

**CLINICAL  
NUTRITION**

Volume

**2**

# **Parenteral Nutrition**

**JOHN L. ROMBEAU, M.D.**

**MICHAEL D. CALDWELL, M.D., Ph.D.**

**CLINICAL  
NUTRITION**

Volume **2**

# **Parenteral Nutrition**

**JOHN L. ROMBEAU, M.D.**

Assistant Professor of Surgery,  
University of Pennsylvania School of Medicine  
Director, Nutritional Support Service and  
Surgical Metabolic Unit  
Veterans Administration Medical Center  
Philadelphia, Pennsylvania

**MICHAEL D. CALDWELL, M.D., Ph.D.**

Associate Professor, Section of Surgery  
Brown University  
Director, Nutritional Support Service and  
Surgical Metabolism Laboratory  
Rhode Island Hospital  
Providence, Rhode Island

Illustrations by David Low, M.D.

**1986**

**W.B. SAUNDERS COMPANY**

Philadelphia • London • Toronto • Mexico City  
Rio de Janeiro • Sydney • Tokyo • Hong Kong

W. B. Saunders Company: West Washington Square  
Philadelphia, PA 19105

**Library of Congress Cataloging in Publication Data**

Main entry under title:

Parenteral nutrition.

(Clinical nutrition; v. 2)

1. Parenteral feeding. I. Rombeau, John L. II. Caldwell,  
Michael D. III. Series: Clinical nutrition (Philadelphia,  
Pa.); v. 2. [DNLM: 1. Nutrition. 2. Parenteral Feeding.  
WB 410 P295]

[RM216.C5775 1984 vol. 2] 615.8'54s 85-2501

[RM224] [615.8'55]

ISBN 0-7216-7645-6

*Editor:* John Dyson

*Designer:* Terri Siegel

*Production Manager:* Bill Preston

*Illustration Coordinator:* Peg Shaw

*Indexer:* Betty Gittens

**PARENTERAL NUTRITION**  
Volume 2 of Clinical Nutrition

ISBN 0-7216-7645-6

© 1986 by W. B. Saunders Company. Copyright under the Uniform Copyright Convention. Simultaneously published in Canada. All rights reserved. This book is protected by copyright. No part of it may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without written permission from the publisher. Made in the United States of America. Press of W. B. Saunders Company. Library of Congress catalog card number 85-2501.

Last digit is the print number: 9 8 7 6 5 4 3 2 1

# Contributors

## NAJI N. ABUMRAD, M.D.

Paul W. Sanger Professor of Surgery and Medicine, Vanderbilt University, Nashville, Tennessee; Attending Surgeon, Vanderbilt University Medical Center and Director, S. R. Light Surgical Research Laboratory, Nashville, Tennessee

*Hormone-Substrate Interrelationships: The Cellular Reactions*

## RONALD M. ABEL, M.D.

Associate Professor of Surgery, University of Medicine and Dentistry of New Jersey, Newark, New Jersey; Attending Surgeon and Director, Nutritional Support Service, Newark Beth Israel Medical Center, Newark, New Jersey

*Nutritional Support and the Cardiac Patient*

## BRUCE A. ADYE, M.D.

Associate Surgeon, The Mason Clinic, Seattle, Washington; Staff Surgeon, Virginia Mason Hospital, Seattle, Washington

*Enteric Fistulas*

## JORGE E. ALBINA, M.D.

Assistant Professor of Surgery, Brown University, Providence, Rhode Island; Director, Nutritional Support Service, Miriam Hospital and Assistant Director, Nutritional Support Service, Rhode Island Hospital, Providence, Rhode Island

*Fluids, Electrolytes, and Body Composition; Perioperative TPN*

## MARVIN E. AMENT, M.D.

Professor of Pediatrics, UCLA School of Medicine, Los Angeles, California; Chief, Pediatric Gastroenterology and Chief, Hospital Parenteral and Enteral Nutrition Support, UCLA Medical Center, Los Angeles, California

*Home Parenteral Nutrition in Infants and Children*

## SAMUEL D. ANG, M.D.

Memorial Sloan-Kettering Cancer Center Fellow, New York, New York

*Potential Complications and Monitoring of Patients Receiving Total Parenteral Nutrition*

## THOMAS T. AOKI, M.D.

Professor of Medicine, University of California School of Medicine, Davis, California; Chief, Endocrinology Division, University of California Medical Center, Davis, California

*The Metabolic Response to Fasting*

## KEITH N. APELGREN, M.D.

Assistant Professor, West Virginia University School of Medicine, Morgantown, West Virginia; Attending Surgeon, West Virginia University Hospital, Morgantown, West Virginia

*Animal Models in Parenteral Nutrition*

## PALMER Q. BESSEY, M.D.

Assistant Professor of Surgery, School of Medicine, University of Alabama at Birmingham, Birmingham, Alabama; Chief, Section of Trauma and Burns and Director of UAB Trauma Center, University of Alabama Hospitals, Birmingham, Alabama

*Animal Models in Parenteral Nutrition; Parenteral Nutrition and Trauma*

## BRUCE R. BISTRAN, M.D., Ph.D.

Associate Professor of Medicine, Harvard Medical School, Boston, Massachusetts; Attending Physician, New England Deaconess Hospital, Boston, Massachusetts

