**Contemporary Diabetes**Series Editor: Aristidis Veves

Aristidis Veves
John M. Giurini
Frank W. LoGerfo *Editors* 

# The Diabetic Foot

Medical and Surgical Management

3rd Edition



### **CONTEMPORARY DIABETES**

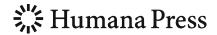
Series Editor: Aristidis Veves, MD, DSc

Aristidis Veves • John M. Giurini Frank W. LoGerfo Editors

# The Diabetic Foot

Medical and Surgical Management

**Third Edition** 



Editors
Aristidis Veves
Joslin-Beth Israel
Deaconess Foot Center
and Microcirculation Lab
Beth Israel Deaconess Medical Center
Harvard Medical School
Boston, MA, USA

John M. Giurini Division of Podiatry Beth Israel Deaconess Medical Center Boston, MA, USA

Frank W. LoGerfo Division of Vascular and Endovascular Surgery Department of Surgery Beth Israel Deaconess Medical Center Boston, MA, USA

ISBN 978-1-61779-790-3 e-ISBN 978-1-61779-791-0 DOI 10.1007/978-1-61779-791-0 Springer New York Dordrecht Heidelberg London

Library of Congress Control Number: 2012935692

#### © Springer Science+Business Media, LLC 2012

All rights reserved. This work may not be translated or copied in whole or in part without the written permission of the publisher (Humana Press, c/o 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

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

#### **Preface**

Although hard to believe, we have already reached the third edition of the book since its first publication in 2002. While we are fully aware that no major breakthroughs have occurred in the management of diabetic foot problems during this period, significant improvements in our knowledge regarding the pathogenesis of diabetic foot problems and in the health care treatment of this condition have taken place. We have therefore tried to include all these developments in this edition. We have no doubt that, given the unabated pandemic of diabetes worldwide, these new developments will be very useful to both researchers and clinical providers involved in the field. As with the previous editions, we have also tried to blend this new knowledge with the timetested principles of diabetic foot management that are part of the long tradition of the Joslin-Beth Israel Deaconess Foot Center.

It is our hope that the third edition will continue to serve the scientific and clinical community at the same level as the previous two editions have done. In that sense, we are really indebted to the contributors of this edition, the majority of which have contributed to the previous editions. We also wish to thank Humana Press for their support in the project.

Boston, MA, USA

Aristidis Veves John M. Giurini Frank W. LoGerfo

# **Contents**

## Part I Clinical Features and Diagnosis

1	Principles of Care in the Diabetic Surgical Patient Kenneth Snow	3
2	Epidemiology and Health Care Cost of Diabetic Foot Problems  Jeremy J. Cook and Donald C. Simonson	17
3	<b>Diabetic Polyneuropathy</b> Solomon Tesfaye	33
4	Clinical Examination and Risk Classification of the Diabetic Foot  Lawrence A. Lavery and David G. Armstrong	59
5	Clinical Features and Diagnosis of Peripheral Arterial Disease Cameron M. Akbari	75
6	Imaging of Infection in the Diabetic Foot	87
Par	t II Pathophysiology	
7	Physiology and Pathophysiology of Wound Healing in Diabetes  Olivera Stojadinovic, Irena Pastar, Katherine A. Gordon, and Marjana Tomic-Canic	127
8	Neuropeptides and Diabetic Wound-Healing Leena Pradhan, Frank W. LoGerfo, and Aristidis Veves	151
9	Induced Regeneration of Skin and Peripheral Nerves in the Adult	163
10	Microvascular Changes in the Diabetic Foot	185

viii Contents

11	Biomechanics of the Diabetic Foot: The Road to Foot Ulceration	203
12	Diabetic Foot Ulcers: Effects of Hyperoxia and Stromal-Derived Factor-1 $\alpha$ on Endothelial Progenitor Cells	217
	Ying Zhuge, Sharyce Gonzalez, and Omaida C. Velazquez	
Par	t III Management of the Diabetic Foot	
13	Wound Bed Preparation of the Diabetic Foot Ulcer Vincent Falanga and Satori Iwamoto	233
14	Foot Pressure Abnormalities in the Diabetic Foot	255
15	Proactive Wound Care	275
16	Local Care of Diabetic Foot Ulcers: Assessment, Dressings, and Topical Treatments Sarah Elder, Oscar M. Alvarez, and Thanh Dinh	289
17	Surgical Treatment of the Ulcerated Foot	307
18	Microbiology and Treatment of Diabetic Foot Infections Adolf W. Karchmer	331
19	Lower Extremity Arterial Reconstruction in Patients with Diabetes Mellitus: Principles of Treatment	347
20	Charcot Arthropathy in the Diabetic Foot	369
21	Soft Tissue Reconstructive Options for the Ulcerated or Gangrenous Diabetic Foot	395
22	Amputations and Rehabilitation	443
Par	t IV Organization and Preventive Care	
23	Organization of the Diabetic Foot Care Team	473
24	Quality of Health Care Emily A. Cook and Marcia A. Testa	481

