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Mini-review: Imaging in medical diagnoses

IMAGE DIAGNOSTICS, PHYSICAL BASIS AND PERSPECTIVES

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ABSTRACT

The purpose of the study is to discuss the physical basis, the application capacity and perspectives of ultrasonographic methods, magnetic resonance imaging and positron emission tomography, with a view to determining their specificity and possibilities of combination with other methods to achieve precision in the diagnostic process. *Methods.* The physical basis for the realisation of the methods is presented. Possibilities for machine design and clinical application are shown. *Results.* Possibilities to develop methods and techniques with regard to their non-invasive nature and minimising patient risk are shown. A combination with some other diagnostic and therapeutic methods is proposed. Advantages derived from obtaining diagnostic information are discussed.

Key words: ultrasonography, positron emission tomography, magnetic resonance imaging

INTRODUCTION

Modernisation of the technique and methods for imaging diagnostics develops at accelerated rates. Physics gives to medicine theories, experimental methods and technical resources. The role of physics extends to improvement and application of the methods for diagnostics and therapy [1, 2].

METHODS

Ultrasound imaging. Ultrasound imaging is a medical diagnostic technique in which very high frequency sound is directed into the body (**Figure 1**). The tissue interfaces reflect the sound, and the resulting pattern of sound reflection is processed by a computer to produce a photograph or a moving image on a monitor.

The sound waves used in the ultrasound beam are produced by rapidly oscillated crystal. A transducer must be in close contact with the skin, and a jellylike substance is smeared on the skin to improve the transmission of sound.

Magnetic Resonance Imaging. Magnetic resonance imaging, based on the phenomenon of nuclear magnetic resonance (NMR), produces images of the human body with excellent soft tissue contrast.

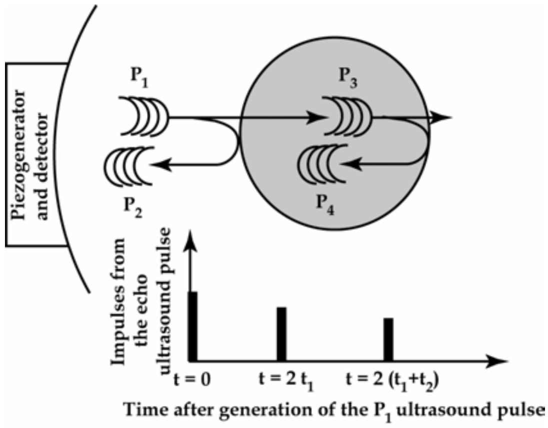

Figure 1. *One-dimensional ultrasonography [1]*

The NMR is an event based on the properties of some kinds of nuclei, placed in magnetic field, to absorb a definite electromagnetic energy $h\nu_{res}$ with a resonance frequency $\nu_{res} = \gamma B_0$, where B_0 is the strength of the applied static magnetic field, and γ is a proportionality constant specific to the nuclear species. Following the absorbance the nuclei become excited. The next stage is to release this energy when the exciting impulse is interrupted (**Fig. 2**). The amplitude of the NMR signal decays exponentially (time

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constant ***T***).

The method was called magnetic resonance tomography (MRT) lately – for three dimension images of organs or soft tissues [3]. The main MRT advantages are: its non-invasive nature and less radiation, three dimensional imaging, high contrast and differentiation of soft tissues.

Positron emission tomography. Positrons are emitted by atoms, and they include, ^{11}C, ^{15}O, and ^{18}F. The annihilation event of electron and positron converts the matter of the two particles into pure energy in the form of two 511 keV photons travelling at 180 degrees to each other. These photons escape the body and strike a pair of scintillation detectors (usually in the form of a ring) made surrounding the patient (**Fig. 3**) [4]. The lines allow computational analysis and temporal and spatial pinpointing of the isotope within the patient. Complex algorithms then use the data to render the imaging slices and generate a whole-body image.