*Theoretic and Practical Issues in the Treatment of Obesity*

## ROBERT H. BOWER, M.D., F.A.C.S.

Associate Professor of Surgery, University of Cincinnati College of Medicine, Cincinnati, Ohio; Director, Nutritional Support, University of Cincinnati Medical Center, Cincinnati, Ohio; Active Staff, University of Cincinnati Medical Center, University Hospital and Holmes Division, Cincinnati, Ohio; Attending Staff, Cincinnati Veterans Administration Medical Center and Children's Hospital Medical Center, Cincinnati, Ohio

*Hepatic Indications for Parenteral Nutrition*

## MURRAY F. BRENNAN, M.D.

Professor of Surgery, Cornell Medical College, New York, New York; Attending Surgeon, New York Hos-



pital-Cornell Medical Center, New York, New York;  
Chief, Gastric and Mixed Tumor Service, Memorial  
Sloan-Kettering Cancer Center, New York, New York  
*Intravenous Feeding of the Cancer Patient*

#### MICHAEL D. CALDWELL M.D., Ph.D.

Associate Professor of Surgery, Brown University, Providence, Rhode Island; Director, Nutritional Support Service and Surgical Metabolism Laboratory, Department of Surgery, Rhode Island Hospital, Providence, Rhode Island

*Hormone-Substrate Interrelationships: The Cellular Reactions; Developmental Considerations in Neonatal TPN*

#### CHRISTINE KENNEDY-CALDWELL, R.N.C., M.S.M.

Pediatric Clinical Nurse Specialist, Maternal-Child Health Faculty, School of Nursing, Salve Regina College, Newport, Rhode Island

*Developmental Considerations in Neonatal TPN*

#### EMMA L. CATALDI-BETCHER, R.D., M.S.

University of Medicine and Dentistry of New Jersey, Rutgers Medical School, Newark, New Jersey  
*Parenteral Nutrition Equipment*

#### RONNI CHERNOFF, Ph.D.

Associate Director, Geriatric Research, Education and Clinical Center, John L. McClellan Memorial Veterans Hospital, Little Rock, Arkansas

*Total Parenteral Nutrition: Considerations in the Elderly*

#### TERRY P. CLEMMER, M.D.

Associate Professor of Medicine, University of Utah College of Medicine, Salt Lake City, Utah; Director of Critical Care Medicine and Nutritional Support Services, LDS Hospital, Salt Lake City, Utah

*Computer Applications in Clinical Nutrition*

#### JOHN M. DALY, M.D.

Associate Professor of Surgery, Cornell University Medical School, New York, New York; Associate Attending Surgeon, Memorial Sloan-Kettering Cancer Center, New York, New York

*Potential Complications and Monitoring of Patients Receiving Total Parenteral Nutrition*

#### DANIEL DEMPSEY, M.D.

Instructor in Surgery, University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania; Chief Resident in Surgery, Hospital of the University of Pennsylvania, Philadelphia, Pennsylvania

*Parenteral Vitamin Therapy in Hospital Patients*

#### STANLEY J. DUDRICK, M.D., F.A.C.S.

Clinical Professor of Surgery, The University of Texas Medical School at Houston, Houston, Texas; Director,

Nutritional Support Services, St. Luke's Episcopal Hospital, Texas Children's Hospital, Houston, Texas  
*History of Intravenous Nutrition*

#### EBEN I. FEINSTEIN, M.D.

Associate Professor of Clinical Medicine, University of Southern California Medical School, Los Angeles, California; Attending Physician, Los Angeles County/University of Southern California Medical Center, Los Angeles, California

*Nutrition in Acute Renal Failure*

#### IRENE D. FEURER, M.S.Ed.

Coordinator, Metabolic Testing Services, Nutrition Support Service, Hospital of the University of Pennsylvania, Philadelphia, Pennsylvania

*Measurement of Energy Expenditure*

#### RICHARD FINLEY, M.D.

Associate Professor of Surgery, University of Western Ontario, London, Ontario, Canada; Chief of Surgery, Victoria Hospital, London, Ontario, Canada

*The Metabolic Response to Fasting*

#### JOSEF E. FISCHER, M.D., F.A.C.S.

Christian R. Holmes Professor of Surgery, University of Cincinnati College of Medicine, Cincinnati, Ohio; Professor and Chairman, Department of Surgery, University of Cincinnati Medical Center and Holmes Hospital Divisions, Cincinnati, Ohio

*Hepatic Indications for Parenteral Nutrition*

#### LORETTA FORLAW, R.N., M.S.N.

Lieutenant Colonel A.N.C. (Army Nursing Core) and Clinical Nurse Specialist, Nutrition Support Service, Walter Reed Army Medical Center, Washington D.C.

