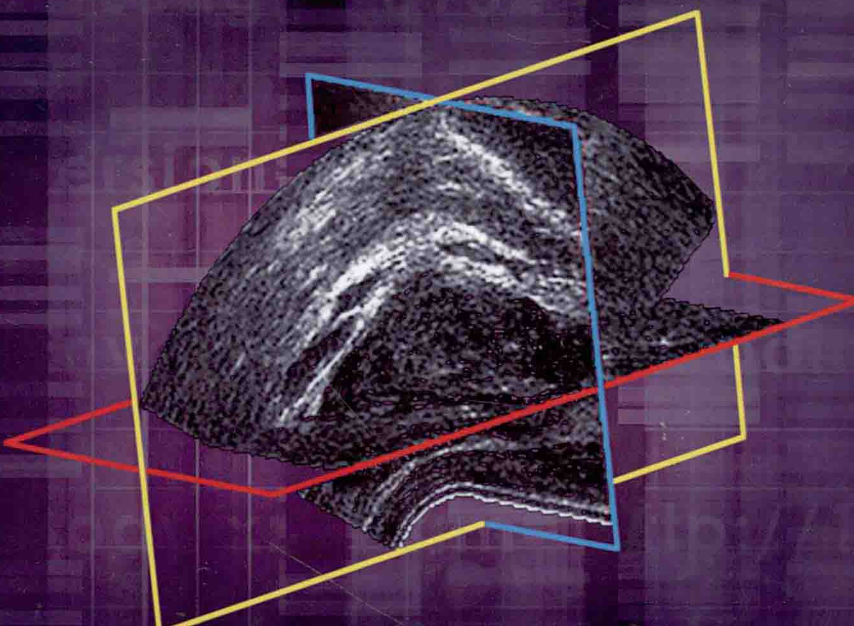
IMAGING IN MEDICAL DIAGNOSIS AND THERAPY

Andrew Karellas and Bruce R. Thomadsen, Series Editors

Ultrasound Imaging and Therapy



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Series Preface

Advances in the science and technology of medical imaging and radiation therapy are more profound and rapid than ever before since their inception over a century ago. Further, the disciplines are increasingly cross-linked as imaging methods become more widely used for planning, guiding, monitoring, and assessing treatments in radiation therapy. Today, the technologies of medical imaging and radiation therapy are so complex and so computer-driven that it is difficult for those (physicians and technologists) responsible for their clinical use to know exactly what is happening at the point of care when a patient is being examined or treated. Medical physicists are well equipped to understand the technologies and their applications, and they assume greater responsibilities in the clinical arena to ensure that what is intended for the patient is actually delivered in a safe and effective manner.

The growing responsibilities of medical physicists in the clinical arenas of medical imaging and radiation therapy are not without their challenges, however. Most medical physicists are knowledgeable in either radiation therapy or medical imaging and expert in one or a small number of areas within their discipline. They sustain their expertise in these areas by reading scientific articles and attending scientific talks at meetings. However, their responsibilities increasingly extend beyond their specific areas of expertise. To meet these responsibilities, medical physicists periodically must refresh their knowledge on the advances in medical imaging and radiation therapy, and they must be prepared to function at the intersection of these two fields. To accomplish these objectives is a challenge.

At the 2007 annual meeting of the American Association of Physicists in Medicine in Minneapolis, this challenge was the topic of conversation during a lunch hosted by Taylor & Francis Group and involving a group of senior medical physicists (Arthur L. Boyer, Joseph O. Deasy, C.-M. Charlie Ma, Todd A. Pawlicki, Ervin B. Podgorsak, Elke Reitzel, Anthony B. Wolbarst, and Ellen D. Yorke). The conclusion of the discussion was that a book series should be launched under the Taylor & Francis Group banner, with each book in the series addressing a rapidly advancing area of medical imaging or radiation therapy of importance to medical physicists. The aim would be for each book to provide medical physicists with the information needed to understand technologies driving rapid advances and their applications to safe and effective delivery of patient care.

Each book in the series is edited by one or more individuals with recognized expertise in the technological area encompassed by the book. The editors are responsible for selecting the authors of individual chapters and ensuring that the chapters are comprehensive and intelligible to someone without such expertise. The enthusiasm of the book editors and chapter authors has been gratifying and reinforces the conclusion of the Minneapolis luncheon that this series addresses a major need of medical physicists.

Imaging in Medical Diagnosis and Therapy would not have been possible without the encouragement and support of the series manager, Luna Han of Taylor & Francis Group. The editors and authors, and most of all I, are indebted to her steady guidance throughout the project.