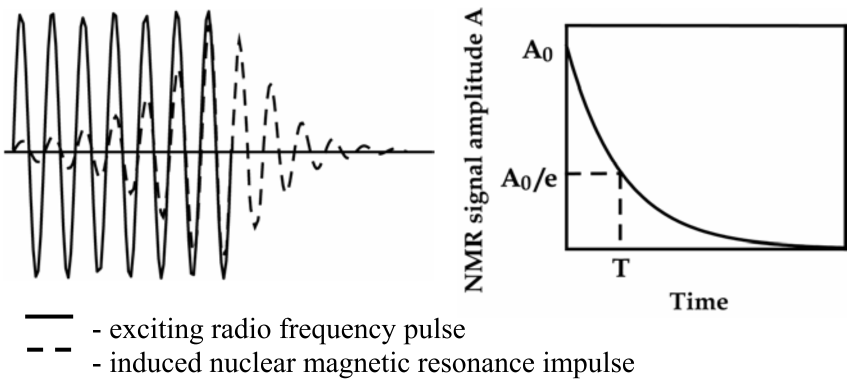

Figure 2.

(a) *Radio frequency exciting impulse provoking an NMR signal* ***(b)*** *– Relaxation time* ***T***

Unstable positron-emitting isotopes do not exist naturally. They must be industrially synthesized employing a cyclotron unit that uses high-powered magnets to accelerate beams of protons, smashing them into stable isotopes. The radioactive isotopes are then attached to the compound that will ultimately be injected into the patient.

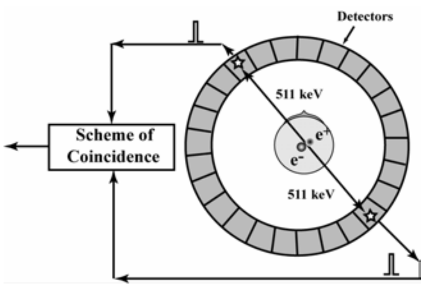

Figure 3*. The physical basis of positron emission tomography*

RESULTS AND DISCUSSION

*Ultarsound imaging***.** Ultrasound can be used to examine the arterial system, heart, pancreas, peritoneal cavity, urinary system, ovaries, venous system, brain, and spinal cord. Fluid conducts the sound waves well, making ultrasound a useful technique for diagnosing cysts, examining fluid-filled structures such as the bladder or biliary system, and viewing the foetus in the amniotic sac. Air, bone, and other calcified tissues absorb nearly all the ultrasound beam, so this technique cannot be used to examine the bones or lungs.

Ultrasound examination of the heart – echocardiography – is used to study congenital heart disease, coronary artery disease, tumours of the heart and other cardiac disorders. Doppler ultrasound is used to measure the blood flow [5].

Endoscopic ultrasonography in which an ultrasonography probe is placed at the tip of endoscope, has been proved to be an accurate technique for studying pancreatic malignancies [6].

Tomography is imaging method containing diagnostic information for biological tissues in one section of the body. The method requires accumulation of enormous data massif, which from special computer software is manipulated and thus the method is called computer tomography.

*Magnetic Resonance Imaging***.** The basis of contrast is the spin density throughout the object. If there are no spins present in a region it is not possible to get an NMR signal at all. Proton spin densities depend on water content for various human tissues [7]. The low proton spin density of bone makes MRI a less suitable choice for skeletal imaging than X-ray shadowgraphs or X-ray CT. Since there is such a small difference in proton spin density between most other tissues in the body, other suitable contrast mechanisms must be employed.

MRI allows neurologists to distinguish between grey and white matter, and brain diseases, e.g tumours. The development of contrast agents suitable for dynamic MRI studies, and improvements in the speed of imaging, opened up the possibility of using the technique for functional brain studies. Later the blood was used as an endogenous contrast agent. The haemoglobin in the blood has different magnetic properties depending on whether it is oxygenated or not; these differences affect the signal recorded in the MR image [8].

Positron emission tomography. A PET scan is often used to detect and evaluate cancer, such as of the lung or breast. It also can be used to evaluate the heart's metabolism and blood flow and examine brain function. Using labelled water, positron emission tomography became the first useful technique which allowed researchers to produce maps of the mind, by measuring blood flow during execution of simple cognitive tasks. Since local blood flow is intimately related to cortical activity, regions of high regional blood flow indicate the area in the cortex responsible for the task being performed [9].

CONCLUSION

A tendency of integration of fundamental and clinical sciences and practice are observed lately. Physics is a fundamental science, creating methods of imaging diagnostics and non-invasive therapy. Their principles need to be discussed with a view to improving their applications in medicine.

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