*Central Venous Catheter Care*

#### JAMESON FORSTER, M.D.

Assistant Instructor in Surgery, Brown University Rhode Island Hospital, Providence, Rhode Island; Fellow in Surgical Metabolism, Rhode Island Hospital, Providence, Rhode Island

*The Use of Total Parenteral Nutrition in the Treatment of Anorexia Nervosa*

#### HERBERT R. FREUND, M.D.

Professor of Surgery, Hebrew University-Hadassah Medical School, Jerusalem, Israel; Chief Physician, Department of Surgery, and Director, Nutritional Support Unit, Hadassah University Medical Center, Jerusalem, Israel

*Parenteral Nutrition in the Septic Patient*

#### ROBERT FRIED, M.D.

Assistant Instructor in Surgery, American Cancer Society Fellow, Clinical Nutrition Fellow, Department of Sur

gery, Hospital of the University of Pennsylvania, Philadelphia, Pennsylvania  
*Malnutrition and Inflammatory Bowel Disease: Indications for and Complications of Parenteral Nutritional Support*

#### MARK S. GLASSMAN, M.D.

Assistant Professor of Pediatrics, Cornell University Medical College, New York, New York; Assistant Attending Physician, New York Hospital-Cornell Medical Center, New York, New York  
*Parenteral Nutrition in the Neonate*

#### DAVID J. GOLDBERGER, B.S., R.Ph.

Pharmacist, Home Health Care of America, Irvine, California

*Parenteral Nutrition Equipment*

#### CLEON W. GOODWIN, M.D., M.P.H.

Associate Professor of Surgery, Cornell University Medical College, New York, New York; Associate Attending Surgeon and Director, Burn Center, New York Hospital, New York, New York  
*Parenteral Nutrition in Thermal Injuries*

#### JOHN P. GRANT, M.D.

Associate Professor of Surgery, Duke University Medical Center, Durham, North Carolina; Durham VA Medical Center, Durham, North Carolina  
*Catheter Access*

#### A. DALE GULLEDGE, M.D.

Head Liaison, Psychiatry, Department of Psychiatry, Cleveland Clinic Foundation, Cleveland, Ohio  
*Home Parenteral Nutrition*

#### ELIE HAMAOU, M.D.

Assistant Professor of Clinical Medicine, State University of New York, Downstate Medical Center, Brooklyn, New York; Chief, Nutrition Section and Nutrition Support Team, Veterans Administration Medical Center, Brooklyn, New York  
*The Nutrition Support Team*

#### MICHELENA I. HELBLEY, R.Ph., B.S.

Pharmacology Lecturer, Rupert J. Turnbull School of Enterostomal Therapy, Cleveland Clinic Foundation, Cleveland, Ohio; Staff Pharmacist, Cleveland Clinic Foundation, Cleveland, Ohio  
*Home Parenteral Nutrition*

#### ROBERT E. HODGES, M.D.

Professor, Department of Family Medicine and Department of Internal Medicine, University of California, Irvine, California  
*Parenteral Vitamin Therapy in Hospital Patients*

#### L. JOHN HOFFER, M.D.

Assistant Professor, Faculty of Medicine, McGill University, Montreal, Quebec, Canada; Attending Physician, Royal Victoria Hospital, Montreal, Quebec, Canada  
*Theoretic and Practical Issues in the Treatment of Obesity*

#### DANNY O. JACOBS, M.D.

Fellow in Nutrition and Metabolism, Harrison Department of Surgical Research, Department of Surgery, University of Pennsylvania, Philadelphia, Pennsylvania  
*Malnutrition and Inflammatory Bowel Disease: Indications for and Complications of Parenteral Nutritional Support*

#### K. N. JEEJEEBHOY, M.B., B.S., Ph.D., F.R.C.P. (Edin., C, Lond.)

Professor and Director of the Division of Gastroenterology, Department of Medicine, University of Toronto, Toronto, Ontario, Canada; Director, Division of Gastroenterology, Toronto General Hospital, Toronto, Ontario, Canada  
*Malabsorption and the Short-Gut Syndrome*

#### KENNETH W. JONES, M.D.

Attending in Surgery, St. Vincent's Medical Center, Methodist Hospital, and University Hospital of Jacksonville, Jacksonville, Florida  
*Parenteral Nutrition Equipment*

#### MARK J. KORUDA, M.D.

Assistant Instructor in Surgery, University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania; Nutrition and Metabolic Research Fellow, Veterans Administration Medical Center and University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania  
*Perioperative Total Parenteral Nutrition*

#### KEITH G. LARSEN, R.Ph.

Adjunct Instructor, University of Utah College of Pharmacy, Salt Lake City, Utah; Director, Clinical Computer Services, LDS Hospital, Salt Lake City, Utah  
*Computer Applications in Clinical Nutrition*

#### DAVID A. LIPSCHITZ, M.D., Ph.D.

Professor of Medicine, University of Arkansas for Medical Sciences, Little Rock, Arkansas; Director, Geriatric Research, Education and Clinical Center and Chief, Hematology/Oncology, Division of Medicine, Veterans Administration Medical Center and University of Arkansas for Medical Sciences, Little Rock, Arkansas  
*Total Parenteral Nutrition: Considerations in the Elderly*

#### NANCY LOUIE, M.S., R.Ph.

Assistant Professor of Pharmacy Practice, College of Pharmacy, University of Arizona, Tucson, Arizona; Clinical Pharmacy Coordinator, Tucson Medical Center, Tucson, Arizona  
*Parenteral Nutrition Solutions*

