Positron Emission Tomography

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Clinical Practice

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Foreword

The use of positron emission tomography (PET) in clinical practice is key to the successful management of many patients with a wide variety of diseases. Whereas in the 1980s and 1990s nuclear medicine physicians struggled to convince other doctors about the potential clinical value of PET, it is now a challenge to keep up with the requests of our clinical colleagues for the various applications of PET. In fact, in most cases the barriers are now related to reimbursement for a given PET procedure. At the time this foreword was written, many FDG/PET procedures are reimbursable, and the U.S. National PET Registry, which is about to be implemented, will allow FDG/PET imaging data to accumulate on rare tumors, while allowing for Center for Medicare and Medicaid Services (CMS) reimbursement. The challenges are now shifting toward solving some of the limitations of FDG/PET through the use of next generation instrumentation and newer tracers that hold the promise of improving on what is already a remarkable achievement with FDG/PET.

It is my hope that there will in fact be an enormous growth of nuclear medicine driven by new imaging tracers that will fuel a growing number of clinical applications. Many failures will occur in order to give rise to the next generation of PET imaging tracers, but these failures are be necessary on the road to a better tomorrow. Perhaps a "Super FDG" will be born out of these efforts, along with very specific imaging tracers useful for very select groups of patients. Technology will continue to drive our ability to identify new cellular targets, new molecular imaging agents against those targets, and the routine high-throughput synthesis and use of those new imaging tracers. Just as PET/CT has markedly influenced the growth of FDG/PET, newer technologies will likely come into play. The debut of MR-PET, molecular imaging technologies such as molecular optical imaging, and many other technologies will likely change the landscape of nuclear medicine forever. To keep the correct perspective we must remember that it is not about the technologies per se, but really about optimal patient care. We must not slip into the future, but plan for the future so we maximize our ability to help patients through the power of nuclear medicine and molecular imaging. However technologies and new tracers evolve, the concepts of interrogation at the cellular and molecular level will continue to define the evolution of nuclear medicine and the interception of disease processes through functional imaging.

The use of PET and PET/CT in patient care is best learned from clinicians at the leading edge of imaging who also routinely interpret the images. This excellent book put together by leading clinicians, who have helped the field of PET to get to the current stage, is an enormous educational resource. It is very thorough with clear examples and covers all major aspects of PET/CT application in patient management. Someday, technologies will surely evolve so that authors will be seen and speak to us virtually and interactively through "digital books." For now we must be content to learn from the best teachers through their words and image examples on paper. This book is the next best thing to having all the contributing authors virtually teaching the student about all aspects of PET/CT. Till the day that digital interactive books arrive, I plan on keeping this book nearby.

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Preface

Peter E. Valk passed away on December 16, 2003 in Berkeley, California. David Townsend wrote in the "*In Memoriam*" that was published in the February 2004 issue of the *Journal of Nuclear Medicine*: "He will be deeply missed by his many friends and colleagues throughout the Nuclear Medicine and PET community world-wide for his insight, knowledge, integrity and humour."

Peter was a dear friend and we certainly miss him. In 2003, Peter coedited *Positron Emission Tomography: Basic Science and Clinical Practice,* a comprehensive contemporary reference textbook on positron emission tomography (PET). A few months before he died, Peter informed me that Springer intended to divide this nearly 900 pages textbook into two separate volumes for clinical and basic sciences. Peter was acutely aware of his prognosis and asked me if I would be willing to take over and edit the clinical volume. I willingly accepted. This book *Positron Emission Tomography: Clinical Practice* is a selected and updated version of the clinical chapters from the original book.

Positron Emission Tomography is an exceptional functional imaging tool. There has been a tremendous increase in interest in PET in the past decade, not only as a research tool but particularly in the clinical arena. The editors of the original book (Peter Valk, Dale Bailey, David Townsend and Michael Maisey) noted how they had collectively been involved in many aspects of PET development, including instrumentation, algorithms and protocol developments and applications, as well as the training of basic scientists and medical specialists, and efforts to convince health bureaucrats of the value of functional imaging in patient management. Through their extensive involvement in all aspects of PET, they progressively became aware of the lack of a comprehensive and contemporary reference work covering the science and clinical applications of PET. The original edition of their book arose from a desire to redress this situation.

