BOOK REVIEWS

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High Intensity Focused Ultrasound in Medicine

Edited by L. R. Gavrilov

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The author of the monograph is Leonid R. Gavrilov, D.Sc., Ph.D., Principal Research Scientist of the N.N. Andreyev Acoustics Institute, Moscow, Russia. One of the experienced Russian experts in medical ultrasound, he began investigating applications of High Intensity Focused Ultrasound (HIFU) in medicine and physiology in the late 1960s. The monograph summarizes the results of investigations carried out in this field, including the very first studies performed in the USA by Professors W. Fry and F. Fry, work conducted in the USSR in the 1970s and 1980s (almost unknown to the colleagues in the West), and more recent studies performed in the USA, Europe, and Asia.

The main content of the monograph is the investigation of the physical and technical foundations of HIFU applications in medicine. The potential to focus ultrasound energy deep in the human body to noninvasively target and ablate remote tissue sites without making any incisions or causing harm to other organs and tissues is extremely important in medicine. The book particularly is devoted to active applications of HIFU that aim to induce various biological effects, such as stimulating neural structures, increasing the permeability of cell membranes, and generating local thermal necrosis of tissues.

Especially during recent decades, the successes achieved in HIFU applications are very impressive. Currently, MR-guided focused ultrasound has been approved in the USA and other countries for the treatment of uterine fibroids. A similar approach has been approved in Europe for the treatment of pain due to metastatic bone cancer. HIFU devices are also used clinically for noninvasive, minimally traumatic prostate surgeries and for treating various types of cancer (kidney and liver, breast, sarcoma of soft tissue, etc.). Several tens of thousands of cancer patients across several countries have been treated with HIFU over the last 10–15 years. There are clinical trials for the treatment of low back pain, tremor, and other neurological disorders. HIFU has also been demonstrated as a potential treatment for many other applications: control of bleeding, vascular effects, dissolution of blood clots to restore flow through blocked vessels, liposuction, targeted drug delivery, gene therapy, and manipulation of neural structures. Finally, there are good prospects for HIFU in cardiology and neurosurgery despite the presence of acoustic barriers such as the skull and ribs. All of these possible applications are discussed in the book.

The monograph begins with a foreword written by the scientific Editor, the President of the Russian Acoustic Society and an Academician of the Russian Academy of Sciences, Victor A. Akulichev. Another foreword is written by the author. The book includes four chapters, a list of publications, and a subject index.

Chapter 1 is devoted to the physical foundations of focused ultrasound as applied to various fields of medicine, with a consideration for the mechanisms underlying biological effects. The basic relations for a single focusing radiator are given along with the acoustic parameters of biological tissues. Other topics related to the physical actions of ultrasound include thermal effects, mechanical effects including cavitation, radiation forces, acoustic streaming, microstreaming, shear stresses, and chemical effects. Safety aspects and threshold doses for ablation are also discussed.

Chapter 2 is devoted to how ultrasound can be focused in tissues, with consideration of possible focusing systems. Among these systems are single-element transducers (either curved or flat with acoustic lenses) and powerful, multi-element phased arrays. Both linear and two-dimensional arrays are described, and two-dimensional arrays with randomly distributed elements are emphasized as a subject of particular scientific interest to the author.

In Chapter 3, methods for generating and controlling ultrasound are considered. The tissue-mimicking phantoms are discussed as well as approaches for monitoring and controlling temperature and cavitation. Because the irradiation of tissue with focused ultrasound is inherently noninvasive, it would be ideal to use remote and non-damaging methods of feedback and control. Therefore, noninvasive methods for measuring acoustic fields, cavitation, and temperature in biological tissues are considered in detail.

Finally, Chapter 4 discusses numerous applications of high intensity focused ultrasound in clinical and experimental medicine. Applications in neurosurgery with ultrasound radiation through an open or intact skull are considered in addition to other types of surgery that require sonication through the rib cage. The surgical applications discussed include hyperthermia of tumors, sonosensitisation and sonodynamic therapy of tumors, treatment of prostate tumors, control of bleeding, vascular effects, treatment of blood clots, drug delivery, gene therapy, reversible changes in neural structures, and neuromodulation of brain structures. Other applications are also described involving ophthalmology, cardiology, uterine fibroids, liposuction, intervertebral disks, essential tremors, and physiotherapy. The author is known as an expert in the application of focused ultrasound for activation of different peripheral receptor structures and the use of these effects for diagnosis of various skin, neurological and hearing diseases; accordingly, this field of investigation is described in detail. The conclusive part of this chapter includes a tabular summary of biological effects of HIFU, associated mechanisms, and also prospective directions of future work.

The length of the book is 656 pages, including 128 figures and 1140 references. On the very last page, the author notes that the rate of progress for HIFU applications in medicine is increasing very rapidly, as indicated and by the corresponding number of publications each month. Consequently, even the reasonably large size of the book did not permit the inclusion of many very important topics that are essential to the field of medical ultrasound. Building on this statement, it is worth noting that a separate book could be written on investigations of nonlinear effects arising with the use of HIFU. In fact, in modern devices used in ultrasound surgery, the intensity in the focal region often reaches tens of kW/cm^2, which leads to the generation of higher harmonics in the propagating wave, distortion of its profile, the formation of shocks, and additional absorption of wave energy at the shock fronts. In these cases, local and very fast heating can occur—overheating of tissues to temperatures higher than 100 °C and the initiation of boiling are possible within a few milliseconds. The use of nonlinear regimes of sonication could lead to the development of new HIFU technologies. The use of lithotripters and associated mechanisms for destroying stones and tissues is discussed very briefly in this book, as well as the problems of ultrasound medical metrology. However, it would be useful to have further description of precise methods for measuring and calculating the fields of focused ultrasound transducers. The list of similar gaps in the content of this book could be continued. So a task of future authors is to write new books and fill these gaps.

There are not that many books devoted to applications of HIFU in medicine. One such book is the second edition of *Physical Principles of Medical Ultrasonics* (edited by C. R. Hill, J. C. Bamber, and G. R. ter Haar, John Willey & Sons, London, 2004). This well-known book describes all aspects of medical ultrasound, including, first of all, its application for visualizing diagnostic information by acoustic methods. However, particular issues associated with HIFU applications are discussed rather briefly in this book. Another recent book is *MRI-Guided Focused Ultrasound Surgery* (edited by F. A. Jolesz and K. H. Hynynen, Informa Healthcare, USA, 2008). In accordance with its title, this book concentrates mainly on ultrasound surgery and the use of MRI in surgical procedures. These specific problems are not considered in details in the reviewed book by Dr. Gavrilov.

The monograph will be useful for Russian specialists in physical and medical ultrasound, for engineers developing new devices for medical applications, for physicians applying these devices in different fields of clinical and experimental medicine, and for physiologists and biophysicists.

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Students and graduate students of all these specialties will also find the book to be useful. A characteristic feature of the book is that it is written in plain and clear language understandable to representatives of these different specialties. Thus, this informative and useful book certainly merits translation into English.

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