GOLDEN'S DIAGNOSTIC RADIOLOGY
Laurence L. Robbins, M.D. Editor

Section 20:
DIAGNOSTIC NUCLEAR MEDICINE

edited by
ALEXANDER GOTTSCHALK, M.D.

and
E. JAMES POTCHEN, M.D.

GOLDEN'S DIAGNOSTIC RADIOLOGY
Laurence L. Robbins, M.D., Editor

Section 20:
DIAGNOSTIC NUCLEAR MEDICINE

edited by
ALEXANDER GOTTSCHALK, M.D.

Professor of Diagnostic Radiology
and Chief of the Section of Nuclear Medicine
Yale University School of Medicine
New Haven, Connecticut
(formerly, Director, The Franklin McLean
Memorial Research Institute and Professor
of Radiology, University of Chicago,
Chicago, Illinois

and
E. JAMES POTCHEN, M.D.

Professor of Radiology and Dean
of Management Resources,
Johns Hopkins University, School
of Medicine, Baltimore, Maryland

The Williams & Wilkins Company Baltimore

Made in the United States of America

Library of Congress Cataloging in Publication Data

Gottschalk, Alexander, 1932–
Diagnostic nuclear medicine.

(Golden's diagnostic radiology; section 20)
1. Radioisotopes in medical diagnosis. I. Potchen, E. James, joint author. II. Title. III. Series.
[DNLM: 1. Diagnosis. 2. Nuclear medicine. WN200 G6181 Sect. 20]
RC78.G6 sect. 20 [RC78.7.R4] 616.07'572'08s [616.07'575]
ISBN 0-683-03669-6

75-4602

Composed and printed at the
Waverly Press, Inc.
Mt. Royal and Guilford Aves.
Baltimore, Md. 21202, U.S.A.

PREFACE

This book is designed to be useful to the practicing radiologist with a significant commitment to nuclear medicine. Many of the chapters about the current practice of nuclear radiology, such as those related to the use of cameras and scanners as well as those describing imaging of various organ systems, have a decided pragmatic nature. Hopefully, they will succeed in being both a combination of useful "tricks of the trade," and a miniatlas with key illustrations available for study or reference.

It is inevitable, however, that nuclear medicine will become progressively more inclusive and therefore more complicated. As a result, several chapters have a more sophisticated bent. It is difficult, if not impossible, to take topics like collimator design; compartments, pools and spaces; and flow measurements; and couch them in terms of "2 × 2" arithmetic. In spite of this, it seems to us that these chapters are necessary both as reference material and for those instances in which the radiologist may be actually involved in utilizing the techniques or principles described. In short, this volume was written to help the radiologists practice better nuclear radiology now, and in the future.

ALEXANDER GOTTSCHALK, M.D.
E. JAMES POTCHEN, M.D.

VOLUMES OF *GOLDEN'S DIAGNOSTIC RADIOLOGY* SERIES

Section 1: **Diagnostic Neuroradiology** (*Taveras & Wood*)
Section 2: **Roentogen Ray Examination of the Paranasal Sinuses and Mastoids** (*Grier*)
Section 3: **Radiology of the Chest** (*Rabin*)
Section 4: **Radiology of the Heart and Great Vessels** (*Cooley & Schreiber*)
Section 5: **The Digestive Tract** (*Golden et al.*)
Section 6: **Roentgen Diagnosis of Diseases of Bone** (*Edeiken & Hodes*)
Section 7: **Lymphography** (*Clouse*)
Section 8: **Urologic Roentgenology** (*Sussman & Newman*)
Section 9: **Uterotubography** (*Robins*)
Section 10: **The Use of the Roentgen Ray in Obstetrics** (*Moloy & Swenson*)
Section 11: **The Roentgen Diagnosis of Fractures** (*Garland*)
Section 12: **Dental Roentgenology** (*Zegarelli*)
Section 13: **The Soft Tissues of the Air and Food Passages of the Neck** (*Young & Funch*)
Section 14: **The Abdomen** (*Taveras & Golden*)
Section 15: **Pediatric Radiology** (*Davis & Shearer*)
Section 16: **Soft Tissue Roentgenology** (*Robbins*)
Section 17: **Development and Application of Body Section Radiography** (*Moore*)
Section 18: **Selective Angiography** (*Hanafee et al.*)
Section 19: **Mammography and Breast Diseases** (*Egan*)
Section 20: **Diagnostic Nuclear Medicine** (*Gottschalk & Potchen et al.*)

EDITOR'S INTRODUCTION—1975

The primary authors and editors indicate this book is designed to be useful to the practicing radiologist who has a significant commitment to Nuclear Radiology.

The editor considers that most of this material is new or practical, and all is current at the time of the writing. The authors prepared the material as a result of long and difficult hours of work. The volume will be of reference value to medical students, residents in Radiology, residents in Nuclear Medicine, and practitioners of Nuclear Radiology or Nuclear Medicine. It is expected that it will be a ready source of provocative and yet practical information to all of the above. It is recognized that some of this material may be controversial and yet will be practical for most practitioners.