The field of PET is progressing rapidly with the developments of multimodality imaging using integrated PET/CT systems. For this separate edition of clinical applications, the intent remains true to the aims of the first edition, namely, to provide a contemporary reference work covering the science and clinical applications of PET with extensive updating to include PET/CT technology. The book is designed to be used by residents and fellows training in medical imaging specialties as well as imaging experts in private or academic medicine who need to become familiar with this technology, and by those whose specialties carry over to PET and PET/CT such as oncologists, cardiologists, neurologists and surgeons.

Chapters 1 to 4 address the basic aspects of PET and PET/CT including physics and instrumentation, an overview of the clinical advantages of the PET/CT technology over PET or CT alone; the viewpoint of the technologist, radiation dosimetry and protection. Chapters 5 to 25 address oncologic applications and have been significantly updated with new data related to the PET/CT technology; many PET/CT illustrations are included. As in the first edition, a chapter is devoted to infectious diseases and another to PET imaging in pediatric disorders. Chapter 26 is an overview of the cardiac applications of PET, and Chapter 27 discusses cardiac PET/CT that some experts envision as the future one-stop-shop cardiac examination. Chapter 28 is an overview of PET imaging in clinical neurology and is probably the least influenced by recent development of PET/CT technology.

To conclude, I restate part of the preface from the first edition:

We are indebted to the many friends and colleagues who have contributed to this book, and who have willingly shared their knowledge and experience.

The functional nature of PET is based on its ability to target specific biochemical pathways through sophisticated radioactive probes and to record the time course of tracer uptake with highly sensitive instrumentation. PET is indeed a rich area in which to work, in part because of the multidisciplinary nature of the field. Developments in instrumentation, for example, are as much driven by radiochemistry and medical challenges as they are by progress in basic physics and instrumentation. Manufacturers of PET instrumentation have also played a major role in the development of the field by sharing many of their designs for critical appraisal at an early stage, and by being willing to listen to, support, and often fund novel prototype concepts. The development of the combined PET/CT scanner is a prime example of this collaboration.

PET is currently moving forward rapidly on a number of fronts: instrumentation is developing at a fast pace; synthetic radiochemistry is becoming more sophisticated and reliable; new reconstruction algorithms and processing methods are becoming more generally usable because of rapid advances in computer hardware and software; clinical applications are burgeoning as PET becomes affordable for more practitioners; and developments in molecular biology and functional genomics provide opportunities for monitoring gene expression and targets for gene therapy.

In this context, it is a challenge to produce a reference work which remains current even during the period from production of the original text to eventual publication, let alone for a significant number of years afterwards. We leave it up to the reader, and to future readers, to assess how successful we have been in this endeavour.

Dominique Delbeke, MD, PhD
December 2005

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Positron emission tomography (PET) is a type of nuclear medicine procedure that measures metabolic activity of the cells of body tissues. PET is actually a combination of nuclear medicine and biochemical analysis. Used mostly in patients with brain or heart conditions and cancer, PET helps to visualize the biochemical changes taking place in the body, such as the metabolism (the process by which cells change food into energy after food is digested and absorbed into the blood) of the heart muscle. Introduction Positron-Emission-Tomography or short PET is the state-of-the-art technique for imaging physiological processes inside humans or animals. This hap-pens in a noninvasive fashion as the distribution of a radioactive, positron emitting radiopharmaceutical inside the body is monitored by surrounding detectors. Positron emission tomography (PET) and PET in combination with computed tomography (PET/CT) represent the most advanced scintigraphic imaging technique developed for in vivo quantification of cardiac physiology and biochemistry. The state-of-the-art PET instrumentation allows delineation of regional tracer activity with high spatial (4â€“8 mm) and temporal resolution (few seconds per image). Positron-emission tomography (PET)[1] is a nuclear medicine functional imaging technique that is used to observe metabolic processes in the body as an aid to the diagnosis of disease. The system detects pairs of gamma rays emitted indirectly by a positron-emitting radionuclide, most commonly fluorine-18, which is introduced into the body on a biologically active molecule called a radioactive tracer. Three-dimensional images of tracer concentration within the body are then constructed by computer analysis. This post aims to explain what positron emission tomography (PET) is and how it works. PET is a unique type of medical imaging that reveals information about the physiology of organs and tissues, unlike CT or MRI machines which only yield images of anatomy. By doing this, PET scans can often detect irregularities such as cancer significantly earlier than other diagnostic tests. The scan works by injecting a radioactive tracer into the