

Clinical PET-CT in Radiology

Paul Shreve • David W. Townsend
Editors

Clinical PET-CT in Radiology

Integrated Imaging in Oncology

Editors

Paul Shreve
Advanced Radiology Services
Grand Rapids, MI
USA
pshreve@earthlink.net

David W. Townsend
Head, PET and SPECT Development
Singapore Bioimaging Consortium
Singapore
david_townsend@sbic.a-star.edu.sg

ISBN 978-0-387-48900-1 e-ISBN 978-0-387-48902-5

DOI 10.1007/978-0-387-48902-5

Springer New York Dordrecht Heidelberg London

© Springer Science+Business Media, LLC 2011

All rights reserved. This work may not be translated or copied in whole or in part without the written permission of the publisher (Springer Science+Business Media, LLC, 233 Spring Street, New York, NY 10013, USA), except for brief excerpts in connection with reviews or scholarly analysis. Use in connection with any form of information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed is forbidden.

The use in this publication of trade names, trademarks, service marks, and similar terms, even if they are not identified as such, is not to be taken as an expression of opinion as to whether or not they are subject to proprietary rights.

While the advice and information in this book are believed to be true and accurate at the date of going to press, neither the authors nor the editors nor the publisher can accept any legal responsibility for any errors or omissions that may be made. The publisher makes no warranty, express or implied, with respect to the material contained herein.

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Preface

It has been nearly a decade since the first PET-CT scanners became commercially available. At the time of the initial launch of clinical PET-CT scanners it was thought at most 30% of the PET scanner market would be in the form of PET-CT scanners. Within only a few years (by 2006), however, PET-CT scanners replaced stand-alone PET scanners completely in commercial offerings, and today over 5,000 PET-CT scanners have been delivered worldwide. The remarkably rapid adoption of PET-CT is not entirely surprising, as the overwhelming clinical application of PET-CT has been body oncology imaging, and the merging of the anatomic and metabolic information provided by CT and FDG PET scans was a natural and already ongoing practice for body oncology imaging.

The original intent of PET-CT was to provide clinical CT and clinical PET in one scan procedure with the images sets inherently registered and aligned to facilitate interpretation of both modalities. The notion of merging the anatomic information of CT with the metabolic information of PET was suggested by a cancer surgeon in the early 1990s, but in fact the practice of integrating the interpretation of complimentary imaging modalities for clinical diagnosis has been ongoing in disease-based or organ system-based medical imaging subspecialties. This trend has accelerated recently with the widespread application of PACs and teleradiology as well as continued refinements in image registration and image fusion software. The acceptance of PET-CT hybrid scanners has more recently led to commercial SPECT-CT hybrid scanners and to the tentative development of PET-MRI scanners; the concept of hybrid imaging and multimodality imaging diagnosis is a broad and pervasive process occurring in medical imaging.

Since the introduction of commercial PET-CT scanners, published textbooks have approached the subject mainly from a nuclear medicine perspective, including applications to neurologic and cardiac imaging, and discussion of PET radiotracers other than FDG. The true necessity of the hybrid scanner applies to body imaging and in particular the vast majority of applications of clinical PET-CT today remain in body oncology imaging. In this textbook we bring together all aspects of PET-CT relevant to clinical body oncology imaging using clinical CT and clinical FDG PET. The intent is to provide practicing imaging physicians with both a comprehensive and practical text, which treats PET-CT as an integrated anatomic-metabolic medical imaging procedure applied to cancer imaging that it currently is, and was always intended to be. Ample coverage of the relevant physics and clinical oncology is included for reference. The physics and instrumentation chapters are oriented to provide an overview of the available technology and some of the physical concepts without entering into excessive detail. The clinical chapters are structured to provide concise and structured background regarding the clinical management of each cancer and the role of PET-CT imaging in all phases of patient management. It is assumed the reader has some background in both PET and CT interpretation. The intent of each clinical chapter is to help the imaging physician more completely understand the relationship and role of the integrated modality imaging with respect to the overall treatment of the cancer patient. We hope that this text will be a valuable companion for the imaging physician and further establish PET-CT in the mainstream of cancer imaging.