The editor wishes to extend his appreciation to Alexander Gottschalk and James Potchen for their tremendous, diligent application to the development of this presentation.

In addition, The Williams & Wilkins Company has supplied tremendous help from Mrs. Ruby Richardson and her associates.

It is hoped that you, as a reader, will not only enjoy but learn from the material presented.

LAURENCE L. ROBBINS, M.D.

CONTRIBUTORS

S. JAMES ADELSTEIN, M.D., PH.D., Professor of Radiology, Harvard Medical School, Boston, Massachusetts

PHILIP O. ALDERSON, M.D., Instructor in Radiology, The Edward Mallinckrodt Institute of Radiology, Washington University School of Medicine, St. Louis, Missouri

JOHN E. ARNOLD, M.B., B.S., M.R.A.C.P., Assistant Professor of Radiology, University of Chicago; Associate Attending Physician, Department of Medicine, Michael Reese Hospital & Medical Center, Chicago, Illinois

ROBERT N. BECK, B.S., Associate Professor of Radiology, Department of Radiology and The Franklin McLean Memorial Research Institute, University of Chicago, Chicago, Illinois

EDWARD G. BELL, M.D., PH.D., Associate Professor of Radiology, Department of Radiology, Upstate Medical Center, Syracuse, New York

BEN C. BERG, JR., M.D., Associate Radiologist, Director, Division of Nuclear Medicine, Department of Radiology, St. Francis Hospital, Clinical Associate, Radiology, Peoria School of Medicine, Peoria, Illinois

M. DONALD BLAUFOX, M.D., PH.D., Associate Professor of Medicine and Radiology, Director, Division of Nuclear Medicine, Albert Einstein College of Medicine, Bronx, New York

FREDERICK J. BONTE, M.D., Dean and Professor of Radiology, The University of Texas Southwestern Medical School, Dallas, Texas

RONALD G. EVENS, M.D., Elizabeth Mallinckrodt Professor and Head, Department of Radiology, Washington University School of Medicine, Director, The Edward Mallinckrodt Institute of Radiology, St. Louis, Missouri

ERNEST W. FORDHAM, M.D., Professor of Nuclear Medicine, Rush-Presbyterian St. Luke's Medical Center, Chicago, Illinois

FRANCIS A. GOSWITZ, M.D., Senior Research Clinician, Oak Ridge Associated Universities, Medical Division, Oak Ridge, Tennessee

ALEXANDER GOTTSCHALK, M.D., Professor of Diagnostic Radiology and Chief of the Section of Nuclear Medicine, Yale University School of Medicine, New Haven, Connecticut (formerly, Director, The Franklin McLean Memorial Research Institute and Professor of Radiology, University of Chicago, Chicago, Illinois)

E. R. N. GRIGG, M.D., Chairman, Division of Nuclear Medicine, Cook County Hospital, Chicago, Illinois

PAUL VINCENT HARPER, A.B., M.D., Professor, Departments of Surgery and Radiology, University of Chicago School of Medicine and The Franklin McLean Memorial Research Institute, Chicago, Illinois

C. CRAIG HARRIS, M.S., Associate Professor of Radiology, Division of Nuclear Medicine, Department of Radiology, Duke University Medical Center, Durham, North Carolina

LARRY L. HECK, M.D., Division of Nuclear Medicine, Methodist Hospital, Clinical Assistant Professor of Radiology, University of Indiana School of Medicine, Indianapolis, Indiana

ROBERT E. HENRY, M.D., Assistant Professor of Medicine, St. Louis University School of Medicine, Associate Chief, Nuclear Medicine Service, St. Louis Veterans Administration, St. Louis, Missouri

PAUL B. HOFFER, M.D., Professor of Radiology and Director, Section of Nuclear Medicine, University of California, San Francisco, California (formerly, Associate Professor of Radiology and Director, Section of Nuclear Medicine, University of Chicago, Chicago, Illinois)

B. LEONARD HOLMAN, M.D., Assistant Professor of Radiology, Harvard Medical School, Nuclear Radiologist, Joint Program in Nuclear Medicine, Peter Bent Brigham Hospital and Children's Hospital Medical Center, Boston, Massachusetts

A. EVERETTE JAMES, JR., Sc.M., M.D., Associate Professor Radiology, Assistant Professor Radiological Sciences, Director, Radiological Research, Johns Hopkins Medical Institutions, Baltimore, Maryland

JOSEPH P. KRISS, M.D., Professor and Director of Nuclear Medicine, Departments of Radiology and Medicine, Stanford University Medical Center, Stanford, California

KENNETH KROHN, PH.D., Assistant Professor of Radiology (Nuclear Medicine), University of California School of Medicine, Davis, California (formerly, Research Instructor in Radiology, The Edward Mallinckrodt Institute of Radiology, Washington University School of Medicine, St. Louis, Missouri)

SILVIU LANDMAN, M.D., Attending Radiologist, Lourdes Memorial Hospital, Binghamton, New York (formerly, Assistant Professor, Department of Radiology, University of Rochester, School of Medicine and Dentistry, Rochester, New York)