**STEPHEN F. LOWRY, M.D.**

Assistant Professor of Surgery, Cornell Medical College, New York, New York; Assistant Attending Surgeon and Director, Hyperalimentation Unit, New York Hospital-Cornell Medical Center, New York, New York; Assistant Attending Surgeon, Gastric and Mixed Tumor Service, Memorial Sloan-Kettering Cancer Center, New York, New York

*Intravenous Feeding of the Cancer Patient*

**MAUREEN MacBURNLEY, R.D., M.S.**

Assistant Director, Nutrition Support Service, Brigham and Women's Hospital, Boston, Massachusetts

*Parenteral Nutrition in Pregnancy*

**CATHLEEN C. MAREIN, R.N., B.S.N.**

Nutrition Support Nurse, Department of General Surgery, Cleveland Clinic Foundation, Cleveland, Ohio

*Home Parenteral Nutrition*

**GEORGE MELNIK**

Nutritional Support Pharmacist, Pharmacy Service, Veterans Administration Medical Center, Philadelphia, Pennsylvania

*Fluids, Electrolytes, and Body Composition*

**PATRICE M. MISNY, R.N., B.S.N.**

Nutrition Support Nurse, Department of General Surgery, Cleveland, Ohio

*Home Parenteral Nutrition*

**JAMES L. MULLEN, M.D.**

Associate Professor of Surgery and Director, Nutrition Support Service Hospital of the University of Pennsylvania, Philadelphia, Pennsylvania

*Measurement of Energy Expenditure*

**DENISE M. NEY, M.S., R.D.**

Ph.D. Candidate, Nutrition Department, University of California, Davis, California

*Lipid Metabolism in Parenteral Nutrition*

**PAUL W. NIEMIEC, B.S., Ph.D.**

Clinical Pharmacy Coordinator, Surgery-Critical Care Division, Johns Hopkins Hospital, Baltimore, Maryland

*Parenteral Nutrition Solutions*

**JAMES F. ORME, Jr., M.D.**

Clinical Associate Professor of Medicine, University of Utah College of Medicine, Salt Lake City, Utah; Co-Director, Shock/Trauma ICU and Director, Medical/Surgical ICU, LDS Hospital, Salt Lake City, Utah

*Computer Applications in Clinical Nutrition*

**JOHN PALOMBO, M.D.**

Research Associate and Laboratory Supervisor, New England Deaconess Hospital, Boston, Massachusetts

*Theoretic and Practical Issues in the Treatment of Obesity*

**STEVEN C. PATCHING, M.D.**

Chief Resident, Department of Surgery, University of California, Davis, California

*Cost Effectiveness of Nutritional Support*

**GILBERTO R. PEREIRA, M.D.**

Associate Professor of Pediatrics, University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania; Neonatologist, Children's Hospital of Philadelphia, Philadelphia, Pennsylvania

*Parenteral Nutrition in the Neonate*

**JONATHAN E. RHOADS, M.D.**

Professor of Surgery, University of Pennsylvania, Philadelphia, Pennsylvania; Staff Surgeon, Hospital of the University of Pennsylvania and Consultant, Pennsylvania Hospital, Germantown Hospital, and Children's Hospital of Philadelphia, Philadelphia, Pennsylvania

*History of Intravenous Nutrition*

**ROLANDO ROLANDELLI, M.D.**

Research Associate, Harrison Department of Surgical Research, University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania

*Malnutrition and Inflammatory Bowel Disease: Indications for and Complications of Parenteral Nutritional Support*

**JOHN L. ROMBEAU, M.D.**

Assistant Professor of Surgery, University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania; Hospital of the University of Pennsylvania and Director, Nutrition Support Service, Veterans Administration Medical Center, Philadelphia, Pennsylvania

*The Nutrition Support Team; Perioperative Total Parenteral Nutrition; Malnutrition and Inflammatory Bowel Disease: Indications for and Complications of Parenteral Nutritional Support*

**BRIAN J. ROWLANDS, M.D., F.R.C.S., F.A.C.S.**

Associate Professor of Surgery, University of Texas Health Science Center at Houston, Houston, Texas; Attending Surgeon and Director of Nutritional Support Services, Hermann Hospital/The University Hospital, Houston, Texas

*Intravenous Nutrition for Acute and Chronic Pancreatitis*

**JOHN A. RYAN, JR., M.D.**

Surgeon and Head, Section of General, Vascular, and Thoracic Surgery, The Mason Clinic, Seattle, Washington; Chairman, Therapeutic Nutrition Committee, Virginia Mason Hospital, Seattle, Washington

*Enteric Fistulas*

**MARTIN H. SAVITZ, M.D., F.A.C.S., F.I.C.S.**

Assistant Clinical Professor of Neurosurgery, Mount Sinai School of Medicine, New York, New York; Associate Attending Neurosurgeon, Mount Sinai Hospital, New York, New York, and Chief of Neurosurgery, Nyack and Good Samaritan Hospitals, Rockland County, New York