David Townsend, Ph.D.
Singapore

Paul Shreve, M.D.
Grand Rapids, Michigan

Contents

1 Principles, Design, and Operation of Multi-slice CT	1
Marc Kachelriess	
2 PET Imaging Basics	21
Timothy G. Turkington	
3 Design and Operation of Combined PET-CT Scanners	29
David W. Townsend	
4 CT-Based Attenuation Correction for PET	39
Jonathan P.J. Carney	
5 Technical Artifacts in PET-CT Imaging	47
Thomas Beyer	
6 Quantitation of PET Data in Clinical Practice	61
Michael M. Graham	
7 Patient Preparation and Management	67
Nancy M. Swanston and Paul Shreve	
8 Radiation Protection of Technologists and Ancillary Personnel	83
Robert E. Reiman	
9 Application of CT Contrast Agents in PET-CT Imaging	91
Gerald Antoch, Patrick Veit, Andreas Bockisch, and Hilmar Kuehl	
10 Performance, Interpretation, and Reporting of PET-CT Scans for Body Oncology Imaging	103
Paul Shreve and Harry Agress Jr.	
11 Pediatric Management and Preparation in PET-CT	117
Joseph J. Junewick and Paul Shreve	
12 PET-CT in Radiation Treatment Planning	121
Jacqueline Brunetti	
13 Probability and the Principles of Diagnostic Certainty in Medical Imaging	131
Steven Kymes and James W. Fletcher	

14 Principles of Medical Imaging in the Diagnosis and Staging of the Cancer Patient	147
Anthony F. Shields	
15 Principles of PET in Cancer Treatment for the Assessment of Chemotherapy and Radiotherapy Response and for Radiotherapy Treatment Planning	157
Natalie Charnley, Terry Jones, and Pat Price	
16 PET-CT Imaging of Lung Cancer	163
Vikram Krishnasetty and Suzanne L. Aquino	
17 PET-CT of Esophageal Cancer	181
Gary J.R. Cook	
18 PET-CT of Head and Neck Cancers	193
Barton F. Branstetter IV, Sanjay Paidisetty, Todd M. Blodgett, and Carolyn Cidis Meltzer	
19 PET-CT of Thyroid Cancer	209
Trond Velde Bogsrud, Val J. Lowe, and Ian D. Hay	
20 PET-CT in Breast Cancer	227
Mehmet S. Erturk, Rick Tetrault, and Annick D. Van den Abbeele	
21 PET-CT in Colorectal Carcinoma	245
Michael Blake, James Slattery, Owen O'Connor, Dushyant Sahani, and Mannudeep Kalra	
22 PET-CT Imaging of Lymphoma	267
Lale Kostakoglu	
23 PET-CT Imaging in Multiple Myeloma, Solitary Plasmacytoma, and Related Plasma Cell Dyscrasias	295
Ronald C. Walker, Marisa H. Miceli, and Laurie Jones-Jackson	
24 PET-CT of Melanoma	315
Chuong Bui and Paul Shreve	
25 PET-CT of Ovarian Cancer	331
Carlos A. Buchpiguel	
26 PET-CT of Cervical and Uterine Cancer	339
Yat Yin Yau	
27 PET-CT of Testicular Malignancies	359
Mark Tann and Paul Shreve	
28 PET-CT in Pediatric Malignancies	371
Joseph J. Junewick and Paul Shreve	
29 PET-CT of Renal Cell Carcinoma	389
Todd M. Blodgett and Sanjay Paidisetty	

30 PET-CT in Soft Tissue Malignancies.....	399
Edwin L. Palmer, James A. Scott, and Thomas F. DeLaney	
31 PET-CT of Pancreatic Cancer	409
Todd M. Blodgett, Sanjay Paidisetty, and Paul Shreve	
32 PET-CT of Bone Metastases.....	421
James A. Scott and Edwin L. Palmer	
Index.....	435

Contributors

Harry Agress Jr. M.D.

Chairman, Department of Radiology, Hackensack University Medical Center,
Hackensack NJ, USA

Gerald Antoch, M.D.

Professor, Department of Diagnostic and Interventional Radiology, University Hospital
Essen, Essen, Germany

Suzanne L. Aquino, M.D.

Consultant, NightHawk Radiology Services, Scottsdale AZ, USA

Thomas Beyer, Ph.D.