Contents

25	Psychosocial and Educational Implications of Diabetic		
	Foot Complications	503	
	Katie Weinger, Arlene Smaldone, and Elizabeth A. Beverly		
26	The Role of Footwear in the Prevention of Diabetic		
	Foot Problems	519	
	Luigi Uccioli and Claudia Giacomozzi		
Ind	ex	537	

#### **Contributors**

**Cameron M. Akbari, MD, MBA, FACS** Department of Vascular Surgery, Washington Hospital Center, Washington, DC, USA

Oscar M. Alvarez, PhD, CCT, FAPWCA Department of Medicine, Center for Curative and Palliative Wound Care, Calvary Hospital, New York, NY, USA

**David G. Armstrong, DPM, PhD** Department of Surgery, University of Arizona and Southern Arizona Limb Salvage Alliance, Tucson, AZ, USA

**Christopher E. Attinger, MD** Division of Wound Healing, Georgetown University Hospital, Washington, DC, USA

**Bernadette Aulivola, MD** Division of Vascular Surgery and Endovascular Therapy, Department of Surgery, Loyola University Medical Center, Maywood, IL, USA

**Elizabeth A. Beverly, PhD** Department of Clinical, Behavioral, and Outcome Research, Joslin Diabetes Center, Harvard Medical School, Boston, MA, USA

Mark W. Clemens II, MD Department of Plastic Surgery, The University of Texas MD Anderson Cancer Center, Houston, TX, USA

**Emily A. Cook, DPM, MPH, CPH** Division of Podiatric Surgery, Department of Surgery, Mount Auburn Hospital, Cambridge, MA, USA

**Jeremy J. Cook, DPM, MPH, CPH, FACFAS** Department of Surgery, Mount Auburn Hospital, Harvard Medical School, Cambridge, MA, USA

**Thanh Dinh, DPM** Assistant Professor in Surgery, Harvard Medical School, Division of Podiatry, Beth Israel Deaconess Medical Center, Boston, MA, USA

**Sarah Elder, DPM** Division of Podiatry, Beth Israel Deaconess Medical Center, Boston, MA, USA

**Vincent Falanga, MD** Department of Dermatology and Skin Surgery, Roger Williams Medical Center, Providence, RI, USA

**Robert G. Frykberg, DPM, MPH** Podiatry Section, Department of Surgery, Carl T. Hayden VA Medical Center, Phoenix, AZ, USA xii Contributors

Claudia Giacomozzi, MD Istituto Superiore di Sanità, Rome, Italy

**John M. Giurini, DPM** Division of Podiatry, Beth Israel Deaconess Medical Center, Boston, MA, USA

**Sharyce Gonzalez** Division of Vascular and Endovascular Surgery, Jackson Memorial Hospital, University of Miami Miller School of Medicine, Miami, FL, USA

**Katherine A. Gordon** Wound Healing and Regenerative Medicine Research Program, Department of Dermatology, University of Miami Miller School of Medicine, Miami, FL, USA

Mary G. Hochman, MD, MBA Musculoskeletal Imaging Section, Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, MA, USA

**Satori Iwamoto, MD, PhD** Department of Dermatology and Skin Surgery, Roger Williams Medical Center, Providence, RI, USA

Department of Dermatology, Boston University, Boston, MA, USA

**Antonios Kafanas, MD** Department of Anatomic Pathology, State General Hospital of Serres, Serres, Greece

**Adolf W. Karchmer, MD** Division of Infectious Diseases, Lowry Medical Office Building, Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, MA, USA

Adam Landsman, DPM, PhD Division of Podiatric Surgery, Department of Surgery, Cambridge Hospital, Cambridge, MA, USA Department of Surgery, Harvard University School, Boston, MA, USA Department of Research, California School of Podiatric Medicine at Samuel Merritt University, Oakland, CA, USA