*The Neurologic or Neurosurgical Patient*

## CONTRIBUTORS

### MURRAY H. SELTZER, M.D.

Chairman, Nutrition Support Committee, Department of Surgery, University of Medicine and Dentistry, Newark, New Jersey; Attending Surgeon, St. Barnabas Medical Center, Livingston, New Jersey  
*Parenteral Nutrition Equipment*

### JOHN SHARP, A.C.S.W.

Social Worker, Cleveland Clinic Hospital, Cleveland, Ohio  
*Home Parenteral Nutrition*

### HARRY M. SHIZGAL, M.D.

Professor of Surgery, McGill University, Montreal, Quebec, Canada; Senior Surgeon, Royal Victoria Hospital, Montreal, Quebec, Canada  
*Energy and Nitrogen Interactions*

### JOHN H. SIEGEL, M.D.

Professor of Surgery, University of Maryland School of Medicine, Baltimore, Maryland, and Professor of Surgery, Johns Hopkins University School of Medicine, Baltimore, Maryland; Director, Clinical Center, Maryland Institute for Emergency Medical Services Systems, University of Maryland Medical System, Baltimore, Maryland  
*Physiologic and Nutritional Implications of Abnormal Hormone-Substrate Relations and Altered Protein Metabolism in Human Sepsis*

### BERNADETTE A. SLOCUM, R.N., M.A.

Nutrition Support Service Nurse, St. Barnabas Medical Center Livingston, New Jersey  
*Parenteral Nutrition Equipment*

### NOEL W. SOLOMONS, M.D.

Affiliated Investigator, Division of Nutrition and Health, Institute of Nutrition of Central America and Panama, Guatemala City, Guatemala  
*Trace Minerals*

### FAITH SRP, R.N.

Nutrition Support Nurse, Department of General Surgery, Cleveland Clinic Foundation, Cleveland, Ohio  
*Home Parenteral Nutrition*

### EZRA STEIGER, M.D.

Head, Section of Surgical Nutrition, Department of General Surgery, Cleveland Clinic Foundation, Cleveland, Ohio; Staff Surgeon, Cleveland Clinic Foundation, Cleveland, Ohio  
*Home Parenteral Nutrition*

### T. P. STEIN, Ph.D.

Professor of Surgery (Research), University of Medicine and Dentistry, of New Jersey, Newark, New Jersey; School of Osteopathic Medicine and Adjunct Professor of Surgery, University of Pennsylvania, Philadelphia, Pennsylvania  
*Protein Metabolism and Parenteral Nutrition*

### ROBERT M. SUSKIND, M.D.

Professor of Pediatrics, Louisiana State University School of Medicine, New Orleans, Louisiana; Charity Hospital of New Orleans, Childrens Hospital, New Orleans, Louisiana  
*Parenteral Nutrition in the Pediatric Patient*

### RIYAD Y. TARAZI, M.D.

Resident, Department of Thoracic and Cardiovascular Surgery, Cleveland Clinic Foundation, Cleveland, Ohio  
*Home Parenteral Nutrition*

### MICHAEL H. TOROSIAN, M.D.

Clinical Instructor of Surgery, Department of Surgery, University of Pennsylvania, Philadelphia, Pennsylvania  
*Central Venous Catheter Care*

### PATRICK L. TWOMEY, M.D.

Associate Professor of Surgery, University of California, Davis, California; Chief, Gastrointestinal Surgery, Martinez VA Medical Center, Martinez, California  
*Cost Effectiveness of Nutritional Support*

### J. VAN EYS, M.D. Ph.D.

Professor of Pediatrics, The University of Texas System Cancer Center and The University of Texas School of Medicine at Houston, Houston, Texas; Chairman, Department of Pediatrics, Chairman, Department of Experimental Pediatrics, and Head, Division of Pediatrics, The University of Texas System Cancer Center, M. D. Anderson Hospital and Tumor Institute, Houston, Texas  
*Nonglucose Carbohydrates in Parenteral Nutrition*

### RAJ N. VARMA, Ph.D.

Assistant Professor of Nutrition, Youngstown State University, Youngstown, Ohio  
*Parenteral Nutrition in the Pediatric Patient*

### HARRY M. VARS, Ph.D.

Late Professor Emeritus, Harrison Department of Surgical Research, Department of Surgery, School of Medicine, University of Pennsylvania, Philadelphia, Pennsylvania  
*History of Intravenous Nutrition*



**ALEX J. WEINSTEIN, M.D.**

Resident in Surgery, Virginia Mason Hospital, Seattle,  
Washington  
*Enteric Fistulas*

**DOUGLAS W. WILMORE, M.D.**

Professor of Surgery, Harvard Medical School, Boston,  
Massachusetts; Senior Staff Surgeon, Brigham and  
Women's Hospital, Boston, Massachusetts  
*Animal Models in Parenteral Nutrition; Parenteral Nutrition  
in Pregnancy*

**BRUCE M. WOLFE, M.D.**

Associate Professor of Surgery, University of California,  
Davis, California  
*Lipid Metabolism in Parenteral Nutrition*

**ROBERT WOLFE, Ph.D.**

Associate Professor of Surgery, Anesthesia, and Bio-  
chemistry, University of Texas Medical Branch, Galves-  
ton, Texas; Chief of Metabolism, Shriners Burns Insti-  
tute, Galveston, Texas  
*Carbohydrate Metabolism and Requirements*

**BYRON YOUNG, M.D.**

Professor and Chairman, Division of Neurosurgery, De-  
partment of Surgery, Albert B. Chandler Medical Center,  
University of Kentucky, Lexington, Kentucky  
*The Neurologic or Neurosurgical Patient*

# Foreword

Dr. Michael D. Caldwell and Dr. John L. Rombeau edited a very useful volume on Enteral Nutrition and Tube Feeding that was published in 1984. They have followed this, as expected, with this volume on Parenteral Nutrition.