Professor, Department of Nuclear Medicine, University Hospital Essen, Essen, Germany
and cmi-experts GmbH Zurich, Switzerland

Michael Blake, M.D., B.Sc., MRCPI, FFR (RCSI), FRCR

Director of Abdominal PET-CT, Department of Abdominal Imaging and Intervention,
Massachusetts General Hospital, Boston MA, USA

Todd M. Blodgett, M.D.

Assistant Professor, President, FRG Molecular Imaging, Department of Radiology,
University of Pittsburgh Medical Center, Foundation Radiology Group, Pittsburgh PA, USA

Andreas Bockisch, M.D., Ph.D.

Director, Clinic and Policlinic for Nuclear Medicine, Department of Nuclear Medicine,
University Hospital Essen, Essen, Germany

Trond Velde Bogsrud, M.D.

Researcher, Department of Diagnostic Imaging, Division of Nuclear Medicine,
University Clinic, The Norwegian Radium Hospital/Rikshospitalet University Hospital,
Montebello Oslo, Norway

Barton F. Branstetter, IV M.D.

Associate Professor, Director, Head and Neck Imaging, Clinical Director of Neuroradiology,
Departments of Radiology, Otolaryngology and Biomedical Informatics, University of
Pittsburgh Medical Center, Pittsburgh PA, USA

Jacqueline Brunetti, M.D.

Associate Clinical Professor, Medical Director, Department of Radiology, Columbia
University College of Physicians and Surgeons, Holy Name Hospital, Teaneck NJ, USA

Carlos A. Buchpiguel, M.D., Ph.D.

Associate Professor, Director PET-CT Laboratory, Department of Radiology, São Paulo
University School of Medicine, Hospital do Coração, São Paulo, Brazil

Chuong Bui, MBBS, FRACP

Clinical Lecturer, Medicine, Staff specialist, Nepean Clinical School, Nuclear Medicine Department, Nepean Hospital, The University of Sydney, NSW, Australia

Jonathan P.J. Carney, Ph.D.

Assistant Professor, Department of Radiology, University of Pittsburgh Medical Center, Pittsburgh PA, USA

Natalie Charnley, MBChB, MRCP, FRCR

Researcher, University of Manchester Wolfson Molecular Imaging Centre, Preston, Lancashire, United Kingdom

Gary J.R. Cook, MBBS, M.Sc., M.D., FRCR, FRCP

Consultant Nuclear Medicine Physician, Department of Nuclear Medicine and PET, Royal Marsden Hospital, Surrey, United Kingdom

Thomas F. DeLaney, M.D.

Associate Professor, Medical Director, Department of Radiation Oncology, Harvard Medical School, Northeast Proton Therapy Center, Massachusetts General Hospital, Boston MA, USA

Sukru Mehmet Erturk, M.D.

Associate Professor, Department of Radiology, Sisli Etfal Training and Research Hospital, Istanbul, Turkey

James W. Fletcher, M.D.

Professor, Director, Division of Nuclear Medicine/PET, Director, PET Imaging Center, Division of Nuclear Medicine/PET, Department of Radiology, Indiana/Purdue University, Indiana University School of Medicine, Indianapolis IN, USA

Michael M. Graham, M.D., Ph.D.

Professor, Department of Radiology-Nuclear Medicine, University of Iowa, Iowa City IA, USA

Ian D. Hay, M.D., Ph.D.

Professor, Section of Endocrinology, Department of Internal Medicine, Mayo Clinic, Rochester MN, USA

Terry Jones, D.Sc., F Med Sci

Professor, The PET Research Advisory Company, Cheshire, United Kingdom

Laurie B. Jones-Jackson, M.D.

Assistant Professor of Clinical Radiology & Radiological Sciences, Vanderbilt University Medical Center, Nashville TN, USA

Joseph J. Junewick, M.D.

Chairman, Department of Radiology, Spectrum Health Hospitals, Grand Rapids, Advanced Radiology Services, PC, Grand Rapids Division, Grand Rapids MI, USA

Marc Kachelrieß, Dipl.-Phys

Professor, Department of Medical Imaging, Institute of Medical Physics (IMP), University of Erlangen Nuremberg, Erlangen, Germany

Mannudeep Kalra, MBBS, M.D., DNB

Director of MGH, Department of Radiology, Center for Evaluation of Radiologic Technologies, Massachusetts General Hospital, Boston MA, USA

Lale Kostakoglu, M.D.

Professor, Section of Nuclear Medicine, Department of Radiology, Mt. Sinai Medical Center, New York, NY, USA

Vikram Krishnasetty, M.D.

