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BIOMEDICAL ENGINEERING: AN INTERDISCIPLINARY APPROACH IN THE LIFE SCIENCES *
(Biyomedikal Mühendisliği: Hayati Bilimlerde Disiplinler Arası Bir Yaklaşım)

Dr. Ahmet ARSLAN *, Dr. Abdurrahman KUTLU **, Dr. Faruk AKSOY ***, Dr. Emsal H. UĞUR****
* S.Ü.T.F. Tıbbi Biyoloji ve Genetik Anabilim Dalı, ** S.Ü.T.F. Ortopedi ve Travmatoloji Anabilim Dalı,
*** S.Ü.T.F. Genel Cerrahi Anabilim Dalı, **** S.Ü.T.F. Radyoloji Anabilim Dalı

ÖZET

Fiziksel bilimlerin tıbta uygulanması ve tıp bilimleriyle bütünleştirilmesi bu makalede tartışılmıştır. Sağlık hizmetlerinde olan gelişmeler, temel tıp bilimleri alanlarında bir hayli deneysel çalışmalara imkan hazırlamaktadır. Bunlardan implantasyon, doku toleransı, materyal teknolojisi, model ve kalıpçılık, ve alet donanımı gibi çalışmalar biomedikal mühendisliğinin ve biomedikal temel bilimlerinin önemini ortaya koymaktadır.

ABSTRACT

Integration and possible means of application of physical sciences in medicine has been discussed. Progressive improvements in health care opens explorative research areas in the medical sciences (implantation, tissue tolerance, high quality material, modelling and remolding, and instrumentation) that makes biomedical engineering and sciences a must.

INTRODUCTION

Biomedical Engineering is an interdisciplinary science which lends itself on the various aspects of life, particularly human health. It's interest covers from pure and applied sciences (Physics, Chemistry, Applied Mathematics, Molecular Biology, and Medicine) to engineering (Mechanical, Electrical and Electronics, and Material Sciences). It is not therefore unusual sometimes to be called Clinical Engineering.

AN OVERVIEW

There is an ever increasing demand for engineers with a biomedical training. Over the last decade the worldwide interest in improving plant design and external body support systems has been matched by industry's eagerness to develop these ideas into products. Such developments include partial and total replacement of joints and organs, and specialized splint and dressings. Biomedical Engineers must have a complete understanding of the function of individual body components, their relationship to eachother and their performance in the environment in which they operate. Since, Biomedical Engineering, embracing many areas of the physical sciences, the emphasis of the research should be placed on the use of physical concepts in medical engineering applications to clinical problems. These include: 1) diagnostic and therapeutic thermography; microwave hyperthermia and therapeutic thermography; microwave hyperthermia and deep temperature mapping for use in cancer therapy. 2) Biomedical applications of laser, in other words, the application of lasers in medicine. Laser Doppler studies of blood flow through heart valve substitutes and in the microcirculation. Flow cytometry. Image measurements by light intensity evaluation. 3) Biomedical applications of Ultrasound and audiometry. Clinical application and development of techniques for ultrasound imaging. Blood flow measurement by Doppler Ultrasound. Tissue characterisation by ultrasound. Audiology. 4) Bioelectric and biomagnetic measurements; electrophysiological measurements; recording and data processing of low level signals from whole nerve trunks and muscle (smooth and striated). Pattern recognition of respiratory and evoked potential waveforms. Cardiac electrophysiology; Cardiac stimulation and recognition of arrhytmias. Static and dynamic imaging using the electrical impedance properties of different tissues. Feature extraction from medical images. Magnetic stimulation

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Haberleşme Adresi: Dr. Ahmet Arslan, S.Ü. Tıp Fakültesi Tıbbi Biyoloji ve Genetik Anabilim Dalı, Konya.

of nerves. 5) biomechanics and biofluid mechanics; computer aided desing of systems for evaluating pressure distributions under the foot. Desing and evaluation of hearth valve substitutes. Cardiovascular and renal fluid dynamics. Cardiovascular simulation systems. Tissue mechanics. The development of biomaterials for use in vascular prosthesis. Mechanical testing of orthopedic devices. 6) Nuclear imaging; dynamic studies of organ perfusion, isotopic image processing, whole body counting procedures. radiotherapy and diagnosis.

PRACTICES

The vaste interests mentioned above found their practices in the area of physiology, orthopedics, sport medicine, physical therapy and rheumatology, surgery in general, plastic surgery, burn treatments, wound and suture materials, and diagnostics. It should be pointed out that the effectiveness and the prolonged success of the works in these fields must go in hand with the invention, development, and improvement of the precise instrumentations as well. The precision and ease of the use of the instruments is important especially in implantation.