KATHERINE AUSTIN LATHROP, B.S., M.S., Associate Professor, Department of Radiology, University of Chicago School of Medicine and The Franklin McLean Memorial Research Institute, Chicago, Illinois

JOHN F. LINDEMAN, M.D., Assistant Professor of Medicine, St. Louis University School of Medicine, St. Louis, Missouri

BARBARA J. MCNEIL, M.D., PH.D., Clinical Fellow in Radiology (Nuclear Medicine), Harvard Medical School, Boston, Massachusetts

BERNARD E. OPPENHEIM, M.D., Assistant Professor of Radiology, The University of Chicago, Chicago, Illinois

ROBERT W. PARKEY, M.D., Associate Professor of Radiology, Chief of Nuclear Medicine, The University of Texas Health Science Center at Dallas, Dallas, Texas

E. JAMES POTCHEN, M.D., Professor of Radiology, Johns Hopkins School of Medicine, Baltimore, Maryland

JAMES L. QUINN III, M.D., Professor of Radiology, Northwestern University, Director of Nuclear Medicine, Northwestern Memorial Hospital, Chicago, Illinois

SAMUEL REFETOFF, M.D., Associate Professor of Medicine, Director of the Thyroid Function Laboratory, The Thyroid Study Unit, University of Chicago and The Pritzker School of Medicine, Chicago, Illinois

LAWRENCE H. RESNICK, M.D., Fellow in Nuclear Medicine, The Edward Mallinckrodt Institute of Radiology, Washington University School of Medicine, St. Louis, Missouri

ROGER H. SECKER-WALKER, M.D., M.R.C.P., Associate Professor of Medicine and Physiology, Saint Louis University School of Medicine, St. Louis, Missouri

BARRY A. SIEGEL, M.D., Assistant Professor of Radiology, Director, Division of Nuclear Medicine, The Edward Mallinckrodt Institute of Radiology, Washington University School of Medicine, St. Louis, Missouri

REBECCA K. STUDER, M.S., Research Instructor, The Edward Mallinckrodt Institute of Radiology, Washington University School of Medicine, St. Louis, Missouri

DENNIS M. WELCH, M.D., Fellow in Nuclear Medicine, The Edward Mallinckrodt Institute of Radiology, Washington

University School of Medicine, St. Louis, Missouri

MICHAEL J. WELCH, PH.D., Associate Professor of Radiation Chemistry in Radiology, The Edward Mallinckrodt Institute of Radiology, Washington University School of Medicine, St. Louis, Missouri

HARRY SAUL WINCHELL, M.D., PH.D., D.SC. (HON.), Executive Vice President, Medi-Physics, Inc., Emeryville, California

CONTENTS

Section I

HISTORICAL CONSIDERATIONS

1

The Beginnings of Nuclear Medicine

E. R. N. GRIGG, M.D.

As a rule, basic scientific advances acquire notoriety only after their practical applications. The discovery of x-rays by the college physics teacher Wilhelm Conrad Roentgen (1845–1923) in Germany resulted in both immediate and numerous applications, and thereby achieved almost instant recognition.

But when in a given field the applications are slow in coming, continued pure scientific advances tend to clutter the chronology in competition for subsequently coveted priorities. If one disregards the "mysterious" darkening of photographic plates by Crookes' tubes prior to 1895 (Grigg, 1965), Radiology started on November 8, 1895, when Roentgen produced the first x-ray image of his wife's hand. There is no such clear-cut starting date for Nuclear Medicine.

DEFINITION AND NOMENCLATURE

To list the cardinal terms or key words (computer people call them "buzz" words) encountered in the discipline under consideration, and to learn their origin and meanings is more than merely desirable. To modern historians this type of etymologic evaluation is a basic tool, mandatory before any other retrospective investigation. The point is readily proved by reference to the paper announcing the discovery of polonium (1898) in which Pierre Curie (1859–1906) and Marja Sklodowska-Curie (1867–1934) coined the words *radioactive* and *radioactivity*.

In a terminologic handbook (Young and Likos, 1972), Nuclear Medicine is defined as that branch which employs radioisotopes in the diagnosis and treatment of diseases. The nucleomedical researcher and historiographer Marshall Herbert Brucer reached a similar definition by exclusion, noting first that Nuclear Medicine is not Radiophysics, not Health Physics, not Instrument Design, not Radiation Therapy, albeit a bit of each of these and of several more: according to Brucer (1966), Nuclear Medicine is a mixed discipline which emphasizes isotopes in diagnosis and therapy. On the current (1973) application blank of the first American College of Nuclear Medicine incorporated in Texas in 1971, prospective members are called "isotopologists."

By innuendo, the use of the term *isotope* in such definitions implies that Nuclear Medicine utilizes substances which are artificially radioactive. Their largest supplier, the United States Atomic Energy Commission (A.E.C.), coined for these substances the term *by-products* because at the time plutonium (of A-bomb fame) was the main product in breeder reactors.

Isotopes are two or more elements with the same atomic number, the same location on the periodic table of elements, and nearly identical