Private Practice, Columbus Radiology Corporation, Columbus OH, USA

Hilmar Kuehl, M.D.

Senior Physician, Department of Diagnostic and Interventional Radiology, University Hospital Essen, Essen, Germany

Steven Kymes, Ph.D., MHA

Research Assistant Professor, Department of Ophthalmology and Visual Sciences, Washington University School of Medicine, St. Louis MO, USA

Val J. Lowe, M.D.

Professor, Department of Radiology, Division of Nuclear Medicine, Mayo Clinic, Rochester MN, USA

Carolyn Cidis Meltzer, M.D.

Associate Dean for Research, Professor and Chair, Department of Radiology, School of Medicine, Emory University Hospital, Emory University School of Medicine, Atlanta GA, USA

Marisa H. Miceli, M.D.

Resident, Department of Internal Medicine, Oakwood Hospital and Medical Center, Dearborn MI, USA

Sanjay Paidisetty, BS

Intern, Department of Radiology, University of Pittsburgh Medical Center, Pittsburgh PA, USA

Edwin L. Palmer, M.D.

Associate Radiologist, Nuclear Imaging – Division of Molecular Imaging & PET-CT, Massachusetts General Hospital, Boston MA, USA

Pat Price, M.D., FRCP, FRCR

Professor, Imaging Department, Imperial College, London, United Kingdom

Robert E. Reiman, MSPH, M.D.

Assistant Clinical Professor, Radiation Safety Division, Duke University Medical Center, Durham NC, USA

Dushyant Sahani, M.D.

Medical Director of CT Services, Department of Abdominal Imaging and Intervention, Massachusetts General Hospital, Boston MA, USA

James A. Scott, M.D.

Associate Professor, Department of Radiology, Massachusetts General Hospital, Boston MA, USA

Anthony F. Shields, M.D., Ph.D.

Professor of Medicine and Oncology, Department of Internal Medicine, Karmanos Cancer Institute, Wayne State University, Detroit MI, USA

Paul Shreve, M.D.

Advanced Radiology Services, P.C., Michigan State University College of Human Medicine, Spectrum Health Lemmen-Holten Cancer Center, Grand Rapids MI, USA

James Slattery, MRCPI, FFR (RCSI), FRCR

Fellow, Division of Abdominal Imaging and Interventional Radiology,
Massachusetts General Hospital, Boston MA, USA

Nancy M. Swanston, CNMT, PET, RT(N)

Manager, Diagnostic Imaging, Division of Diagnostic Imaging, The University
of Texas M.D., Anderson Cancer Center, Houston TX, USA

Mark Tann, M.D.

Associate Professor of Clinical Radiology, Department of Radiology and Imaging Sciences,
Indiana University School of Medicine, Indianapolis IN, USA

Rick Tetrault, CNMT, RT(N), PET

Administrative Director of Imaging Services, Department of Radiology, Dana-Farber Cancer
Institute, Boston MA, USA

David W. Townsend, Ph.D.

Head, PET and SPECT Development, Singapore Bioimaging Consortium, Singapore

Timothy G. Turkington, Ph.D.

Associate Professor, Department of Radiology and Department of Biomedical Engineering,
Duke University and Duke University Medical Center, Durham NC, USA

Annick D. Van den Abbeele, M.D.

Chief, Founding Director, Department of Imaging, Center for Biomedical Imaging
and Oncology, Dana-Farber Cancer Institute, Boston MA, USA

Patrick Veit, M.D.

Radiologist, Department of Diagnostic and Interventional Radiology,
University Hospital Essen, Germany

Ronald C. Walker, M.D., FACNM

Professor, Clinical Radiology & Radiological Sciences, Vanderbilt University Medical
Center, Nashville TN, USA

Yat Yin Yau, MBBS (OLD), FHKCR, FHKAM

Associate Professor, Director, Diagnostic Imaging, Nuclear Medicine and PET-CT,
Department of Radiology, University of Hong Kong, Hong Kong Adventist Hospital,
Hong Kong, China

Clinical PET-CT in Radiology

Integrated Imaging in Oncology

Shreve, P.; Townsend, D.W. (Eds.)

2011, XIV, 437 p. 690 illus., 149 illus. in color.,

Hardcover

ISBN: 978-0-387-48900-1