While nearly 100 per cent of the human race take their nourishment orally, and even in hospital populations, over 95 per cent are nourished orally or enterally, parenteral nutrition has a special field of usefulness. Because of the relative abundance of nourishment in the United States and in most Western countries, protein-calorie malnutrition is seldom seen except in patients who have an intrinsic nutritional disability, such as a stricture of the alimentary tract, a fistula, or a very abnormal rate of nutrient loss caused either by a fistula from the alimentary tract or by a protein-losing lesion such as an extensive burn, or in some cases of Ménétrier's syndrome in which albumin escapes through the stomach. Thus, one finds that the very people who need nutritional support most urgently tend to be the same people for whom it cannot be provided by the enteral route. Because so many of these patients have lesions of the alimentary tract, they tend to gravitate toward surgical services, where gastrointestinal surgeons undertake to re-establish functioning alimentary tracts by operative correction of the defects. Unfortunately, patients with severe nutritional deficits are relatively poor surgical risks, a theme that will be expanded in the body of this text. Therefore, methods of restoring the patient's nutritional deficits prior to operation become of crucial importance. It was, indeed, this motive that led to many of the developments in parenteral nutrition, particularly so-called *intravenous hyperalimentation* (IVH), by which we refer to regimens providing substantially more caloric and nitrogen intake than is required even to meet the postoperative hypermetabolic state. Indeed, it was not until the goal of nitrogen equilibrium had been superseded by 30 to 50 per cent that Dudrick, Vars, and Rhoads began to see the dramatic changes that can often be brought about by appropriate intravenous feeding.

Both Dr. Caldwell and Dr. Rombeau have been pioneers in the clinical nutrition field. Dr. Caldwell had the special advantage of being the original editor of the *Journal of Parenteral and Enteral Nutrition*, the official organ of the American Society for Parenteral and Enteral Nutrition (known as ASPEN). He saw most of the reports in this field for a number of years and proved himself to be a superb editor. He is now on the faculty of Brown University School of Medicine, Director of the Nutritional Support Service at the Rhode Island Hospital, and Director of the Surgical Metabolism Laboratory at the same hospital. Dr. Rombeau is on the faculty at the School of Medicine of the University of Pennsylvania and is Director of the Nutrition Support Service at the Philadelphia VA Medical Center. In editing this volume, they have called

on many, indeed most, of the people who brought this field from its early laboratory stages at the University of Pennsylvania to the very wide use it serves today. This has been done by careful study and refinement of the details of the parenteral nutrition procedure, resulting in a diminished risk, improved products, advances in the techniques of administration, and far better organization of nutritional support teams.

This volume begins with a chapter on the history of the development of intravenous feeding, going far back in medical history to the many roots of physiologic chemistry and nutritional science, and proceeds in an orderly way to chapters on the basic biochemistry of the nutritional process, the experimental pathology attending nutritional deficits in animals and humans, the assessment of nutritional deficits in patients, and the many phases of the problem, both theoretical and practical. It should serve not only as a book of reference but also as a practical guide to the management of a wide variety of nutritional problems seen in clinical medicine, pediatrics, and surgery.

JONATHAN E. RHOADS, M.D., D.Sc.

# Preface

The science of parenteral nutrition has undergone many changes since the report that documented its efficacy in 1967. Similar to what occurred with other medical advances, a period of underutilization was followed by a time of overutilization. More recently, attempts have been made via controlled clinical trials to identify the appropriate utilization of parenteral nutrition and to confirm its metabolic and clinical benefits. Certainly, no one can deny that parenteral nutrition has been life-saving for many individuals, such as those afflicted with short-gut syndromes. It is less clear, however, whether its use is justified in illnesses such as severe hepatic failure or extensive cancer. What can be concluded is that, in most instances, parenteral nutrition functions as a therapy adjuvant to primary treatments such as surgery, antibiotics, and other medical therapies.

The most important need in the field of parenteral nutrition is for the documentation of its effect on clinical outcome. Unfortunately, this may be an impossible task because of the multiple factors that influence clinical outcome. Furthermore, this issue is compounded by the moral and ethical dilemmas that arise when one realizes that the only alternative to parenteral nutrition, in some instances, is starvation.

There are many available texts on parenteral nutrition, and therefore it is important to question the rationale for another book. In our opinion the justification for this text results from the need to communicate the clinical and metabolic advances in parenteral feeding that have occurred so rapidly over the past few years. Furthermore, there has been a recent transition from the general applications of parenteral nutrition to more specific approaches based on nutrient requirements of individual disease states. In other words, parenteral feeding has evolved into an era of prescription nutrition. A major objective of this text has been to reflect these changes and to incorporate them into a reference source for parenteral nutrition. To meet this objective, contributors have been chosen with both clinical and research expertise, and they have been encouraged to document their chapters as extensively as possible.

