decreased. If the difference in tissue density is very different, then the sound is completely reflected, resulting in total acoustic shadowing. Acoustic shadowing is present behind bones, calculi (stones in kidneys, gallbladder, etc.) and air (intestinal gas) (See Fig. 1 with acoustic shadowing).Echoes are not produced if there is no difference in a tissue or between tissues. Homogenous fluids like blood, bile, urine, contents of simple cysts, as cites and pleural effusion are seen as echo-free structures.[1[7]

Principle

Ultrasound refers to sound waves that are not detectable by the human ear with frequencies greater than 20,000 cycles/sec (Hz). Diagnostic ultrasound commonly uses frequencies between 2 and 15 MHz (10^6 cycles/sec). Intravascular transducers commonly use frequencies up to 30 MHz, and ultrasound biomicroscopy systems with transducers using frequencies up to 100 MHz have been reported (Foster et. al 2000; Turnbull et al. 1995). At these frequencies, sound waves are transmitted though soft tissue relative to the acoustic ipedance of each tissue. The acoustic impedance of a particular tissue is the product of the transmission velocity of sound and the tissue density. The transmission velocity in most soft tissues and blood is nearly uniform at 1540 m/sec[18]

Benefits

- Most ultrasound scanning is noninvasive (no needles or injections).
- Occasionally, an ultrasound exam may be temporarily uncomfortable, but it should not be painful.
- Ultrasound is widely available, easy-to-use and less expensive than other imaging methods.
- Ultrasound imaging is extremely safe and does not use any ionizing radiation.
- Ultrasound scanning gives a clear picture of soft tissues that do not show up well on x-ray images.

- Ultrasound is the preferred imaging modality for the diagnosis and monitoring of pregnant women and their unborn babies.
- Ultrasound provides real-time imaging, making it a good tool for guiding minimally invasive procedures such as needle biopsies and fluid aspiration.[19]

Risks

- For standard diagnostic ultrasound, there are no known harmful effects on humans.

CONCLUSION

In general there are other ways that **physics is important in medicine**, but this should get across the fact that **physics** plays a huge role in **medical** practice. Physics can be found in a variety of other areas of medicine too. For example, many types of ventilator wouldn't be possible without an understanding of fluid pressure and pulse frequency so that the ventilation rate and amount of pressure applied is appropriate. Medical physics is facing significant changes, particularly with quick development of biological sciences, more complex research requiring interdisciplinary teams and strong need for translational research. The changes towards personalized medicine are opening new avenues for medical physicists like molecular imaging and extending beyond radiation therapy. In order to prepare medical physicists for the future, education and training should be properly adjusted including more basic non-physical sciences, particularly biology, more imaging, especially molecular imaging, and with more interdisciplinary and translational research components. Only in this way will we secure long-term future for medical physics.

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