William Hendee
Founding Series Editor
Rochester, Minnesota

Preface

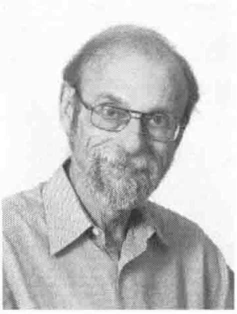
For the past 50 years, ultrasound imaging has been used extensively for diagnosis of a wide range of diseases. With improvements in image quality and reduction of cost for advanced features, ultrasound imaging is playing an ever-greater role in diagnosis and image-guided interventions. The pace of innovations is increasing, and new improved applications are constantly being described. Many of these have been adopted by clinicians for routine use. This book offers an overview of ultrasound imaging for diagnosis, covering its use in image-guided interventions and ultrasound-based therapy and highlighting the latest advances. It discusses both improvements on current techniques already in clinical use as well as techniques in an advanced state of testing with great potential for adoption into routine clinical use. The scope extends from background on the state of the art in transducers and beam formers for use in 2-D, 3-D, and 4-D ultrasound as well as developments in tissue characterization, Doppler techniques, use of ultrasound contrast agents, ultrasound-guided biopsy and therapy, and use of ultrasound to deliver therapy.

Many books have been written on this subject, but this field is advancing rapidly, with ever-expanding applications. During this last decade, ultrasound imaging has increased its role in image-guided delivery and monitoring of therapy. As a result, increasing numbers of medical physicists, radiation therapy physicists, and biomedical engineers are making use of this technology in their work and research. In addition, more computer scientists have been needed to develop image processing algorithms for diagnostic and interventional applications. Thus, this book has two objectives: (1) to inform the audience on the state of the art of current and developing techniques and (2) to identify trends in the use of ultrasound imaging and the technical and computational problems that need to be solved.

We have aimed the book at individuals working on diagnostic and therapeutic applications. Thus, the audience is quite broad and includes researchers, trainees, academic physicians, technicians, and technologists in research laboratories and diagnostic and therapy departments. It will be of particular importance to researchers and their trainees who are trying to identify areas that require innovative solutions to unsolved problems. In addition, it will be of value to those working in diagnostic and treatment centers with interest in identifying trends and future offerings by vendors. Because many of the applications require computational algorithmic solutions, computer science researchers and trainees will find a useful review of major problems and specifications that should be met.

The book is organized into three main sections. The first chapters deal with advances in the technology, including transducers (2-D, 3-D, and 4-D), beamformers, 3-D imaging systems, and blood velocity estimation systems. The second section deals with diagnostic applications, including elastography, quantitative techniques for therapy monitoring and diagnostic imaging, and ultrasound tomography. The last two chapters address the use of ultrasound in image-guided interventions, for image-guided biopsy and brain imaging.

Editors



Aaron Fenster, PhD, is a founding director of the Imaging Research Laboratories (IRL) at the Robarts Research Institute and a professor in the Department of Medical Biophysics and Department of Medical Imaging at the University of Western Ontario (UWO). He is also the founder and associate director of the Graduate Program in Biomedical Engineering at UWO. Dr. Fenster earned his PhD degree from the Department of Medical Biophysics of the University of Toronto for research under the supervision of Dr. H. E. Johns. His first academic appointment was at the Department of Radiology and Medical Biophysics of the University of Toronto from 1979 to 1987 as a director of the radiological research laboratories of the Department of Radiology.

His research group focuses on the development of 3-D ultrasound imaging with diagnostic and surgical and therapeutic cancer applications. His team developed the world's firsts in 3-D ultrasound imaging of the carotids and prostate, 3-D ultrasound-guided prostate cryosurgery and brachytherapy, 3-D ultrasound-guided prostate and breast biopsy for early diagnosis of cancer, and 3-D ultrasound images of mouse tumors and their vasculature. Among his numerous honors, Dr. Fenster is the recipient of the 2007 Premier's Discovery Award for Innovation and Leadership, the 2008 Hellmuth Prize for Achievement in Research at the UWO, and the Canadian Organization of Medical Physicists 2010 Gold Medal Award. He is also a fellow of the Canadian Academy of Health Sciences.

James C. Lacefield, PhD, is an associate professor jointly appointed to the Department of Electrical and Computer Engineering and the Department of Medical Biophysics at the University of Western Ontario. He is also a faculty member of the Graduate Program in Biomedical Engineering, an associate scientist of the Imaging Research Laboratories at Robarts Research Institute, and a mentor in Western's CIHR Strategic Training Program in Cancer Research and Technology Transfer. Dr. Lacefield earned his PhD in biomedical engineering at Duke University, where he was an NSF/ERC predoctoral fellow in the Center for Emerging Cardiovascular Technologies. He served as a visiting research associate of the Diagnostic Ultrasound Research Laboratory in the Department of Electrical and Computer Engineering at the University of Rochester from 1999 through 2001.

His research activities address physical acoustics and signal-processing aspects of biomedical ultrasound imaging, with an emphasis on applications of ultrasound to cancer and cardiovascular research. Dr. Lacefield is a member of the Acoustical Society of America, the American Society for Engineering Education, the Institute of Electrical and Electronics Engineers, and the Association of Professional Engineers of Ontario.

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