The description and understanding of the mechanism of injury or degeneration has led to an understanding of disabling conditions arising in human bones and joints. Thus, the design of orthopedic implants for the treatment of arthritis or trauma has included studies of the mechanical properties and fatique failure of the articular cartilage surfaces of human joints (1,2). Projects dealing with such studies led to inventions for total joint replacement, which included hip, knee, elbow and finger joint replacements together with instruments to enable them to be planted with the exact accuracy (3). At present, a localized cartilage defect due to arthritic disease or a victim of a car accident, or a sport player with an extensively torn cartilage must be lived with until it is of such disabling magnitude that the replacement of the joint is warranted (4). Although, methods of transplanting preserved tisues from animal joints, or live tissues cultured from other human joints are being developed (4). But these works have shown that the tissue's reaction to a particular implant type is affected greatly by the mechanical environment, necessitating the development of instruments that allow segments of articular joint surfaces to be fitted accurately into the patient (4,5). Methods also needed to check mechanically invisible implants and progress is still continuing but contact pressure mapping and indendation stiffness mapping are promising (6,7). Additionally, these mappings will help for possibility of repairing the back of the patella, which suffers frequently from localized arthritis, and replacements for the small bones of the wrist which often cannot be repaired after fractures.

Material Sciences dealing with biomaterials interested in the structure and properties of bone, and the development of bone replacement materials for orthopedic surgery (8,9,10,11). The development of novel materials which include corals that have intercommunucating porous structure akin to the bone and the possibility of such implants with cartilage cells cultured in a laboratory (4). It is desirable to devalop bone cement using dental materials to reduce the incidence of cement fracture and bone resorption, and hence the incidence of component loosening(12). Others such as a new method of attaching a ceramic femoral head to a metal stem to form the femoral component of a total hip prosthesis that has previously been developed (13). Impact tests, fatique tests in simulated body fluids at body temperature, and tests of the strength of fixation of head to stem, suggested that the method offers significant advantages over the currently used taper fit method. A desingn of an instrument which will allow surgeons to attach the head in the operating room, after choosing the optimum stem and neck length and head diameter is understudy at various institutions and companies (4,14,15).

Other field of interest relating to this subject is the degradation of ultra-high molecular weight polyethylene in the human body. Surgeons are expressing the views that the ultra-high molecular weight polyethylene used in artificial joints wears at very different rates in different patients and that a build-up of wear debris can lead to loosening, and failure (2,3). In addition, laboratory studies have raised the possibility that a gradual degradation of the material in the body might lead to an accelerating wear rate. Therefore, a testing procedure is needed to measure laboratory wear and mechanical testing of polyethylene retrieved from patients after different periods of implantation.

Accidental loss of ligaments similar to bone stems or torn cartilages are crippling and the development of artificial ligaments should be a major interest. Presently, the ligaments have been constructed of multiple fine flaments of inert polymers such as polyesters or carbon fibers (16,17). Multiple fine flament construction encourages ingrowth of host tissue and the observations showed that the implant soon becomes enmashed in a new composite material of artificial polymer fibers and host protein fibers (18). This property as an engineering artifact appears to strengthen patients condition progressively in response to what would normally be seen as fatique loading conditions (16).

Research is also proceeding on soft tissue treatments, particularly skin (19,20,21,22,23), adhesion and adhesives for medical applications (19,21,24), the use of biodegradable some internal fixation materials after implantation and/or fructures for eliminating second operation for removal (25,26,27,28).

The normal function of the human brain depends on a delicately balanced system of physiologic mechanisms. Nervous impulses, neurotransmitter synthesis and release, glucose, and oxygen metabolism, endothelial transport and blood flow all interact to create the optimum environment for a given functional activity. The regulation of this enviroment is the object of homeostasis.

During the severe cerebrovasculer accident experienced as an ischemic stroke the homeostatic mechanism fails. The neuronal environment no longer supports proper brain function and survival. Some neurous die, particularly in the regions of the brain that are most severely struck by the ischemics. Other neurons lose their function and enter a stage of enforced hibernation. From this state, the cells only seem to recover, when the hibernation is of limited duration or when the changes of the neuronal environment are of limited severity. To cilinicians, the obstacle to rational therapy of postischemic brain damage is the lack of knowledge of which of the two limitations is the more important.

Inactive neurons hibernating after ischemia have become the object of intense research. The studies suggest that hibernating neurons, react negatively toward excitation before the normal neuronal environment has been restored.