This is the second volume of a two-volume set. Because of this format, certain general topics that are covered in Volume I, such as nutritional assessment, have not been repeated in Volume II. Other topics covered in Volume I have been included in Volume II when sufficient information specifically relevant to parenteral nutrition is available. It is acknowledged that many readers will be interested only in one volume; therefore, some topics are included in Volume II with the realization that a degree of overlap with Volume I is unavoidable.

Several important new areas are included in this volume. An improved understanding of disease-specific substrate requirements has led to contemporary chapters on this topic. Important advances have occurred in trace element requirements for parenteral nutrition, and this topic is covered extensively. Furthermore, there is now sufficient new information to include specific chapters on the role of parenteral nutrition in the treatment of anorexia nervosa, geriatric illnesses, sepsis, and in ameliorating the gastrointestinal complications associated with pregnancy. Finally, and of major importance, is an objective discussion of the costs and risks and benefits of parenteral nutrition.

It is acknowledged that a major improvement in the delivery of parenteral nutrition has resulted from the formation of multidisciplinary support teams. There is a need to provide updated scientific information to assist these teams in the provision of optimal nutritional care. Therefore, this text includes chapters of interest to such hospital nutrition team members as pharmacists, nurses, and dietitians; however, it is emphasized that its contents are directed primarily to the physician.

We wish to acknowledge the outstanding secretarial support of Jo Ann Graham and Betty Hoaque. A special thanks is extended to Linda Belfus, John Dyson, Evelyn Weiman, and Janet Macnamara-Barnett at the W. B. Saunders Company for their outstanding editorial assistance. Our gratitude is also extended to the many faculty, fellows, and residents who have directly and indirectly made important suggestions in the development of this book. Finally, our deepest gratitude is expressed to our wives and families for their inordinate understanding and forbearance.

JOHN L. ROMBEAU, M.D.

MICHAEL D. CALDWELL, M.D., PH.D.

# Contents

<b>HISTORY OF INTRAVENOUS NUTRITION .....</b>	<b>1</b>
<i>Jonathan E. Rhoads, Stanley J. Dudrick, and Harry M. Vars</i>	
 <i>Chapter 1</i>	
<b>THE METABOLIC RESPONSE TO FASTING .....</b>	<b>9</b>
<i>Thomas T. Aoki and Richard T. Finley</i>	
 <i>Chapter 2</i>	
<b>HORMONE-SUBSTRATE INTERRELATIONSHIPS: THE CELLULAR REACTIONS .....</b>	<b>29</b>
<i>Naji N. Abumrad and Michael D. Caldwell</i>	
 <i>Chapter 3</i>	
<b>CARBOHYDRATE METABOLISM AND REQUIREMENTS .....</b>	<b>53</b>
<i>Robert R. Wolfe</i>	
 <i>Chapter 4</i>	
<b>LIPID METABOLISM IN PARENTERAL NUTRITION .....</b>	<b>72</b>
<i>Bruce M. Wolfe and Denise M. Ney</i>	
 <i>Chapter 5</i>	
<b>PROTEIN METABOLISM AND PARENTERAL NUTRITION .....</b>	<b>100</b>
<i>T. P. Stein</i>	
 <i>Chapter 6</i>	
<b>FLUIDS, ELECTROLYTES, AND BODY COMPOSITION .....</b>	<b>135</b>
<i>Jorge E. Albina and George Melnik</i>	
 <i>Chapter 7</i>	
<b>PARENTERAL VITAMIN THERAPY IN HOSPITAL PATIENTS .....</b>	<b>154</b>
<i>Daniel Dempsey and Robert E. Hodges</i>	
 <i>Chapter 8</i>	
<b>TRACE MINERALS .....</b>	<b>169</b>
<i>Noel W. Solomons</i>	



Chapter 9	
NONGLUCOSE CARBOHYDRATES IN PARENTERAL NUTRITION .....	198
<i>J. van Eys</i>	
Chapter 10	
ENERGY AND NITROGEN INTERACTIONS .....	210
<i>Harry M. Shizgal</i>	
Chapter 11	
MEASUREMENT OF ENERGY EXPENDITURE .....	224
<i>Irene D. Feurer and James L. Mullen</i>	
Chapter 12	
THE NUTRITION SUPPORT TEAM .....	237
<i>Elie Hamaoui and John L. Rombeau</i>	
Chapter 13	
PARENTERAL NUTRITION EQUIPMENT .....	257
<i>Murray H. Seltzer, Bernadette A. Slocum, Emma L. Cataldi-Betcher, David J. Goldberger, and Kenneth W. Jones</i>	
Chapter 14	
PARENTERAL NUTRITION SOLUTIONS .....	272
<i>Nancy Louie and Paul W. Niemec</i>	
Chapter 15	
CATHETER ACCESS .....	306
<i>John P. Grant</i>	
Chapter 16	
CENTRAL VENOUS CATHETER CARE .....	316
<i>Loretta Forlaw and Michael H. Torosian</i>	
Chapter 17	
POTENTIAL COMPLICATIONS AND MONITORING OF PATIENTS RECEIVING TOTAL PARENTERAL NUTRITION .....	331
<i>Samuel D. Ang and John M. Daly</i>	
Chapter 18	
COMPUTER APPLICATIONS IN CLINICAL NUTRITION .....	344
<i>Terry P. Clemmer, Keith G. Larsen, and James F. Orme</i>	
Chapter 19	
COST-EFFECTIVENESS OF NUTRITIONAL SUPPORT .....	358
<i>Patrick L. Twomey and Steven C. Patching</i>	
Chapter 20	
PERIOPERATIVE TOTAL PARENTERAL NUTRITION .....	370
<i>Jorge E. Albina, Mark J. Koruda, and John L. Rombeau</i>	