**Lawrence A. Lavery, DPM, MPH** Department of Plastic Surgery, UT Southwestern Medical Center, Dallas, TX, USA

**Frank W. LoGerfo, MD** Division of Vascular and Endovascular Surgery, Department of Surgery, Beth Israel Deaconess Medical Center, Boston, MA, USA

**Thomas E. Lyons, DPM** Division of Podiatry, Department of Surgery, Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, MA, USA

**Coleen Napolitano, DPM** Department of Orthopedic Surgery and Rehabilitation, Loyola University Stritch School of Medicine, Maywood, IL, USA

**Irena Pastar** Wound Healing and Regenerative Medicine Research Program, Department of Dermatology, University of Miami Miller School of Medicine, Miami, FL, USA

**Michael Pinzur, MD** Department of Orthopedic Surgery, and Rehabilitation, Loyola University Stritch School of Medicine, Maywood, IL, USA

Frank B. Pomposelli Jr., MD Department of Surgery, Harvard Medical School, Boston, MA, USA

Division of Vascular Surgery, Beth Israel Deaconess Medical Center, Boston, MA, USA

**Leena Pradhan, PhD** Division of Vascular and Endovascular Surgery, Department of Surgery, Beth Israel Deaconess Medical Center, Boston, MA, USA

**Lee C. Rogers, DPM** Amputation Prevention Center at Valley Presbyterian Hospital, Los Angeles, CA, USA

**Barry I. Rosenblum, DPM** Division of Podiatric Surgery, Department of Surgery, Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, MA, USA

Ronald A. Sage, DPM Department of Orthopedic Surgery and Rehabilitation, Loyola University Stritch School of Medicine, Maywood, IL, USA

Carine van Schie, MSc, PhD Department of Rehabilitation, Academic Medical Centre, University of Amsterdam, DE Amsterdam, The Netherlands

Dutch Burns Foundation, AJ Beverwijk, The Netherlands

**Donald C. Simonson, MD, MPH, Sc D** Division of Endocrinology, Diabetes, and Hypertension, Brigham and Women's Hospital, Harvard Medical School, Boston, MA, USA

**F.J. Slim, MD, PhD** Department of Rehabilitation Medicine, St. Antonius Hospital, EM Nieuwegein, The Netherlands

**Arlene Smaldone, DNSc, CPNP, CDE** Columbia University School of Nursing, New York, NY, USA

**Kenneth Snow, MD** Joslin Diabetes Center, Harvard Medical School, Boston, MA, USA

Eric C. Soller, PhD Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, MA, USA

**Olivera Stojadinovic** Wound Healing and Regenerative Medicine Research Program, Department of Dermatology, University of Miami Miller School of Medicine, Miami, FL, USA

**Rodney Stuck, DPM** Department of Surgery, Edward Hines Junior Veterans Administration Hospital, Hines, IL, USA

**Francesco Tecilazich, MD** Department of Surgery, Beth Israel Deaconess Medical Center, Boston, MA, USA

**Solomon Tesfaye, MD, FRCP** Diabetes Research Unit, Royal Hallamshire Hospital—Sheffield Teaching Hospitals, Sheffield, South Yorkshire, UK

xiv Contributors

Marcia A. Testa, PhD, MPhil, MPH Department of Biostatistics, Harvard School of Public Health, Boston, MA, USA

Marjana Tomic-Canic Wound Healing and Regenerative Medicine Research Program, Department of Dermatology, University of Miami Miller School of Medicine, Miami, FL, USA

**Luigi Uccioli, MD** Department of Internal Medicine, University of Rome 'Tor Vergata', Rome, Italy

**Omaida C. Velazquez, MD** Division of Vascular and Endovascular Surgery, Jackson Memorial Hospital, University of Miami Miller School of Medicine, Miami, FL, USA

**Aristidis Veves, MD, DSc** Joslin-Beth Israel Deaconess Foot Center and Microcirculation Lab, Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, MA, USA

**Katie Weinger, EdD, RN, FAADE** Department of Clinical, Behavioral, and Outcomes Research, Joslin Diabetes Center, Harvard Medical School, Boston, MA, USA

**Ioannis V. Yannas, PhD** Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, MA, USA

**Ying Zhuge, MD** Division of Vascular and Endovascular Surgery, Jackson Memorial Hospital, University of Miami Miller School of Medicine, Miami, FL, USA

**Ann Zmuda, DPM** Department of Endocrinology and Orthopedic Surgery, University of Chicago, Chicago, IL, USA