The cause of the damage that excitation inflicts on hibernating neurons appears to be the rise of intracellular calcium that follows opening of special calcium-ion conducting channels in the neuronal membrane. A rise of intracellular concentration of calcium ion above certain treshold level is harmful to the cell. After an ischemic insult, the cell cannot get rid of the calcium that enters during excitation, and calcium may therefore rise to levels that are not compatible with continued survival. The chemicals responsible for the harmful stimulation of hibernating neurons after ischemia are the excitatory aminoacid neurotransmitters, glutamate and aspartate, that nerve terminals release in large quantities at the onset of anoxia. How stimulation can be prevented? How can neurologist prolong the hibernation of neurons suffering from the effects of anoxia? The therapy should attempt to block the calcium channels opened by the excitatory aminoacids or hinder the access of the aminoacids to the nerve cell receptors that mediate the opening of the channels. To do this, research should be conducted to measure physiological variables that characterize nervous activity. Time dependent studies of metabolic changes associated with ischemia provide informations to resume normally functioning nerve cells from postischemic hibernation. However, the investigation of human cerebral function is not easy. Investigators have used electrophysiological, neuropathological and radiological approaches. Although, these techniques were instrumental for understanding of normal and abnormal cerebral function,but little is known about the local biochemistry and physilogy of human cerebral substructures. New analitical measurements of biochemical, physiological, and hemodynamic processes can be made locally in three dimensions using Positron Emission Tomography (PET) (29,30,31,32,33). The underlying principle of this technology is the ability of detection of annihilated photons which are emitted 180^{o} apart which makes imaging possible (34,35). As all we know, positrons are positively charged electrons that are emitted by certain unstable nuclei as they decay, when a positron combines with an electron they annihilate; that is, the masses they fromed are converted to electromagnetic radiation (like any other emitted light, photons) and produce a pair of high energy annihilation photons in essentially 180^{o} oposite direction which is exploited with PET devices.

The radioisotopes of oxygen, nitrogen, carbon fluoride etc. allows for the labelling of various substrates, substrate analogs, and drugs without disturbing their biochemical behaviour (36, 37, 38, 39).

Among the imaging technologies, Computed Radiography, Computerized Tomography (CT), Magnetic Resonance Imaging (MRI) can be named a few. The computed radiography system is a new X-ray projection technique that may replace conventional X-ray film. In computed radiography the detector is a stimulatable phosphorous screen which the information is stored in excited electron states, later on, the integration of the stored information into feature picture archiving and communication system, eliminates the need for x-ray film and it's processing. Computed Radiography or Digital Radiography System (DIGISCAN) are interchangebly used names for this system, and it reduces X-ray dose to the patient, reduces exposure times, but it is an expensive unit to be competative with the conventional X-ray radiography (40,41).

In contrast to computed radiography, in X-ray computed tomography (X-Ray CT) the image of an object is reconstructed from multiple projections of object. The ray projections are formed by scanning a thin cross-section of the body with a narrow X-ray beam and measuring the transmitted radiation with a sensitive radiation dedector.

Computed tomography has had many names, each referring to at least one aspect of the technique. Presently, computerized axial tomography (CAT) and Computed (Computerized) Tomography (CT) are the preferred names (42,43).

The basic principle behind Nuclear Magnetic Resonance (NMR) is the magnetic field strength which is proportional to the resonance radio frequency. All nuclei exibits Lamor frequency in a given external magnetic field. However, Larmor frequency of nuclei in a given external magnetic field may differ in some degree depending upon the proton environment. For example, Larmor resonance frequency of hydrogen nuclei of hydrocarbon differs from the hydrogen nuclei of water (40 MHz vs 30 MHz). Like this diffe-rence in the same magnetic field is known as chemical shift and is exploided greatly in elucidating molecular structure of pure compounds provided that signal/noise ratio is sufficient to give recognizable peaks. Different nuclei such as ^{13}C, ^{14}N, ^{15}N, ^{23}Na, ^{39}K, and ^{31}P give different Larmor resonance frequencies than 1H. The nuclei resonance in a given magnetic field and frequency has been realized as an invaluable tool to elucidate complex heterocyclic compounds in natural product chemistry, polymer chemistry, and pharmaceutical sciences.

Magnetic Resonance Imaging requires an additional weaker external magnetic field to create a magnetic gradient between strong magnetic field produced by a large magnet and a second weaker magnetic field that varies across the sample, a radio transmitter and receiver, and a powerfull computer to calculate an image. The energy of MRI is about nine orders of magnitude lower than that of x-rays and radioisotope technique, and this maks MRI much safer than x-rays, CT, and radioisotope technique (44,45,46).

In conclusion, it is hoped that this review article will generate some stimulus among the scientists in different disciplines to produce some collaborative works which are applicaple in health sciences. Enterdepartmental and justment within the university to create machine-shops will enable university students to gain some experiences at young agess, the possibilities of job openings, and products that are marketable within the university and within the community.

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