## CONTENTS

Chapter 21	
MALNUTRITION AND INFLAMMATORY BOWEL DISEASE. INDICATIONS FOR AND COMPLICATIONS OF PARENTERAL NUTRITIONAL SUPPORT .....	380
<i>Danny O. Jacobs, Rolando Rolandelli, Robert Fried, and John L. Rombeau</i>	
Chapter 22	
INTRAVENOUS NUTRITION FOR ACUTE AND CHRONIC PANCREATITIS .....	401
<i>Brian J. Rowlands</i>	
Chapter 23	
ANIMAL MODELS IN PARENTERAL NUTRITION .....	409
<i>Keith N. Apeltgren, Palmer Q. Bessey, and Douglas W. Wilmore</i>	
Chapter 24	
ENTERIC FISTULAS .....	419
<i>John A. Ryan, Jr., Bruce A. Adye, and Alex J. Weinstein</i>	
Chapter 25	
MALABSORPTION AND THE SHORT-GUT SYNDROME .....	437
<i>K. N. Jeejeebhoy</i>	
Chapter 26	
INTRAVENOUS FEEDING OF THE CANCER PATIENT .....	445
<i>Stephen F. Lowry and Murray F. Brennan</i>	
Chapter 27	
PARENTERAL NUTRITION AND TRAUMA .....	471
<i>Palmer Q. Bessey</i>	
Chapter 28	
PARENTERAL NUTRITION IN THERMAL INJURIES .....	489
<i>Cleon W. Goodwin</i>	
Chapter 29	
THE NEUROLOGIC OR NEUROSURGICAL PATIENT .....	508
<i>Martin H. Savitz and Byron Young</i>	
Chapter 30	
THE USE OF TOTAL PARENTERAL NUTRITION IN THE TREATMENT OF ANOREXIA NERVOSA .....	520
<i>Jameson Forster</i>	
Chapter 31	
PARENTERAL NUTRITION IN THE SEPTIC PATIENT .....	533
<i>Herbert R. Freund</i>	

## CONTENTS

Chapter 32	
PHYSIOLOGIC AND NUTRITIONAL IMPLICATIONS OF ABNORMAL HORMONE-SUBSTRATE RELATIONS AND ALTERED PROTEIN METABOLISM IN HUMAN SEPSIS .....	555
<i>John H. Siegel</i>	
Chapter 33	
NUTRITIONAL SUPPORT AND THE CARDIAC PATIENT .....	575
<i>Ronald M. Abel</i>	
Chapter 34	
NUTRITION IN ACUTE RENAL FAILURE .....	586
<i>Eben I. Feinstein</i>	
Chapter 35	
HEPATIC INDICATIONS FOR PARENTERAL NUTRITION .....	602
<i>Robert H. Bower and Josef E. Fischer</i>	
Chapter 36	
PARENTERAL NUTRITION IN PREGNANCY .....	615
<i>Maureen MacBurne and Douglas W. Wilmore</i>	
Chapter 37	
THEORETIC AND PRACTICAL ISSUES IN THE TREATMENT OF OBESITY .....	634
<i>L. John Hoffer, John Palombo, and Bruce R. Bistrian</i>	
Chapter 38	
TOTAL PARENTERAL NUTRITION: CONSIDERATIONS IN THE ELDERLY .....	648
<i>Ronni Chernoff and David A. Lipschitz</i>	
Chapter 39	
HOME PARENTERAL NUTRITION .....	654
<i>Ezra Steiger, Faith Srp, Michelena I. Helbley, Patrice M. Misny, Cathy Marien, John Sharp, A. Dale Gullledge, and Riyad Tarazi</i>	
Chapter 40	
DEVELOPMENTAL CONSIDERATIONS IN NEONATAL TPN .....	680
<i>Christine Kennedy-Caldwell and Michael D. Caldwell</i>	
Chapter 41	
PARENTERAL NUTRITION IN THE NEONATE .....	702
<i>Gilberto R. Pereira and Mark Glassman</i>	
Chapter 42	
PARENTERAL NUTRITION IN THE PEDIATRIC PATIENT .....	721
<i>Raj N. Varma and Robert M. Suskind</i>	
Chapter 43	
HOME PARENTERAL NUTRITION IN INFANTS AND CHILDREN .....	731
<i>Marvin E. Ament</i>	
INDEX .....	741