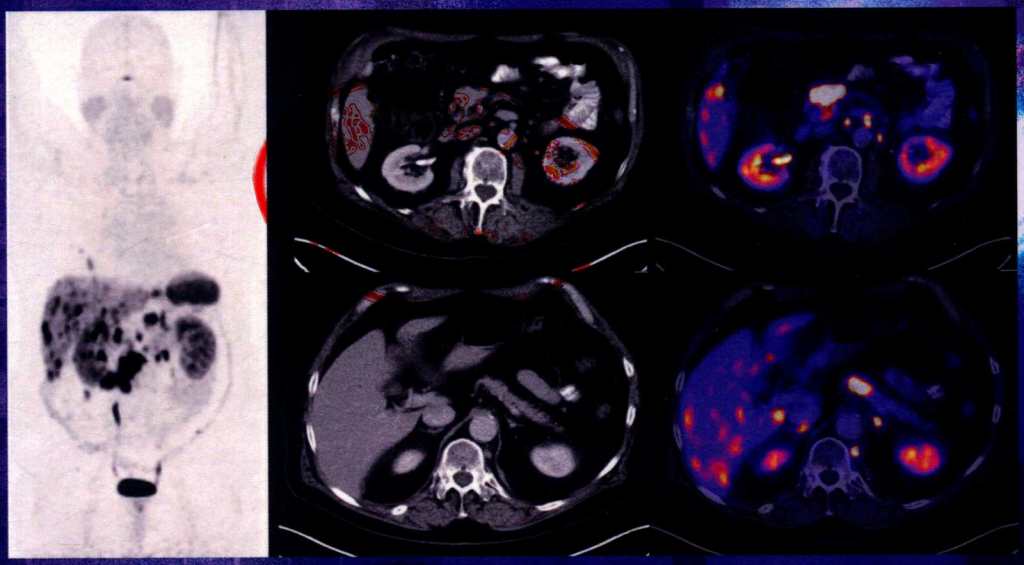
IMAGING IN MEDICAL DIAGNOSIS AND THERAPY

Andrew Karellas and Bruce R. Thomadsen, Series Editors

Physics of PET and SPECT Imaging



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Physics of PET and SPECT Imaging

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Physics of PET and SPECT Imaging
Magnus Dahlbom, Editor

To my family – my wife Maggie and my children Katarina, Kristian, Michele, and Vanessa for your constant support and encouragement, and infinite amount of love and patience.

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 more than a century ago. Further, the disciplines are increasingly cross-linked as imaging methods become more widely used to plan, guide, monitor, and assess 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 the persons (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. The persons best equipped to understand the technologies and their applications are medical physicists, and these individuals are assuming 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. In contrast, their responsibilities increasingly extend beyond their specific areas of expertise. To meet these responsibilities, medical physicists periodically must refresh their knowledge of advances in medical imaging or radiation therapy, and they must be prepared to function at the intersection of these two fields. How 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 this discussion was that a book series should be launched under the Taylor & Francis banner, with each volume 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 volume to provide medical physicists with the information needed to understand technologies driving a rapid advance and their applications to safe and effective delivery of patient care.

Each volume 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 volume editors and chapter authors has been gratifying and reinforces the conclusion of the Minneapolis luncheon that this series of books addresses a major need of medical physicists.

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

William Hendee, Founding Series Editor
Rochester, Minnesota

Preface

The fields of positron emission tomography (PET) and single-photo emission computed tomography (SPECT) imaging are continuously developing. New developments in detector technologies have allowed a broad spectrum of new imaging possibilities. Much of this development comes from the discovery of new scintillator materials, improvements and innovation in photodetector development, and new innovative system designs and image reconstruction algorithms. All of these areas of development have allowed improved image quality, spatial resolution, and simultaneous multimodality imaging.

Although there are a few excellent textbooks on the subject of nuclear imaging, this book is intended as the first to focus on PET and SPECT instrumentation, reflecting the most recent developments, including the challenges of multimodality imaging.

The book is aimed at an audience of graduate students in biomedical physics and postdocs in molecular imaging and related fields. We also expect the book to be useful as a reference for other professionals involved in molecular imaging, in both academics and industry. One of my hopes in assembling it is to provide an advanced-level textbook that goes beyond the general concepts described in introductory textbooks.

The chapters are organized into five sections, starting with an introduction to the field from a researcher and clinician's perspective, and covering the basics of PET and SPECT physics. The second section addresses detector technology, starting with scintillators, photodetectors for use with scintillators, and solid-state detectors, in addition to a chapter that covers system electronics (e.g., digital pulse processing) and the use of advanced computing methods (e.g., use of the graphics processing unit for image reconstruction and processing). The third section turns to various aspects of producing quantitative images, such as techniques for image reconstruction, corrections to the data to produce quantitative images, and characterization and evaluation of images, as well as challenges of dynamic imaging in PET and SPECT. The fourth section covers instrumentation for multimodality imaging, which includes PET/CT, SPECT/CT, and PET/MR. The final section looks at specialized instrumentation used in preclinical imaging using PET and SPECT, with a final chapter on clinical applications.

Magnus Dahlbom

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Foremost, I thank all the authors who have taken time out of their busy schedules to contribute with their knowledge and expertise to this book. I would like to thank Ms. Amber Hain for administrative support. Finally, I would like to give special thanks to Ms. Luna Han, Senior Publishing Editor at CRC Press for her help, guidance, and patience throughout this project.

Editor

Magnus Dahlbom has been working in the field of nuclear medicine for close to 30 years. He earned his BSc in physics from the University of Stockholm in 1982. He earned his PhD from the University of California, Los Angeles (UCLA) in 1987. His PhD research was on high-resolution PET detectors and image processing. In 1989, he was part of the team that started the first clinical PET operation in the United States at UCLA. Around the same time, together with Drs. Edward J. Hoffman and Michael E. Phelps, he developed the whole-body PET imaging technique, which is currently used in more than 90% of all PET studies performed. His research interests are in PET and SPECT instrumentation and image processing. Since 1989, he has been the chief physicist at the Nuclear Medicine Services at UCLA, where he is responsible for all imaging instrumentation, including SPECT, SPECT/CT, and PET/CT systems. At UCLA, he is the faculty graduate advisor in the biomedical physics graduate program. He is teaching graduate-level courses on the basics of nuclear medicine imaging and instrumentation. Dr. Dahlbom has authored and coauthored more than 120 research papers and 11 book chapters on nuclear imaging instrumentation and processing. He was also coeditor of a PET/CT atlas. For the last 6 years, he has been serving as an editorial consultant to the editor in chief of the *Journal of Nuclear Medicine*.

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Contents

PART 1

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